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**Improving the throughput of plasticating extruders:
Manufacture of non-circular pellets, measurement of their
interparticulate friction coefficient, and implications for screw
design**

Liu, Chia-Ying, Ph.D.

New Jersey Institute of Technology, 1992

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**IMPROVING THE THROUGHPUT OF PLASTICATING EXTRUDERS:
MANUFACTURE OF NON-CIRCULAR PELLETS, MEASUREMENT
OF THEIR INTERPARTICULATE FRICTION COEFFICIENT, AND
IMPLICATIONS FOR SCREW DESIGN**

by

Chia-Ying Liu

A Dissertation

Submitted to the Faculty of the Graduate Division of the
New Jersey Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy

Department of Mechanical and Industrial Engineering

January 1992

APPROVAL SHEET

Title of Dissertation : Improving the Throughput of Plasticating Extruders:
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Interparticulate Friction Coefficient, and Implications for
Screw Design.

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ABSTRACT

Title of Dissertation : Improving the Throughput of Plasticating Extruders: Manufacture of Non Circular Pellets, Measurement of their Interparticulate Friction Coefficient, and Implications for Screw Design.

Chia-Ying Liu : Doctor of Philosophy in Mechanical Engineering, 1992

Dissertation Directed by: Dr. Keith T. O'Brien *Keith T. O'Brien*
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This dissertation addresses the hypothesis that the interparticulate friction coefficient of a bed of polymeric particulates is a function of the cross-section of the pellets. Most pellets have a circular cross-section especially those that are strand cut. But when such pellets constitute a particulate bed there are few restrictions to adjacent pellets turning with respect to each other, or of the beds rupturing under shear load. This rupture can occur in plasticating extrusion, and it results in a poorly mixed melt with an inhomogeneous temperature distribution. The temperature fluctuations cause viscosity fluctuations which in turn cause pressure fluctuations. The pressure fluctuations cause throughput variations which lead to thickness variations in the product. That results in poor quality product. This sequence of events is termed surging. If the rupture of the solid bed can be prevented then surging can be curtailed.

An increase in the interparticulate friction coefficient is expected to reduce solid bed rupturing. And the interparticulate friction coefficient can be increased if pellets with non-circular cross-section constitute it. Due to the fact that trilobal fibers

are used to provide interlocking in the textile industry, the trilobal cross-section was first tested. This led to tests on bilobal and quadrilobal cross-sections as well.

However, prior to testing the pellets required manufacture. Since bilobal, trilobal and quadrilobal cross-sections are different profile cross-sections, it was first necessary to design and build a series of profile extrusion dies. Each die was capable of producing a variety of pellet cross-sections if the material was changed, or if the throughput rate was varied. So many pellet geometries could be readily produced. Each variation of material and geometry was tested independently in a direct shear cell to measure the interparticulate friction coefficient. It was clearly found that the highest interparticulate friction coefficients occurred with pellets of bilobal cross-section, a 31% to 81% increase over pellets with circular cross-section. In addition pellets with trilobal and quadrilobal cross-section exhibited an improved interparticulate friction coefficient, a 20% to 34% increase compared to pellets with circular cross-sections. Consolidation pressure and time had minimal effects whereas agitation caused interparticulate friction coefficient increases from 51% to 89%. The effect of additives in the particulate continuum on the interparticulate friction coefficient was also studied.

Since production runs could not be made to test if surging could in fact be reduced, due to the vast amounts of feedstock required, resort was made to numerical experimentation. An existing software package was modified to allow study of the transport of a portion of the solid bed. In this way rupture could be predicted based on the value of the interparticulate friction coefficient. Thus it could be inferred that surging would be reduced.

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**This dissertation is dedicated to
my beloved parents
Ning-Ming Liu and Yang Yin-Dien Liu
my wife
Chiu-Hui Tu
and
my son
Kevin Liu**

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TABLE OF CONTENTS

	Page
LIST OF TABLES.....	x
LIST OF FIGURES.....	xii
LIST OF SYMBOLS.....	xxvii
 Chapter	
1. INTRODUCTION.....	1
1.1 Introductory Comments	1
1.2 Previous Studies.....	3
1.3 Scope of the Present Work	4
2. THE BASIS FOR ENHANCING THE INTERPARTICULATE FRICTION COEFFICIENT IN PLASTICATING EXTRUSION	10
2.1 Fundamentals of Single Screw Extruders	10
2.2 Solids Conveying Zone	11
2.3 Melting Zone.....	12
2.4 Melt Conveying Zone	14
2.5 Extrudate Quality	15
3. DESIGN OF EXTRUSION PROFILE DIES FOR THE MANUFACTURE OF PELLETS WITH PROFILED CROSS-SECTIONS.....	19
3.1 Aspects of Die Design.....	19
3.1.1 Die Swell.....	20
3.1.2 Die Land Length	22
3.1.3 Die Entry Geometry	23
3.2 Specific Die Design	24
3.3 Profile Die Inserts.....	25

4. MANUFACTURE OF PELLETS OF NON-CIRCULAR CROSS-SECTIONS.....	33
4.1 Preparation of the Polymer Feedstock.....	33
4.1.1 Acetal Copolymer	33
4.1.2 Nylon 6.....	34
4.1.3 Polyethylene.....	35
4.1.4 Polypropylene	35
4.1.5 Polystyrene	35
4.1.6 Acrylonitrile-Butadiene-Styrene	36
4.2 Procedure for Operating the Extruder.....	36
4.3 The Operating Conditions for Profile Extrusion	38
5. MECHANISM OF INTERPARTICULATE FRICTION IN POLYMERIC PARTICULATE CONTINUA.....	56
5.1 Mechanics of Friction	56
5.2 Agglomeration	57
5.3 Interparticulate Strength.....	58
6. TEST APPARATUS AND TEST PROCEDURE FOR THE MEASUREMENT OF THE INTERPARTICULATE FRICTION COEFFICIENT	62
6.1 Test Apparatus	62
6.2 Test Procedure.....	63
6.3 V-Blender	63
6.4 Method of Calculation for IPFC	64
6.5 Validation of the Test Results	65
7. EXPERIMENTAL RESULTS FOR THE INTERPARTICULATE FRICTION COEFFICIENT	72
7.1 Pellets with Circular Cross-Sections	72
7.2 Pellets with Bilobal Cross-Sections	73
7.3 Pellets with Trilobal Cross-Sections.....	78
7.4 Pellets with Quadrilobal Cross-Sections	80
7.5 Pellets with Consolidation Pressure and Consolidation Time	81
7.6 Pellets with Surface Lubricant and Additive	81

8. DISCUSSION - THE INTERPARTICULATE FRICTION	
COEFFICIENT	121
8.1 Comparison of the IPFC for Pellets with Circular and Bilobal Cross-Sections	121
8.2 Comparison of the IPFC for Pellets with Circular and Trilobal Cross-Sections	135
8.3 Comparison of the IPFC for Pellets with Circular and Quadrilobal Cross-Sections	139
8.4 Pellets with Bilobal, Trilobal and Quadrilobal Cross-Sections	142
8.4.1 Effect of Normal Pressure	142
8.4.2 Effect of Extruder Screw Speed.....	142
8.4.3 Effect of Molecular Weight	143
8.4.4 Effect of Extrusion Die Geometry.....	143
8.4.5 Effect of Agitation of the Particulate Bed	143
8.4.6 Effect of Consolidation Pressure of the Particulate Bed.....	149
8.4.7 Effect of Consolidation Time of the Particulate Bed.....	150
8.4.8 Effect of Particulate Powders.....	150
8.4.9 Effect of Surface Lubricants.....	151
8.5 Comparison of the IPFC for Pellets with Bilobal ,Trilobal and Quadrilobal Cross-Sections.....	151
8.6 Effect of the IPFC Increases on the Performance of Plastics Solid Conveying Equipment	152
9. THE SIMULATION OF THE PLASTICATING EXTRUSION	
PROCESS WITH EMPHASIS ON THE CONVEYING OF	
POLYMERIC PARTICULATES.....	222
9.1 Summary of the Simulation Procedure	222
9.2 Geometry of the Screw	227
9.3 Operating Variables.....	228
9.4 Simulation Input	229
9.5 Description of the Simulation Printout	231
9.6 Simulation Results.....	233
9.6.1 Varying the Screw Speed	240
9.6.2 Varying the Flow Rate.....	241
9.6.3 Varying the IPFC	242

9.7 Simulation Discussion.....	244
9.7.1 Effect of Screw Speed.....	244
9.7.2 Effect of Flow Rate	244
9.7.3 Effect of IPFC	245
10. POSTLUDE.....	256
10.1 Conclusions.....	256
10.2 Future Work.....	258
10.2.1 Additional Profile Shapes	258
10.2.2 Additional Resin	258
10.2.3 Additional Resin Grades	258
10.2.4 Field Trials.....	259
 BIBLIOGRAPHY	 263
 APPENDIX A.....	 268
 APPENDIX B	 301

LIST OF TABLES

Table	Page
3.1 Specification of the Profile Die Inserts	25
4.1 Drying Conditions of the Polymer Feedstocks for Acetal Copolymer, Polyethylene, Polypropylene, Polystyrene, Nylon 6 and ABS.....	38
4.2 Material Resin & Codes	38
4.3 Material Mechanical Properties.....	39
4.4 Operating Conditions of Profile Die A211 for Acetal Copolymer.....	40
4.5 Operating Conditions of Profile Die A212 for Acetal Copolymer.....	41
4.6 Operating Conditions of Profile Die A221 for Acetal Copolymer.....	42
4.7 Operating Conditions of Profile Die A231 for Acetal Copolymer.....	43
4.8 Operating Conditions of Profile Die A241 for Acetal Copolymer.....	44
4.9 Operating Conditions of Profile Die A311 for Acetal Copolymer.....	45
4.10 Operating Conditions of Profile Die A411 for Acetal Copolymer.....	46
4.11 Operating Conditions of Profile Die A211 for PE, PP, PA 6, ABS and PS	47
4.12 Operating Conditions of Profile Die A212 for PE, PP, PA 6, ABS and PS	48
4.13 Operating Conditions of Profile Die A221 for PE, PP, PA 6, ABS and PS	49
4.14 Operating Conditions of Profile Die A231 for PE, PP, PA 6, ABS and PS	50
4.15 Operating Conditions of Profile Die A241 for PE, PP, PS, PA 6 and ABS	51
4.16 Operating Conditions of Profile Die A311 for PE, PP, PA 6 and PS	52
4.17 Operating Conditions of Profile Die A411 for PE and PP	53
6.1 The Friction Coefficients of the Polymer for Acetal Copolymer, Polyethylene, Polypropylene, Polystyrene, Nylon 6, and ABS on Steel Surface	66
8.1 Effect of Normal Pressure on the Average IPFC for Acetal Copolymer.....	141
8.2 Effect of Normal Pressure on the Average IPFC for PE, PP, PS, PA 6 and ABS.....	141

8.3	Effect of Extruder Screw Speed on the Average IPFC for Acetal Copolymer	142
8.4	Effect of Extruder Screw Speed on the Average IPFC for PE, PP, PS, PA 6 and ABS	142
8.5	Effect of Molecular Weight on the Average IPFC for Acetal Copolymer	143
8.6	Effect of Die Geometry on the Average IPFC for Acetal Copolymer	143
8.7	Effect of Die Geometry on the Average IPFC for PE, PP, PS, PA 6 and ABS	144
8.8	The Average IPFC values for Pellets with Bilobal, Trilobal and Quadrilobal Cross-Section for Acetal Copolymer, PE, PP, PS, PA 6 and ABS	144

LIST OF FIGURES

Figure	Page
1.1 Solids Bed in Plasticating Screws, (a) Solids Conveying Zone, (b) Melting Zone	6
1.2 The Fracture Plane on Solid Bed	7
1.3 Forces Acting on a Portion of the Solids Bed	8
1.4 Non-Circular Pellet Cross-Sections, (a) Possible Geometries, (b) Possible Interlocking Mechanisms, (c) Multi-Lobals	9
2.1 Typical Single Screw Extruder with Three Zones (a) Solid Conveying Zone, (b) Melting Zone, (c) Melt Conveying Zone	18
3.1 Plate Type Profile Extrusion Die	27
3.2 Streamlined Profile Extrusion	27
3.3 Effect of Entrance Flow Channel and Die Length on Extrudate Swelling	28
3.4 Typical Curves Showing Effect of Capacity Entry Angle on Critical Shear Rate for Three Different Resin	28
3.5 Diagram of Entry Geometry	29
3.6 Original Die in Test Extruder	30
3.7 Modified Die in Test Extruder	31
3.8 Profile Die A211, A212, A221, A231, A241, A311 and A411 - Details	32
4.1 Drying Oven Manufactured by Blue M. Electric, Co	55
4.2 Extruder Manufactured by Wayne Tool and Die, Co	55
5.1 The Yield Locus of Cohesive System	61
5.2 The Yield Locus of Noncohesive System	61
6.1 Direct Shear Cell Apparatus	68
6.2 Schematic Diagram of the Shear Cell for the Measurement of the Interparticulate Friction Coefficient	69
6.3 V-Blender	70
6.4 Acting Force on Shear Cell	71

7.1	IPFC of Cylindrical for Pellets With Circular Cross-Sections (a) U-10, (b) M-25, (c) M-90, (d) M-270, (e) M-450	83
7.2	IPFC of Cylindrical for Pellets With Circular Cross-Sections (a) PE, (b) PP,(c) PS, (d) PA 6, (e) ABS	83
7.3	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM1	84
7.4	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM1	84
7.5	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM1	85
7.6	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM1	85
7.7	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM1	86
7.8	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM2	86
7.9	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM2	87
7.10	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM2	87
7.11	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM2	88
7.12	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM2	88
7.13	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM3	89
7.14	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM3	89
7.15	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM3	90
7.16	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM3	90

7.17	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM3	91
7.18	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM4	91
7.19	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM4	92
7.20	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM4	92
7.21	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM4	93
7.22	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM4	93
7.23	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM5	94
7.24	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM5	94
7.25	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM5	95
7.26	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM5	95
7.27	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM5	96
7.28	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PE	96
7.29	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PE	97
7.30	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PE	97
7.31	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PE	98
7.32	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PE	98

7.33	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PP	99
7.34	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PP	99
7.35	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PP	100
7.36	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PP	100
7.37	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PP	101
7.38	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PS	101
7.39	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PS	102
7.40	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PS	102
7.41	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PS	103
7.42	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PS	103
7.43	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PA 6	104
7.44	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PA 6	104
7.45	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PA 6	105
7.46	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PA 6	105
7.47	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PA 6	106
7.48	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for ABS	106

7.49	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for ABS	107
7.50	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for ABS	107
7.51	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for ABS	108
7.52	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM1	108
7.53	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM2	109
7.54	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM3	109
7.55	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM4	110
7.56	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM5	110
7.57	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PE	111
7.58	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PP	111
7.59	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PS	112
7.60	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PA 6	112
7.61	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM1	113
7.62	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM2	113
7.63	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM3	114
7.64	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM4	114

7.65	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM5	115
7.66	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for PE	115
7.67	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for PP	116
7.68	IPFC for the Pellets Manufactured Using Die A211 with Consolidation Pressure as a Function of Normal Pressure for PE.....	116
7.69	IPFC for the Pellets Manufactured Using Die A211 with Consolidation Time as a Function of Normal Pressure for PE.....	117
7.70	IPFC for Pellets with Circular Cross-Sections with Zinc Stearate as a Function of Normal Pressure for POM3.....	117
7.71	IPFC for Pellets Manufactured Using Die A211 with Zinc Stearate as a Function of Normal Pressure for POM3.....	118
7.72	IPFC for Pellets Manufactured Using Die A212 with Zinc Stearate as a Function of Normal Pressure for POM3.....	118
7.73	IPFC for Pellets with Circular Cross-Section with Mica Clay as a Function of Normal Pressure for PA 6.....	119
7.74	IPFC for Pellets Manufactured Using Die A241 with Mica Clay at Extruder Screw Speed 20rpm as a Function of Normal Pressure for PA 6.....	119
7.75	IPFC for Pellets with Circular Cross-Section with PBT Powder as a Function of Normal Pressure for POM3.....	120
7.76	IPFC for Pellets Manufactured Using Die A212 with PBT Powder at Extruder Screw Speed 15rpm as a Function of Normal Pressure for POM3.....	120
8.1	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM1	157
8.2	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM1	157
8.3	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM1	158

8.4	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM1	158
8.5	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM2	159
8.6	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM2	159
8.7	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM2	160
8.8	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM2	160
8.9	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM3	161
8.10	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM3	161
8.11	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM3	162
8.12	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM3	162
8.13	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM4	163
8.14	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM4	163
8.15	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM4	164
8.16	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM4	164
8.17	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM5	165
8.18	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM5	165
8.19	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM5	166

8.20	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM5	166
8.21	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for PE	167
8.22	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for PE	167
8.23	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for PE	168
8.24	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for PE	168
8.25	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for PP	169
8.26	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for PP	169
8.27	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for PP	170
8.28	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for PP	170
8.29	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for PS	171
8.30	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for PS	171
8.31	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for PS	172
8.32	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for PS	172
8.33	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for PA 6	173
8.34	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for PA 6	173
8.35	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for PA 6	174

8.36	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for PA 6	174
8.37	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for ABS	175
8.38	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for ABS	175
8.39	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for ABS	176
8.40	% Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for ABS	176
8.41	% Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 1	177
8.42	% Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 2	177
8.43	% Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 3	178
8.44	% Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 4	178
8.45	% Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 5	179
8.46	% Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PE	179
8.47	% Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PP	180
8.48	% Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PS	180
8.49	% Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PA 6	181
8.50	% Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 1	181
8.51	% Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 2	182

8.52	% Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 3	182
8.53	% Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 4	183
8.54	% Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM 5	183
8.55	% Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PE	184
8.56	% Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PP	184
8.57	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM1 with Agitation	185
8.58	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM2 with Agitation	185
8.59	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM3 with Agitation	186
8.60	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM4 with Agitation	186
8.61	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM5 with Agitation	187
8.62	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM1 with Agitation	187
8.63	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM2 with Agitation	188
8.64	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM3 with Agitation	188
8.65	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM4 with Agitation	189
8.66	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM5 with Agitation	189
8.67	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM1 with Agitation	190

8.68	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM2 with Agitation	190
8.69	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM3 with Agitation	191
8.70	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM4 with Agitation	191
8.71	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM5 with Agitation	192
8.72	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM1 with Agitation	192
8.73	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM2 with Agitation	193
8.74	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM3 with Agitation	193
8.75	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM4 with Agitation	194
8.76	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM5 with Agitation	194
8.77	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM1 with Agitation	195
8.78	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM2 with Agitation	195
8.79	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM3 with Agitation	196
8.80	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM4 with Agitation	196
8.81	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM5 with Agitation	197
8.82	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PE with Agitation	197
8.83	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PP with Agitation	198

8.84	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PS with Agitation	198
8.85	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PA 6 with Agitation.....	199
8.86	IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for ABS with Agitation	199
8.87	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PE with Agitation	200
8.88	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PP with Agitation	200
8.89	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PS with Agitation	201
8.90	IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PA 6 with Agitation	201
8.91	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PE with Agitation	202
8.92	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PP with Agitation	202
8.93	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PS with Agitation	203
8.94	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PA 6 with Agitation	203
8.95	IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for ABS with Agitation	204
8.96	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PE with Agitation	204
8.97	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PP with Agitation	205
8.98	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PS with Agitation	205
8.99	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PA 6 with Agitation	206

8.100	IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for ABS with Agitation	206
8.101	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PE with Agitation	207
8.102	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PP with Agitation	207
8.103	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PS with Agitation	208
8.104	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PA 6 with Agitation	208
8.105	IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for ABS with Agitation	209
8.106	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM1 with Agitation	209
8.107	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM2 with Agitation	210
8.108	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM3 with Agitation	210
8.109	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM4 with Agitation	211
8.110	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM5 with Agitation	211
8.111	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM1 with Agitation	212
8.112	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM2 with Agitation	212
8.113	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM3 with Agitation	213
8.114	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM4 with Agitation	213
8.115	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM5 with Agitation	214

8.116	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PE with Agitation	214
8.117	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PP with Agitation	215
8.118	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PS with Agitation	215
8.119	IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PA 6 with Agitation	216
8.120	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for PE with Agitation	216
8.121	IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for PP with Agitation	217
8.122	Effect of Consolidation Pressure on IPFC for Pellets Manufactured Using Die A211 of PE	217
8.123	Effect of Consolidation Time on IPFC for Pellets Manufactured Using Die A211 of PE at Consolidation Pressure 126.3kPa	218
8.124	% Increase for Pellets with Circular Cross-Sections of PA 6 with Mica Clay	218
8.125	% Increase for Pellets Manufactured Using A241 of PA 6 with Mica Clay at Extruder Screw Speed 20rpm	219
8.126	% Increase for Pellets with Circular Cross-Sections of POM3 with PBT Powder	219
8.127	% Decrease for Pellets Manufactured Using Die A212 of POM3 with PBT Powder at Extruder Screw Speed 15rpm	220
8.128	% Decrease for Pellets with Circular Cross-Sections of POM3 with Zinc Stearate	220
8.129	% Decrease for Pellets Manufactured Using A211 of POM3 with Zinc Stearate	221
8.130	% Decrease for Pellets Manufactured Using A212 of POM3 with Zinc Stearate	221

9.1	Force Balances on a Differential Element of Particulate Bed, (a) Stationary Solids, $F_o > F_L$, (b) Stationary Solids, $F_o > F_L$, (c) Solids Move at Constant Velocity in the Position X-Direction, (d) Solids Move at Constant Velocity in the Negative X-Direction	246
9.2	Idealized Channel Cross-Section Perpendicular to the Flights Compared to Real Cross-Sections in the Melting Zone	247
9.3	Extruder Manufactured by Prodex Co	248
9.4	Screw Manufactured by Prodex Co	249
9.5	Details of Prodex Screw	250
9.6	The Pressure as a Function of Axial Screw Position for Different Screw Speeds for Acetal Copolymer Grade M90	251
9.7	The Solid Bed Ratio as a Function of Axial Screw Position for Different Screw Speeds for Acetal Copolymer Grade M90	252
9.8	The Pressure as a Function of Axial Screw Position for Different Flow Rates for Acetal Copolymer Grade M90	253
9.9	The Solid Bed Ratio as a Function of Axial Screw Position for Different Flow Rates for Acetal Copolymer Grade M90	254
9.10	The IPFC as a Function of Axial Screw Position at Same Channel Depth for Acetal Copolymer Grade M90	255
10.1	Additional Pellet Cross-Sections, (a) Rectangular, (b) Square, (c) Triangular, (d) Crescent, (e) Star	262

LIST OF SYMBOLS

A	area, in ²
B	bound limit
C _f	channel flight width, in
C _c	channel flight clearance, in
C _{ps}	specific heat of the solid, Btu/lb °F
C _{pm}	specific heat of the melt, Btu/lb °F
D _B	barrel Diameter, in
D _c	channel depth, in
F _c	channel flight clearance, in
F _h	horizontal friction force, N
F _v	vertical contact force, N
G	mass flow rate through the extruder, lb/hr
K	stress factor dependent on the particle shape
F _d	screw flight diameter, in
L	length of the extruder, in
L _f	length of feed zone, in
L _s	length of each geometrical section, in
N	normal force, N
N _s	frequency of screw rotation, rpm
N _c	packing coordination
N _t	number of channels (threads) in parallel
P _o	pressure at entrance of feed zone, psi
P _s	pressure at solid conveying zone, psi
S	shear force, N
S _l	screw lead, in

S_n	number of geometries sections on the screw
T	total externally applied horizontal force, N
T_b	barrel temperature of the polymer, °F
T_m	melting temperature of the polymer, °F
T_{av}	average temperature of the polymer in the film, °F
V	velocity, ft/sec
V_{bx}	velocity component in the x direction of the inner surface of the barrel relative to screw, in/sec
W_r	vertical force due to weight of ring, N
W_r	friction force between ring and material, N
X	solid bed width, in
X_i	solid bed width at the entrance of each axial increment, in
X_o	solid bed width at the exit of each axial increment, in
Z_F	power for feed zone, HP
a	constant
f	fractional density
f_s	screw friction,
f_b	barrel friction,
k_m	thermal conductivity of the melt, Btu/hr
m	mean value,
n	parameter in the "power law" model
r	radius of orifice,
x,y,z	co-ordinate directionns
Φ	dimensionless constant
δ	thickness of the melt film, in
$\dot{\gamma}$	shear rate, s ⁻¹
λ	heat of fusion, Btu/lb

μ	interparticulate friction coefficient
ψ	angle of internal friction
θ	angle of movement of the outer surface of the solid plug, radians
ρ_m	density of melt, lb/ft ³
σ_c	tensile strength, psi
τ	characteristic relaxation time, sec
ϕ_s	helix angle at the screw root, degrees
ϕ_a	helix angle of screw at the average depth of the screw channel, degrees

CHAPTER 1

INTRODUCTION

1.1 Introductory Comments

The classical solids conveying and melting mechanism models for plasticating extrusion, reciprocating-screw injection molding, and extrusion blow molding assume that the solids bed remains intact. During solids conveying the particulates, are initially loosely packed and then, as the pressure is generated by the rotation of the plasticating screw, the particulates pack tightly into a solid bed. This mechanism of conveying was first presented by Darnell and Mol [16], and expanded upon by Tadmor and Klein [49].

The melting mechanism which occurs in plasticating extrusion, reciprocating-screw injection molding and extrusion blow molding, was first explained by Maddock [27] and was also expanded upon by Tadmor, Duvdevani and Klein [47]. Cross-sections of the polymer in the extruder channel are shown in Figure 1.1 in schematic form, for the solids conveying and the melting situations. In the solids conveying zone the solids become tightly packed into a solid bed continuum. As it melts from the surface in contact with the barrel, a melt film forms. The melt film grows until it is thick enough to be scraped from the barrel surface by the rotating screw flight. Then it collects in a recirculating melt pool in front of the screw flight. At this time the solids bed starts to melt from this second solid-melt interface, and consequentially develops a non-rigid side. This allows the possibility of solid bed fracture, since the bed is no longer contained by metallic walls. Gradually, all of the solids melt and the melting process is completed.

Most often this is exactly what happens in single screw plasticating extrusion. However, it is also known that the solid bed can fracture, and a discontinuity in the

continuum will result. When fracture of the solid bed, or solid bed break-up, occurs it is frequently accompanied by surging of the output. The melting discontinuity resulting from the fracture precipitates a temperature non-homogeneity, which leads to a pressure variation at the die, and subsequently throughput variations, or surges. Tadmor and Klein [49] reported that for many materials, under various operating conditions, solid bed break-up can be observed. They also related solid bed break-up to the temperature fluctuations observed by Marshall, Klein and Uhl [30]. Under certain conditions, the solid bed break-up so that it fills up the channel with solids leaving no room for the melt to pass. When this happens the melt accumulating behind the solid plug occasionally breaks through causing a sudden increase in production rate and associated drop in pressure. Such a fluctuation in production rate and pressure is called surging. When surging occurs, the manufacturing system can become unstable, and low quality product can be produced. The product can even fail quality specifications and be rejected altogether. Therefore, surging is considered undesirable, and manufacturing units are frequently slowed down, or stabilized, until the surging is arrested. The causes and effects of surging have been reported by Tadmor and Klein [49]. The plane of fracture is clearly the weakest plane in the solid bed as shown in Figure 1.2. If the forces involved in the fracture are tensile, then the only methods available to maintain the integrity of the solid bed are to eliminate the tensile forces or increase the agglomeration forces of the polymer. However, tensile forces should not occur in a well designed plasticating screw since the solid bed is compressed and shear. If, however, the solid bed fractures as a result of shear loading, then an increase in the resistance of the solid bed to shear will clearly reduce, or eliminate, the solid bed break-up. Although not proven, it seems likely that the curvature of the channel may be responsible for the solid bed break-up since it may place the solid bed in a bending mode. This is illustrated in Figure 1.3. In this circumstance, tensile fracture near the barrel is possible. However, the positive

pressure gradient in the screw channel should inhibit this action. Although not proven, it seems more likely that fracture would occur by the action of shear forces since the external loading is by torsional shear. Thus, if the resistance to the shear forces can be increased, then, solid bed break-up will be reduced. If the solid bed remains intact cold spots due to solids broken up on the melt cannot cause temperature variations in the melt at the die and so viscosity will not occur, therefore pressure variations and output variations will not occur. Clearly, the resistance to any applied shear force will be increased in proportion to the interparticulate friction coefficient. Hence, the onset of surging may be postponed.

1.2 Previous Studies

Although the interparticulate friction coefficient has not been extensively studied, the friction coefficient between polymeric particulates and various metals has received extensive attention. This is due to its importance in solids conveying calculations for the design of plasticating screws for extrusion, injection molding and blow molding, and the need to accurately know the friction coefficients between the metal surfaces and the polymeric particulates. The interparticulate friction coefficient, by contrast, is not measured, but is assumed to be great enough to maintain the integrity of the solid bed.

Schneider [41] was the first to measure the coefficients of friction between metal surfaces and polymeric particulates, noting its dependence on temperature, normal load and relative sliding velocity. Evans [18] confirmed the findings of Schneider in a more sophisticated apparatus. Finally, Huxtable, Cogswell and Wriggles [23] developed an apparatus which accounted for the above effects, as well as channel depth and particulate location. These authors provided extremely accurate, and extensive, results for several polymers. However, no additional results have been reported for the interparticulate friction coefficient since Jenike [25].

Thus, the assumption has always been made that the solid bed remains intact, and that the metal-polymer friction coefficients dominate the solids conveying in plasticating extruders, reciprocating-screw injection molding machines, and extrusion blow molding machines.

Subsequently the development of the barrier screws by Maillefer [29], where the solid and melt fractions are separated, and the many derivatives which followed [4], have provided a way to maintain the integrity of the solid bed, as well as to hasten melting. However, the designs are more complex, the screws more costly, and output is not necessarily increased. In addition, these designs have not penetrated the reciprocating-screw injection molding machine market, or the extrusion blow molding machine market. Yet, solid bed break-up can cause severe aberrations in these processes.

Clearly there is a strong motivation to maintain the production unit close to surging conditions in order to maximize the throughput, but it is taken at the risk of quality diminution. If the throughput could be increased, without the occurrence of surging, the resultant cost benefits would be significant. In fact, only a 5% increase in extruder throughputs would result in billion dollar savings to the industry.

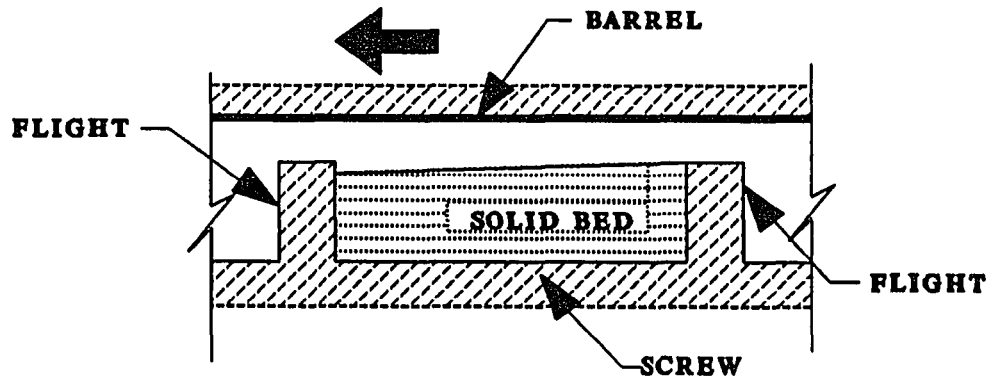
1.3 Scope of the Present Work

In this work, the hypothesis that increasing the interparticulate friction coefficients reduces the likelihood of solid bed fracture is tested. The resistance of the solid bed under shear loading is increased if the interparticulate friction coefficient is increased. The increases of interparticulate friction coefficient are expected if the polymeric particulates can be made to interlock. This action is further hypothesized if the traditional pellets of circular cross-section are replaced by pellets with more complex geometries which allow interlocking to occur. Some examples of pellet geometries which allow interlocking are shown in Figure 1.4 (a) and the

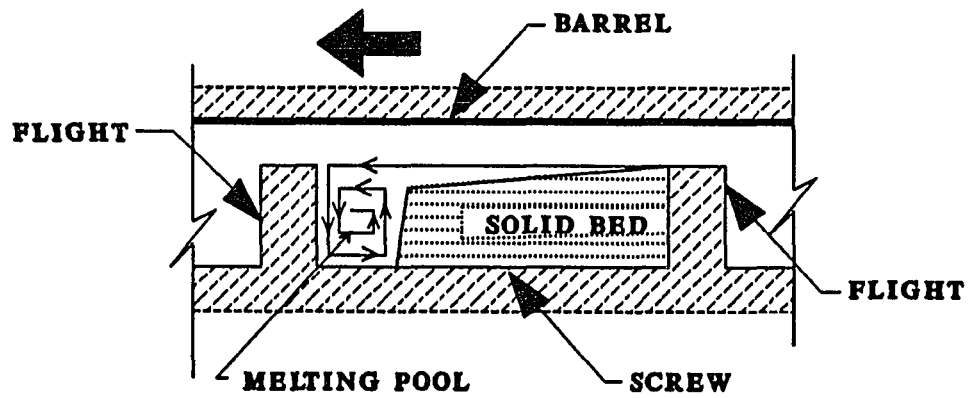
methods by which they may interlock are shown in Figure 1.4 (b). There are many ways that pellets can rest against adjacent pellets, and the real system will involve a statistical combination of all of them. The manner in which they touch directly affects the interparticulate friction coefficient of the particulate continuum, and this coefficient will be utilized as a measure of the behavior of the particulate continuum without studying the explicit details of the situation. Although the interparticulate friction coefficient has not been extensively studied, the friction coefficient between polymeric particulates and various metals has received extensive attention. This is due to its importance in solids conveying.

In this study, the concentration has been placed upon pellets with multi-lobal cross-sections such as the bilobal, the trilobal and the quadrilobal as shown in figure 1.4 (c). The fabrication of pellets with multi-lobal cross-sections is presented in chapter three and four, including the task of designing, constructing and operating a profile die which produces consistently shaped pellets, during extrusion. The measurement of the interparticulate friction coefficient was first presented by Jenike [25], in his classic work on soil mechanics. For polymers, however, scant data is available [48]. The experimental apparatus, known as a direct shear cell, used for these measurements is described in chapter six and the experimental results are presented in chapter seven.

The simulation for the plasticating extrusion process is illustrated in chapter nine, in order to justify the performance of the screw extruder, to accomplish the optimum conditions for the extrusion process.



(a) Solids Conveying Zone



(b) Melting Zone

Figure 1.1 Solids Bed in Plasticating Screws, (a) Solids Conveying Zone, (b) Melting Zone.

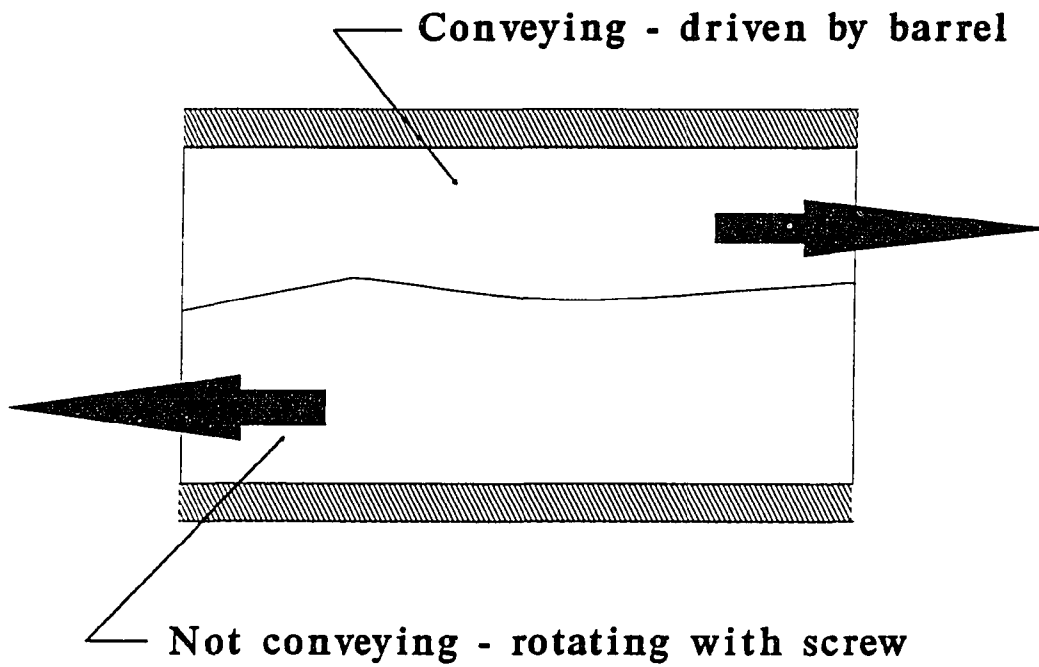


Figure 1.2 The Fracture Plane on Solid Bed.

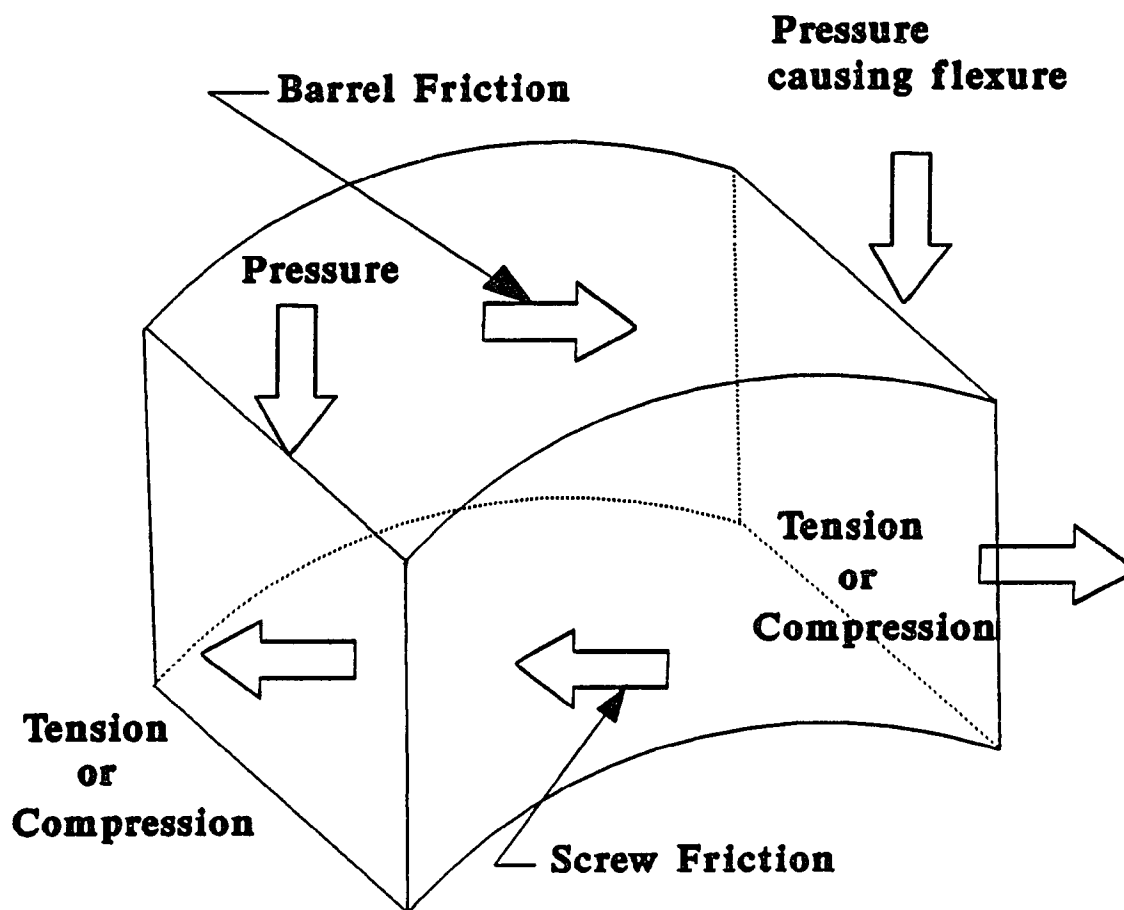


Figure 1.3 Forces Acting on a Portion of the Solids Bed.

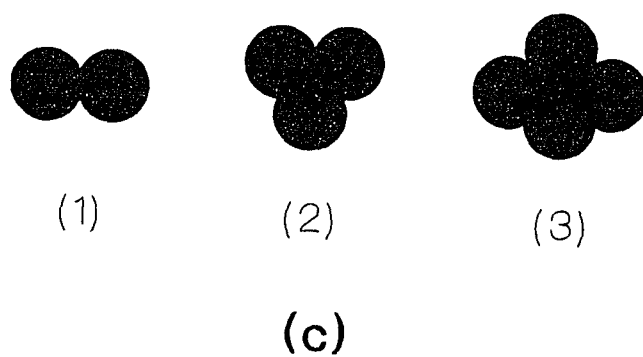
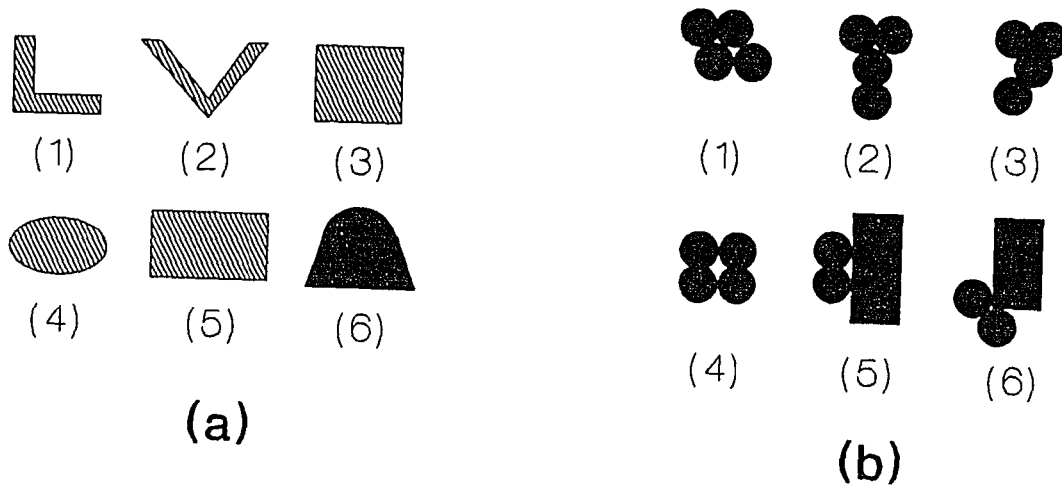


Figure 1.4 Non-Circular Pellet Cross-Sections, (a) Possible Geometries, (b) Possible Interlocking Mechanisms, (c) Multi-Lobals.

CHAPTER 2

THE BASIS FOR ENHANCING THE INTERPARTICULATE FRICTION COEFFICIENT IN PLASTICATING EXTRUSION

2.1 Fundamentals of Single Screw Extruders

The single screw extruder is the most important equipment used in the polymer processing field. All polymers pass through an extruder at least once in the production path from the polymerization reactor to the finished product. The single screw extruder is in fact the central component of a whole group of processing machines, such as the melt extruder, the injection and blow molding machines.

The single screw extruder is shown in Figure 2.1. The plasticating process is divided into three zone. These are,

- a. solid conveying zone
- b. melting zone
- c. melt conveying zone

The solid conveying zone transfers the granules, or pellets, from the hopper at the input of the extruder, and conveys the solid to the melting zone. Its conveying capacity must be at least equal to the metering capacity on a weight basis. In the feed section the solid plastic particles, generally in the form of cylindrical pellets, are pushed along the channel by the rotating screw. The solids conveying zone is considered to end where the solids begin melting. The melting and compression zone starts at that transition point. After all the solids is totally melt, it enters the melt conveying zone.

The variables which control the solid delivery are discussed by Decker [17]. These are the shape and dimensions of the channel, surface temperature, back

pressure. and the coefficient of friction between the plastic and the metal of both the screw and the barrel surface.

2.2 Solids Conveying Zone

The solids conveying mode was proposed by Decker [17]. Though, the conclusions given by Decker correlate qualitatively with experience, the formulas given do not relate well to actual behavior. In 1947 Weber [54] treated the plastic plug as a solid continuum but neglected the forces acting between the barrel and the material.

A much more realistic approach for the conveying of solids in the screw extruder is given by Pawlowski [35]. He proposed a balance of forces on the screw channel. The analysis of this balance is based on the estimation of the mechanical forces acting upon the solid plug of plastic from the barrel and screw. All forces result in either pressures normal to the flight surface or shearing forces due to friction parallel to the contacting surfaces.

Maillefer [28] also discussed the solids conveying section, but his analysis was not made in curved channels where torques are involved, and therefore, did not include all forces acting on the solid plug. Simonds, et al. [44] stressed the importance of friction on solids transport and introduced the balance of torques, but this treatment can predict only whether or not solids will be conveyed. Jackson, et al. [24] performed a similar analysis to that of Maillefer but included the normal force that the pushing flight exerts on the plastic plug. However, because they did not perform the essential balance of torques, the equations have little value.

The most thorough analysis for the conveying of solids in the single screw extruder was performed by Darnell and Mol [16], who also reviewed previous work in this area. The analysis presented by Darnell and Mol [16], will be followed with some modifications. Among these, the width of the flights will be incorporated into

the derivation, and different friction coefficients will be assumed on the barrel and screw surfaces. Since friction forces between the solid polymer and barrel and screw surfaces play a decisive role in the solids conveying mechanism.

2.3 Melting Zone

The melting zone, or phase transition zone, is defined as that portion of the screw in which solid polymer and melt coexist. The melting mechanism in screw extruders was first investigated by Maddock [27] and by Street [46]. They developed the experimental techniques which led to the development of a qualitative mechanism for melting through visual observation, and then enabled the development of a theoretical model for melting through quantitative analysis by Tadmor [48], and by Tadmor, Duvdevani and Klein [47].

Furthermore, a good understanding of the melting mechanism is of paramount importance for the understanding of plasticating screw extruders. The solid pellets which are fed into the hopper start moving toward the die, at a certain point the barrel starts heating, the solid pellets which touch the hot barrel surface. They melt and form a thin film of melted polymer on the barrel surface. When the pellets reach this point, they are no longer loosely packed, since considerable pressure is developed. It tends to compact the pellets into a sturdy solid bed. The bed has the shape of the helical channel and slides in it. In spite of the compacting, the pellets retain their individuality, and the boundaries between the individual pellets are clearly visible in the solid bed way down the channel. The barrel surface is moving relative to the solid bed and the screw. Due to this relative movement, a velocity profile develops in the melt film between the solids bed and surface of the barrel. Thus, the melt in the film starts to flow toward the advancing flight, and as it meets the flight, the latter scrapes the melt off the barrel. The melt collects in the pool of melt in the rear of the channel in front of the advancing flight. As the solid bed slides

down the channel, more and more melt is carried into the pool of melt, the size of which consequently increases, while that of the solid bed decreases. Thus, in spite of the fact that most of the melting occurs at the barrel surface, or rather at the interface of the melt film and the solid bed, the height of the solid bed does not decrease and the solid bed is continuously rearranged while maintaining a constant height. In effect this rearrangement causes the solid bed to continuously move into the interface where it melts. Consequently, the width of the solid bed gradually decreases as it moves down the channel. The total length from the onset of melting to the point where the solid bed width drops to zero is termed length of melting zone. It must be realized that there are two sources of heat in the melting mechanism. One is the heat which comes from the heaters on the barrel. This heat conducted from the hot barrel surface through the film into the interface. Another is the heat that originates from viscous dissipation due to the relative velocity of the barrel and screw shearing the thin film. The ratio of these two heat sources depends entirely on the operating conditions and the polymer properties. The solid bed is composed of compacted solid particles. If the solid bed can not resist the shear force, it will usually break up at some point in the channel. The gap created by the breaking up of the solid bed is quickly filled with melt. This breaking up process, if it occurs, is not accidental or random. The solid bed is dragged forward by the barrel. In addition, large pressure gradients exist in the channel, and the solid bed has a different velocity from that of the neighboring melt. Meanwhile, the rest of the solid bed will move forward until once more external forces overcome the resisting forces. This second and sequent breaking of the solid bed usually occurs at approximately the same point in the extruder as the previous one. Obviously there seems to be an inherent instability in the melting process. The solid bed break up occurs, accompanied by surging of the output. The solid bed fractures as a result of shear loading, then increases in the resistance of the solid bed to shear will clearly reduce, or eliminate,

the solid bed break up. Clearly, the resistance to any applied shear force will be increased in proportion to the interparticulate friction coefficient. Therefore, the surging phenomena may be inhibited or postponed.

2.4 Melt Conveying Zone

The melt conveying zone is the last section of the screw preceding the die. It produces the die pressure which controls the flow rate of the extruder. It acts as a metering pump from which the molten plastics material is delivered to the die system at constant volume and pressure. There are two distinct melt conveying mechanisms. One is downstream the melting zone after the completion of melting, Another melt conveying mechanism occurs in the melt pool, which extends side by side with the solid bed profile, in the melting zone the width of the melt pool changes in the flow direction. Where the model for the melt conveying zone of a plasticating screw extruder discussed by Tadmor and Klein [49] stipulates the equations for calculating the flow rate, pressure, temperature, and velocity distributions across the channel as well as down the channel. In order to solve the basic flow equations, there are two different theoretical models proposed. One is a simplified flow theory where the nature of the polymer melt and the temperature conditions in the channel is based on isothermal Newtonian flow, which was proposed by Rowell and Finlayson [38] and later by Carley, Mallouk and McKelvey [9]. Another is non-Newtonian flow by using the "power law" fluid model, which was proposed by Ostwald [34] and Glyde and Holmes-Walker [20]. Here the melt conveying model is used to calculate local pressure gradients and temperature changes over small finite axial increments using the mean local flow rate and melt pool size. It also provides additional information relevant to extruder design and operation, specifically the power input required for this zone.

2.5 Extrudate Quality

The object of melt extrusion of thermoplastics is the continuous production of useful products of given, uniform cross section, and quality. The appearance of rough extrudates and those whose shapes do not conform to the cross section of the openings of the extrusion dies may result from any of the following causes, such as the presence of volatile material and gel particles in the polymer, extrudate swelling, poor die finish, and melt fracture.

It is well known that volatile constituents such as water may cause crater-like depressions from burst surface bubbles and that gel particles may cause small bumps. Elimination of such defects obviously requires elimination of the volatiles and gels.

The dimensions of the cross section of extrudates always tend to be larger than the corresponding dimensions of the extrusion dies. The extrusion swelling does not usually cause roughness. However, it may result in considerable distortion of the extrudate shape relative to that of the die. The amount of extrudate swelling may be reduced by any of the following - drawing the melt, raising the temperature, lengthening the die, and lowering the throughput.

Rough interior surfaces on extrusion dies may result in rough extrudate surfaces. Tool marks or scratches in a die land in the direction of flow tend to cause marks or streaks along the length of the product. However, a mirror finish on die lands may not be necessary. Sand blasted surfaces and those on which the tool marks are transverse to the flow direction appear to have little effect on the finish of the extrudate surface.

At low extrusion pressures or shear stresses, extrudates are smooth and regular, and the flow rates low. As the pressure is increased, the flow rate and the diameter of the extrudate increases. At and above a critical pressure the extrudates become increasingly irregular. Melt fracture initiates and propagates in die inlets at and above critical pressures described by Tordella [51]. The irregular shapes of the

extrudates result from "elastic memory". After emerging from the die, the extrudates tend to regain the configuration they had before extrusion. Melt fracture, which is an irreversible process, makes the recovered shape asymmetric, Spirals and segments result.

Since melt fracture occurs at and above a critical stress, it may be avoided by suitable manipulation of the extrusion variables to keep the stress below the critical level. Any combination of the following methods may be used to reduce the shear stress to eliminate melt fracture,

1. Lower the viscosity by raising the temperature,
2. Use a streamlined or gradually tapered inlet,
3. Lower the throughput by reducing the pressure.

Of the above expedients by which melt fracture may be avoided, use of streamlined inlets is the most effective. No other change in the operation may be required.

Melt fracture sometimes occurs when operating an extruder at a high throughput rate. The extrudate takes on a rough irregular appearance which cannot be attributed to any other cause than the physical breakdown of the melt or 'melt fracture'. This phenomenon occurs when the shear stress of the melt exceeds its shear strength such as for example in an extrusion die where, due to a substantial reduction in channel width, a sudden increase occurs in the shear rate. Original investigations by Tordella [51] showed that melt fracture occurred at a critical pressure which varied with the viscosity of the melt, the die pressure and the die geometry. As the last fracture was the only one which could be modified without causing a loss of output, the effect of the inlet geometry, and land length of the dies was considered. The theoretical aspects of melt fracture have also been studied by Schulken and Boy [42] and applied to the development of a method of calculating the die entrance geometry. What Tordella [51] called a critical pressure, Schulken

and Boy [42] call a critical shear rate which is dependent principally on the die entry geometry and viscosity.

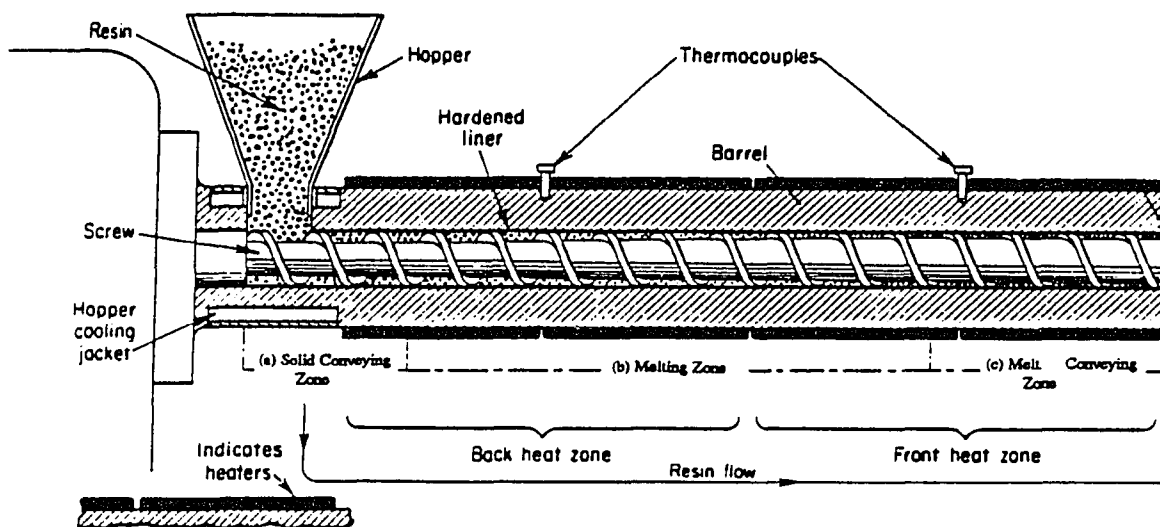


Figure 2.1 Typical Single Screw Extruder with Three Zones (a) Solid Conveying Zone, (b) Melting Zone, (c) Melt Conveying Zone.

(From "Petrothene[®] Polyolefins: Aprocessing Guide," 3d ed., U.S. Industrial Chemicals Co., New York, 1965)

CHAPTER 3

DESIGN OF EXTRUSION PROFILE DIES FOR THE MANUFACTURE OF PELLETS WITH PROFILED CROSS-SECTIONS

3.1 Aspects of Die Design

Extrusion dies can be designed to produce special shapes for different end products. The specific dies are classified into several kinds, such as for sheet, for film, for pipe and tube, for wire covering, and for profiles. The quality of an extruded product, however, depends not only on the extruder and the material used, but also on the efficiency of the die and other pieces of equipment which are part of the process.

The function of an extrusion die is to form the molten material delivered by a screw into a required cross-section. The die is, therefore, a channel whose profile changes from that of the extruder bore to an orifice which produces the required form. The behavior of a thermoplastics melt over the required range of shear rates and temperature and to be able to relate this viscosity with the flow of the melt under pressure through the different sections of which the channel is composed, must be predicted.

Basically, Corbett [14] and Weeks [55] described that the following must be taken into account in designing profile dies: 1. The flow channel must not have any "dead spots" (stagnation points), 2. From the time that it enters the die until it leaves, the melt must be accelerated as constantly as possible until the desired exit velocity of the melt is reached in the die land, 3. The construction of the die should be keep simple and the die should be easily dismountable for cleaning and possible corrections to the flow channel.

There are plate dies and streamline entry dies. The first is illustrated in Figure 3.1 and shows that the shaping orifice is in a flat plate attached to a die holder. It is evident that there is a great deal of stagnation in the region behind the die. For some materials, such as the polyolefins, which are thermally stable, that is not a serious problem. On the other hand, thermally sensitive materials, such as rigid PVC, cannot be run for a significant length of time in plate dies. The degraded material which forms in the stagnation regions will start to release stained and decomposed resin and the result will be an unstable product. Figure 3.2 illustrates a streamlined die which has a transition section that matches the flow from the extruder head diameter to the product shape. This type of tool construction is used to prevent stagnation of material in the die.

3.1.1 Die Swell

The die swell is a characteristic of the material which results as it exits from the die orifice. The visible swelling of the material at the die exit has its cause in the reversible deformations, which are stored in the material as it leaves the die and are a function of the prior deformation and relaxation history investigated by Graessley, Glasscock, and Crawley [21], as well as the rearrangement of the velocity profile at the die orifice to a block profile, which results in local extensions in the cross-section. The two phenomena cannot be separated from each other. Rothermeyer [37] reported that the effect of the prior history on the achievable cross-section was shown in Figure 3.3. It demonstrated that star-shaped and circular inlet regions were selected in the square outer die ring of length L ; $R_{\text{eff}} = (2 A_{\text{die}}/\text{perimeter of die})$, corresponding to a comparison radius in the region similar to half the "hydraulic diameter". The influence of the inlet zone decreases as the length of the outer die ring and therefore the residence time increases. Figure 3.3 also illustrated that a star-

shaped die would be required in the exit region in order to produce an exactly square profile.

This strictly phenomenological finding can also be quantified by calculating the reversible elastic deformations at the outer die ring; for this purpose, experimental data for the material under consideration is required in order to establish a correlation between the calculated values and the swell. It must be noted that these analyses and calculations were carried out one dimensionally, that is, only over the height of the flow channel. The results are therefore directly applicable only to simple profiles such as round, strand, pipe, plane, and sheet. A calculation of the distribution of reversible deformations over a complicated profile of any cross-section is still pending. The already referred to rearrangement of the velocity profile for any profile has also not yet been calculated. However, it is expected that the calculations for both problems will be carried out by the "method of finite elements" in the future.

The swell potential, that is, the reversible deformation, can be decreased in a parallel die land. If the effect of the prior history, in the pre-zone and the inlet zone, on the geometry of the emerging profile cross-section is to be avoided a length, L must be chosen for the die land described by Tanner [50] shown as below,

$$L > \tau_{\text{relax}} \frac{V}{A} \quad (3.1)$$

Here τ_{relax} is a characteristic relaxation time, which can be obtained from experimental, rheological investigations of the flow. Deformations, which are introduced in the die land, also be regarded as providing only an estimate in the case of geometrically complicated profile cross-sections.

The difficulties associated with calculating the swell and the unawareness of the order of magnitude of the velocity profile rearrangement, which also contributes macroscopically to the deformation of the profile emerging from the die orifice, have contributed to the fact that empirical values are used in practice for correcting the die exit cross-section for swell.

3.1.2 Die Land Length

Practical experience has to some extent determined this parameter. In the form of the rule of thumb the land length/orifice thickness ratios which are widely used are about 10 : 1 for materials of high viscosity such as unplasticised PVC and up to a ratio of 30 : 1 may be used for low density polyethylene.

Although it is instructive to calculate the approximate flow through an extrusion die using the foregoing formula, it must be pointed out that the usefulness of this exercise is confined to comparison values only. There are usually far too many imponderables to allow the accurate calculation of die dimensions from theoretical considerations alone and practical experience must, be the guide at least in the early design stages. The die land/orifice thickness ratios referred to above for example take into account the experience of the designer, for surface finish, compound lubrication, filler loading, the construction of the die upstream of the land and the system of product sizing to be used. It is obviously difficult to describe such factors in mathematical terms so that in the final analysis the die land/orifice thickness and other ratios established over the years by trial and error usually form the basis of most practical die designs.

The calculations are, however, often of great value when changes or modifications are required. It has been inferred above that the pressure drop across the lands of a die is proportional to the cube of the thickness. Thus if the wall thickness of a tube is changed to produce a product of different dimensions, the land

must be changed by the cube of this difference to maintain the same pressure gradient at the same melt temperature, or viscosity.

In applying the cubic relationship, it is also important to realize that with dies of very small wall thickness such as used for the production of polyethylene film, the shear rates encountered in the narrow annulus may be quite high. Besides causing a considerable local decrease in viscosity and thus of pressure drop these high rates of shear can also cause a considerable departure from Newtonian flow on which the cubic relationship is based. Moreover, the rigorous application of the cubic relationship to the design of dies for very heavy sections would result in very long dies which could tend to become prohibitive as the thickness increased. However, provided these two extreme conditions are dealt with in an intelligent manner, the cubic expression for land length/annulus width relationship can form a very useful guide in die design.

3.1.3 Die Entry Geometry

By testing each resin with a standard set of capillaries having different entrance angles and plotting the critical shear rate against the half angle of entry was presented by Levy [26], Figure 3.4, a curve for each resin is obtained, which can be used as a reference for calculating entrance geometry from,

$$\dot{\gamma} = \frac{4 Q}{\pi r^3} \quad (3.2)$$

where,

Q is the desired rate of flow,

r is the capillary radius,

$\dot{\gamma}$ is the shear rate.

If the desired output and shear rate are determined, the orifice radius can be calculated from Eq. (3.2),

$$r = \sqrt[3]{\frac{\dot{\gamma}\pi}{4Q}} \quad (3.3)$$

The influence on extrudate quality of die entry length has also been given by White and Kondo [56]. The die entry geometry is shown in Figure 3.5. The importance of entry geometry is not confined to melt fracture problems. Melt expression caused by elastic recovery of the melt as it leaves the die is important in establishing die design.

3.2 Specific Die Design

The original die is schematically shown in Figure 3.6. It is composed of two parts, one part, A, is a flanged type connector, the other part, B, is a long channel profile die. This kind of die design is suitable for simple shapes of profile. If the shape of profile is complicated, due to the long channel, it is hard to fabricate all of part B. Therefore, in order to manufacture different shapes of pellet, the original die has been changed into a four parts assembly, which is schematically shown in Figure 3.7. It is composed of four parts, A, B, C, and D. The part A is the same as in Figure 3.6. It is more convenient to change the different profile dies for the manufacturing process for different shapes of pellets. Only part D is changed. This process can be performed within ten minutes, while the whole body of the profile is unaffected.

Moreover, the new die design, eliminates the disadvantage of the original one. It not only saves the cost of remaking the whole of B for the original die, but also saves the time for replacing the flanged type connector, in order to insert the

different shapes of profile die. It is apparent that the channel of the profile is shorter and easier to fabricate than the original die.

3.3 Profile Die Inserts

In order to manufacture the different shape of pellets, seven profile die inserts were used. Each was fabricated in the work shop of the M.E. Department. The specification of the profile die inserts is categorized in Table 3.1. The first digit represent the number of orifice in the profile die insert, and the second the radius of the orifice. The last indicates the die land length of the die insert.

In Figure 3.8, it contains seven die inserts. The profile die inserts A211 (A201-01) and A212 (A201-02) have the same radius of orifice, but the die land length is different. The profile die inserts A221 (A202-01) and A231 (A203-01) have the same radius of orifice, but the distance between the orifice is different. The profile die inserts A241 (A204-01) has the largest diameter of orifice for the bilobal profile die. The profile die insert A311 (A301-01) has three orifice in profile die for manufacturing the trilobal pellet. The profile die insert A411 (A401-01) is a quadrilobal die for producing the quadrilobal pellet.

Table 3.1 Specification of the Profile Die Inserts.

No	Profile Die	(1th digit) Orifice Number	(2nd digit) Orifice Diameter (in)	(3rd digit) Orifice Die Length (in)
1.	A211	2	5/64	1.0
2.	A212	2	5/64	1.5
3.	A221	2	1/16	1.0
4.	A231	2	1/16	1.0
5.	A241	2	3/32	1.0
6.	A311	3	5/64	1.0
7.	A411	4	5/64	1.0

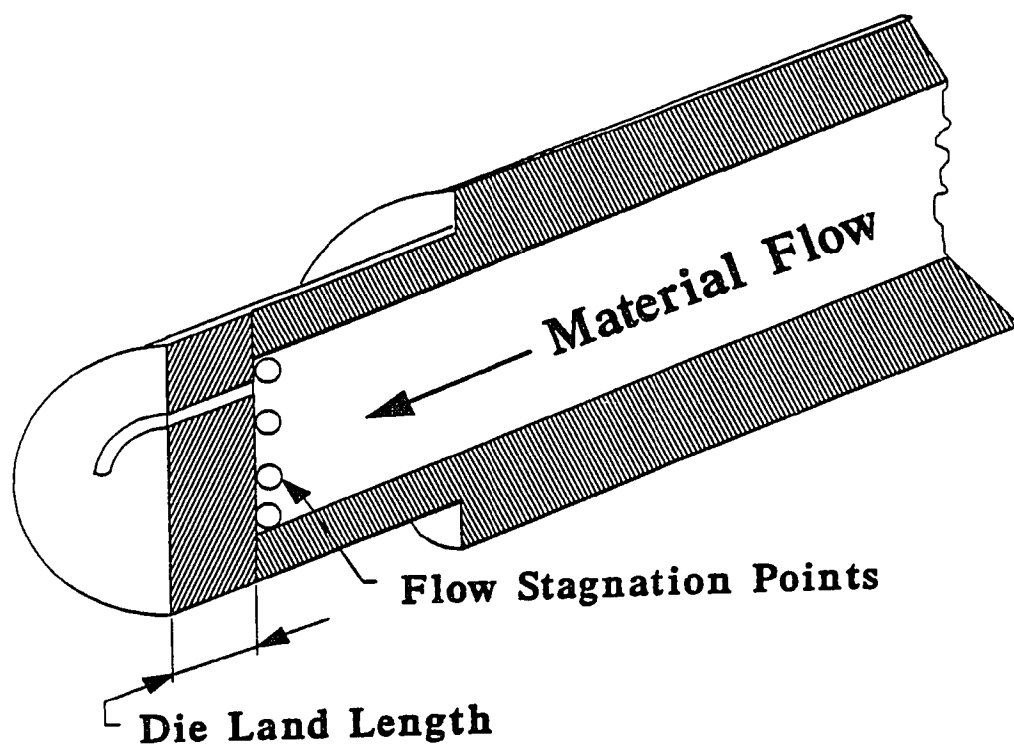


Figure 3.1 Plate Type Profile Extrusion Die.

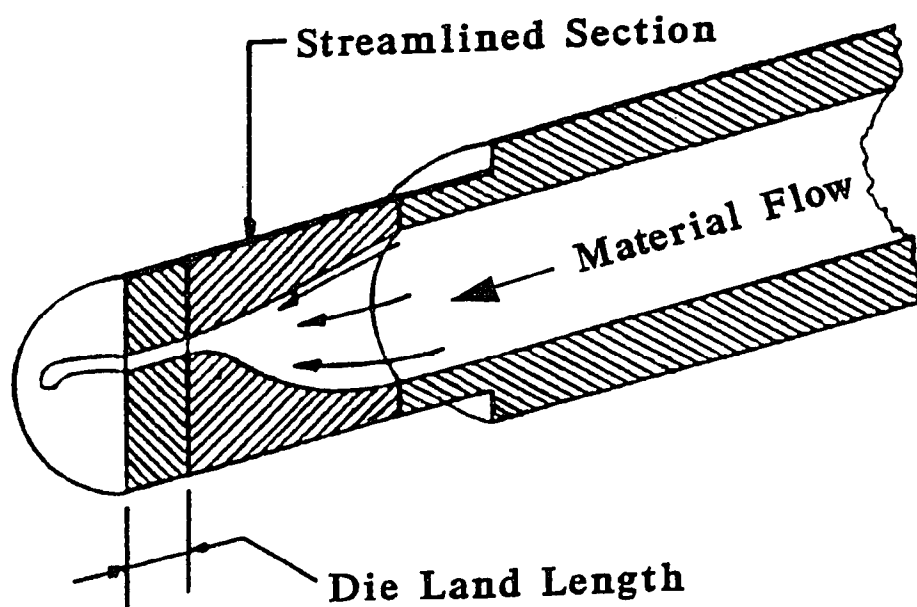


Figure 3.2 Streamlined Profile Extrusion.

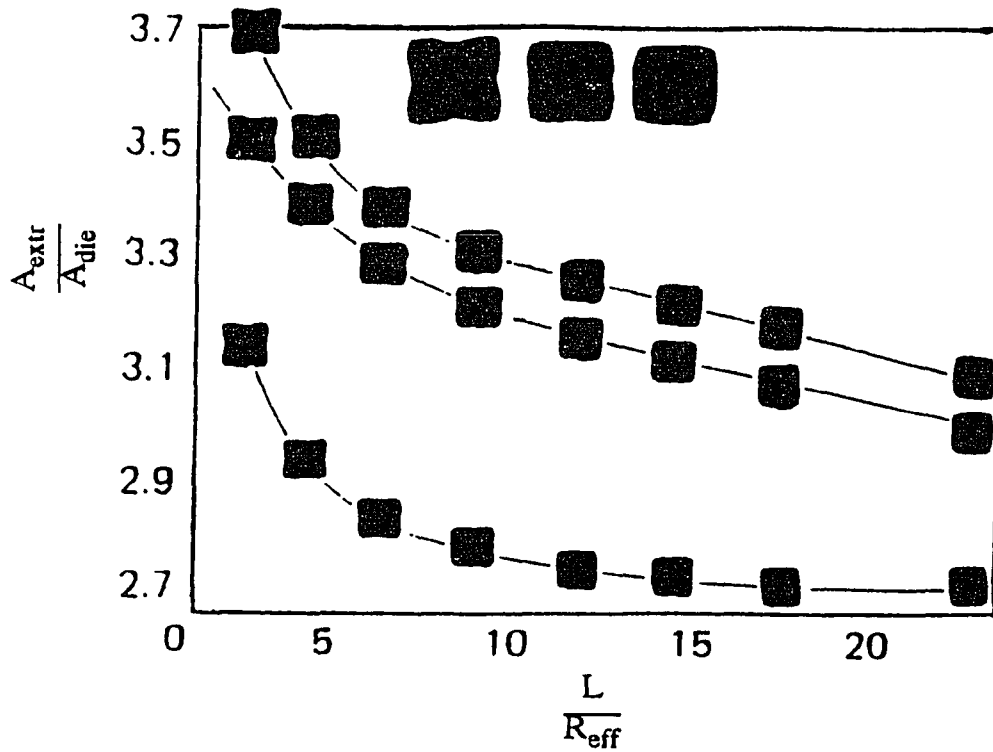


Figure 3.3 Effect of Entrance Flow Channel and Die Length on Extrudate Swelling.
 (From F. Rothemeyer, *Kunststoffe*, 59, 333 1969)

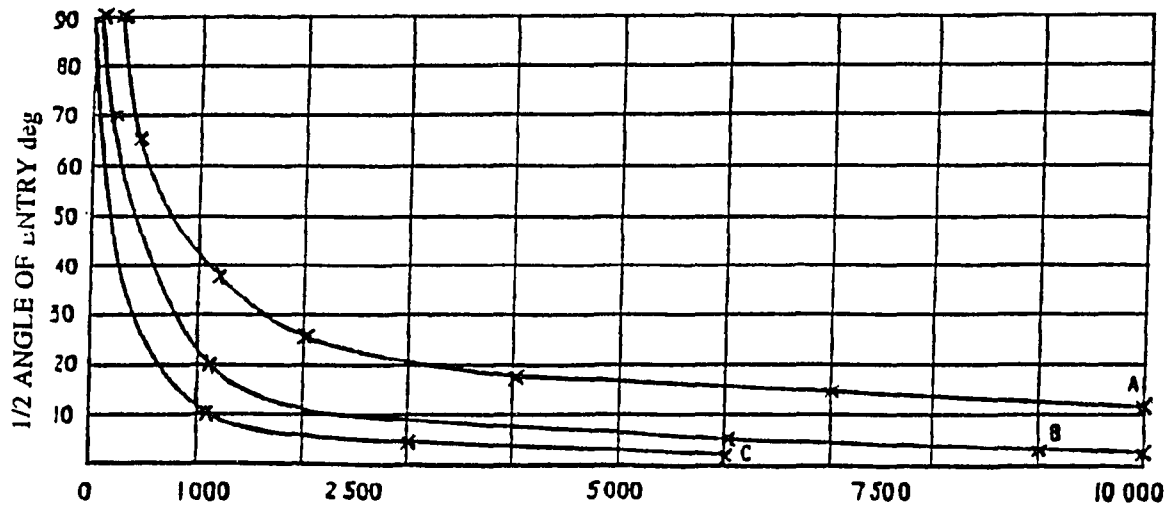


Figure 3.4 Typical Curves Showing Effect of Capacity Entry Angle on Critical Shear Rate for Three Different Resin.
 (From E. G. Fisher, "Extrusion of Plastics," New York, 1976)

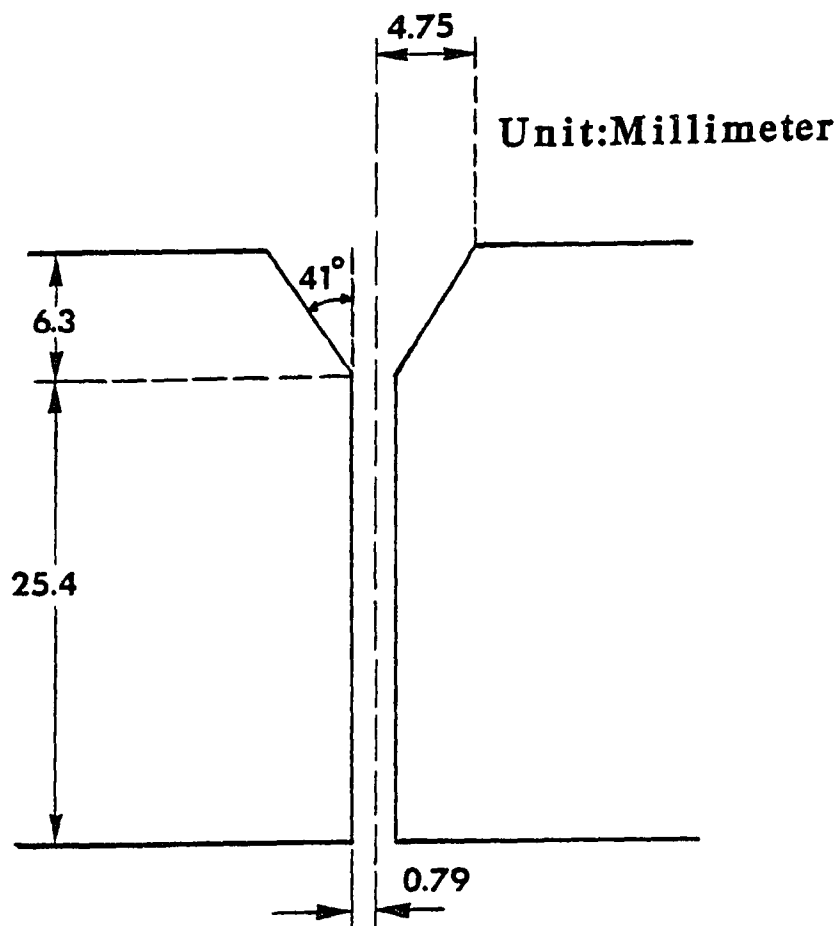


Figure 3.5 Diagram of Entry Geometry.

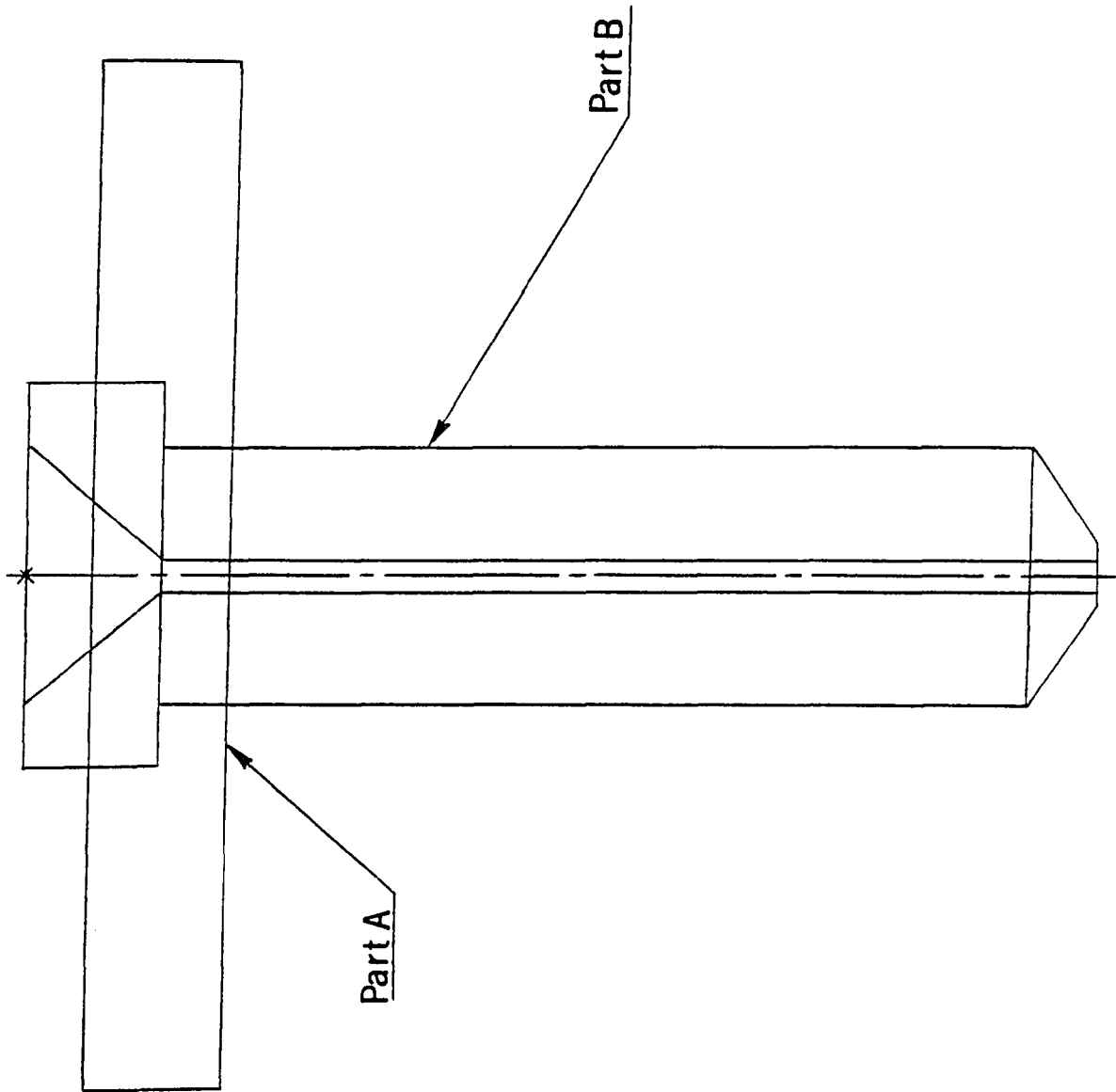


Figure 3.6 Original Die in Test Extruder.

Unit: Millimeter

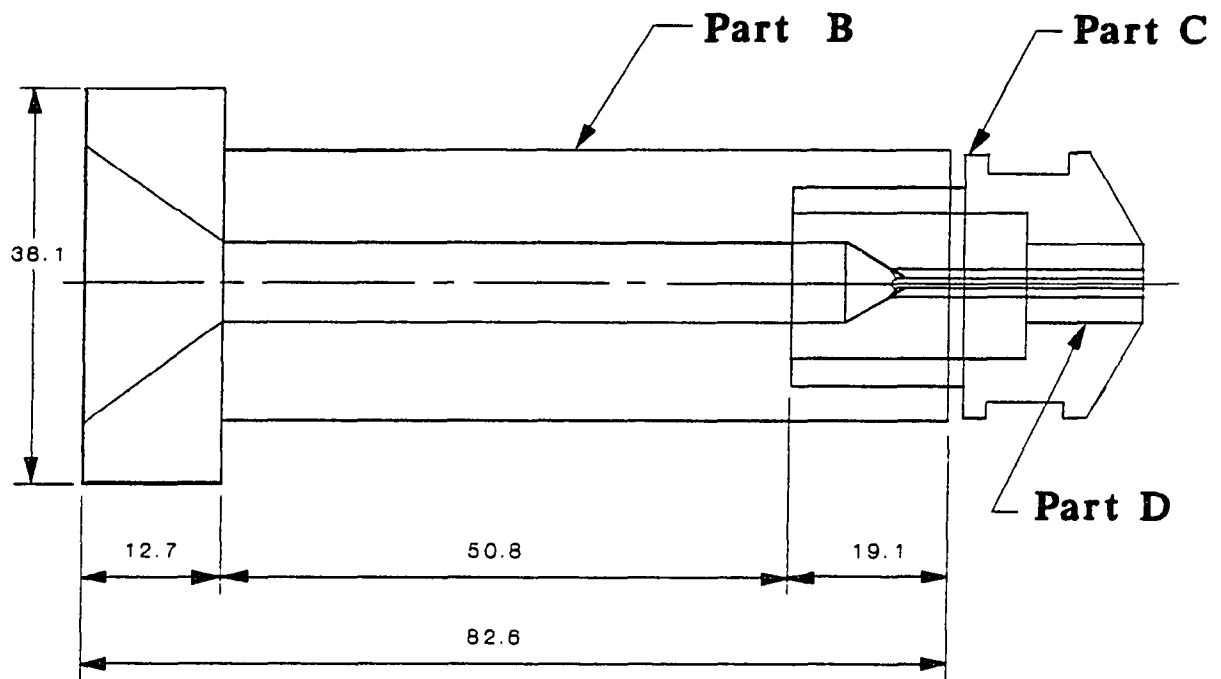


Figure 3.7 Modified Die in Test Extruder.

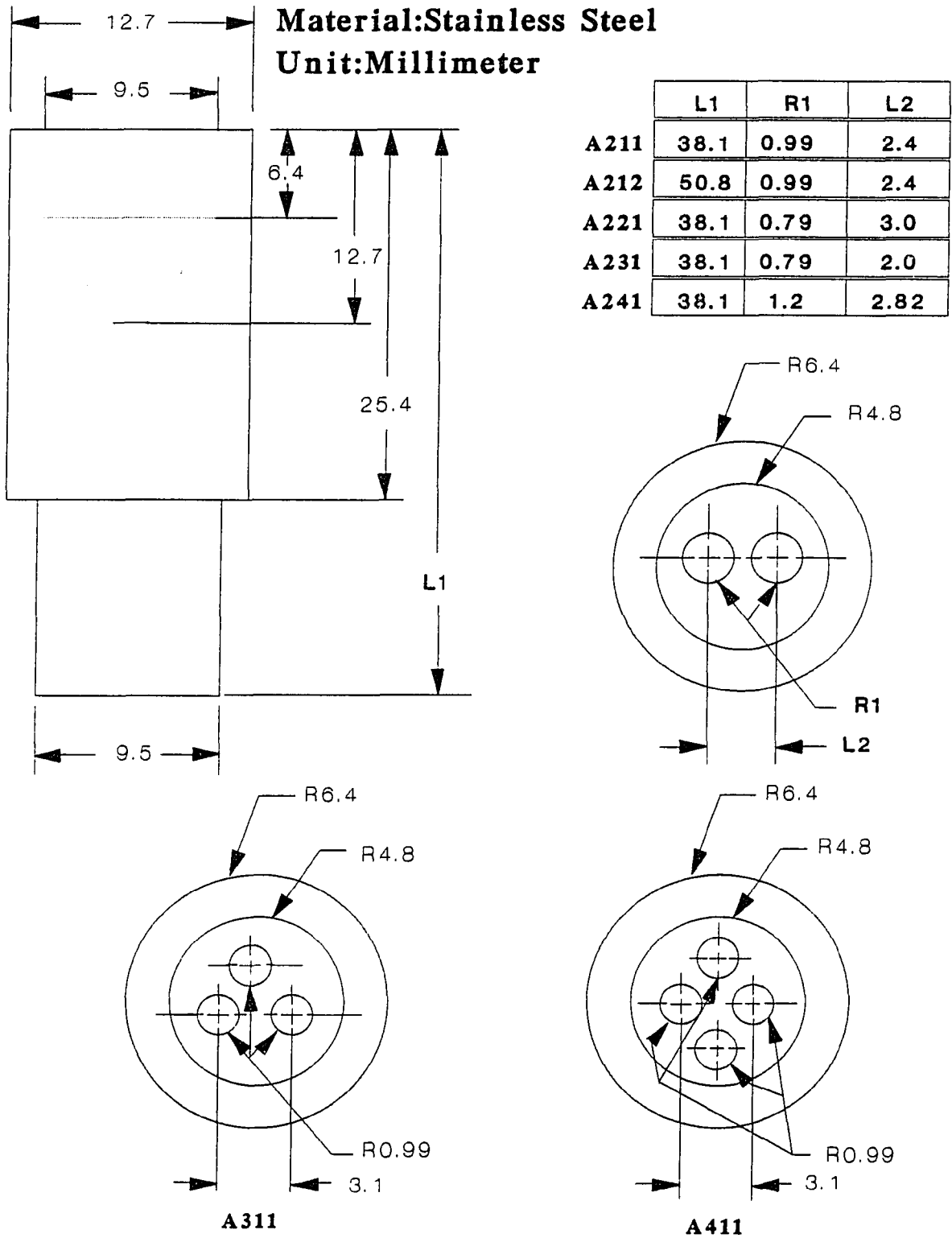


Figure 3.8 Profile Die A211, A212, A221, A231, A241, A311 and A411 - Details

CHAPTER 4

MANUFACTURE OF PELLETS OF NON-CIRCULAR CROSS-SECTIONS

4.1 Preparation of the Polymer Feedstock

Most of the materials is used in the manufacturing the multi-lobal pellets, must be put into the drying oven manufactured by Blue M. Electric, Co. A photograph is shown in Figure 4.1. The feedstocks were dried according to the recommended drying conditions of the feedstock manufacturer. These are shown in Table 4.1.

The extrusion conditions observed in actual processing vary considerably. Extruders differ, for example, in the way in which they run on different materials. Base resins differ from maker to maker. The type of granule, and the class of product will also have an effects on the conditions of extrusion. The following materials were used in this study.

4.1.1 Acetal Copolymer

Acetal copolymer is an engineering thermoplastic offering a unique combination of properties and predictable performance. Because of its highly crystalline structure, it offers a balance of high tensile strength, fatigue resistance, stiffness and toughness. These properties, coupled with excellent creep resistance, resilience, abrasion resistance, low moisture absorption and dimensional stability. Acetal copolymer resins are divided into a number of grades, made by varying the molecular weight [39]. Molecular weight has a direct influence on both certain mechanical properties and on melt viscosity. The various grades of Acetal copolymer resins are classified in terms of their melt viscosity (1.0-45.0). These grades are explained below noting their important characteristics and typical applications.

Polyacetal has been successfully extruded on both conventional and metering type screws of L/D ratio 15 : 1 and above. It is important that both the extruder and the profile die used for processing these materials should be free of dead spots where the material could stagnate, leading to discoloration and depolymerization. U10-01 (POM1), with a melt index of 1.0 (mg/min), provides excellent processability in extrusion blow, injection blow molding and extrusion. The applications of U10-01 include aerosols, containers, industrial articles, rod, tube, slab, profiles and gas tank floats. M25 (POM2), with a melt index is 2.5 (mg/min), it has good processability for injection blow and injection molding. It also provides increased toughness, elongation and impact strength, and it can be extruded into tubing, profiles and sheet. M90 is a general purpose resin for injection molding, offering an excellent balance of moldability and excellent stability in processing. It also provides parts with high surface gloss and good dimensional and property stability. The melt index of M90 (POM3) is 9.0 (mg/min). The applications of M90 include gears, cams, bearings, housings, alternating drive train assemblies, pump impellers, and gasoline pump parts. M270 (POM4), with a melt index is 27.0 (mg/min), offers high flow and hence, fast molding cycles. It also has high surface gloss and good dimensional stability. The applications of M270 include thin walled parts or complex multi-cavity parts, such as pens, pencils, and cassette components. The melt index of M450 (POM5) is 45.0 (mg/min), It offers the highest flow and fastest molding cycles. The applications of M450 include injection molding with complex geometries.

4.1.2 Nylon 6

Nylon 6 (PA 6), or polyamide, is melt processable material available to the extruder, characterized by its processing temperature. It has rapid transition from solid to fluid within a narrow temperature range, and also has a tendency to absorb moisture. The extrusion equipment and its operation must, therefore, be arranged to

cope with these characteristics. A minimum screw length of 20D is recommended with short transition and shallow channel depth. Heater capacity must be sufficient to cope with the high melting point and low shear rate. The applications of nylon 6 include gears, bearings, paint oven, engine fans and wheels.

4.1.3 Polyethylene

Generally speaking the polyethylene (PE) is the easiest material to extrude and the good results which can be obtained on any reasonable machine are reflected in the vast quantity of extruded polyethylene products currently available. In order to obtain optimum output and quality with the higher density materials, however, a long metering type screw with an L/D ratio not less than 20 : 1 is recommended, with a compression ratio between 2.5 and 3.5 : 1 depending upon the final extrudate form. The applications of polyethylene in extrusion include cable, fuel tank, water pipe and profiles.

4.1.4 Polypropylene

Polypropylene (PP), like polyethylene, is also a member of the polyolefin family of thermoplastic materials. The processing of polypropylene is very similar to that of the polyethylene and the same recommendations are applicable. Polypropylene however, develops less frictional heat in the extruder screw and consequently more external heat must generally be supplied by the barrel heaters. The applications of polypropylene in extrusion include textile fibers and filaments.

4.1.5 Polystyrene

Polystyrene (PS) is greatly used at the present time for packaging products (containers, lids, bottles), disposable medical ware, tape reels, and storm windows because of its clarity and fabrication ease. This material gives few problems in extrusion on modern equipment with long screws, but generally the long metering

type of screw is preferred. There are many foam applications for polystyrene include egg cartons, meat packaging trays and cushioning material.

4.1.6 Acrylonitrile-Butadiene-Styrene

Acrylonitrile-butadiene-styrene (ABS), terpolymer, is with a uniform molecular structure and therefore differs from other modified polystyrenes which may be blends of polymers. For best results drying of the material is recommended, or the use of a vented extruder. Extrusion temperature has been found somewhat critical within the range 347 °F - 446 °F. Variations in processing temperatures outside this band have a noticeable effect on surface finish. Metering type screws give a satisfactory extrudate. A point to be noted with the extrusion of these materials is that they are subject to rapid freeze. The applications of Acrylonitrile-butadiene-styrene include radiator grilles, computer housing and consoles.

The material listed in Table 4.2. were those used in this study. Some, such as polystyrene (PS) and acetal copolymers have high modulus and others, such as polyethylene (PE), polypropylene (PP), and nylon 6 (PA 6) have low modulus. Acrylonitrile-butadiene-styrene (ABS) is normal. According to the Modern Plastics Encyclopedia [40], the modulus is taken to mean the tensile modulus as defined by the slope of the initial linear portion of the load extension response (stress-strain curve) of a specimen deform temperature. The mechanical properties of those materials is listed in Table 4.3.

4.2 Procedure for Operating the Extruder

The extruder used to manufacture the multi-lobal pellets was a 1 inch diameter unit manufactured by Wayne Tool and Die, Co. A photograph is shown in Figure 4.2. The unit conveys the feedstock, melts it and pumps it to the die where it is shaped into a multi-lobal strand, which is cooled in a water bath and then pelletized by a Wayne pelletizer. The speed of the plasticating screw, and the pelletizer speed can

be adjusted to control the size, and shape of the pellets from the die, to some extent. Thus, for each die, a range of pellet geometries for friction testing can be produced, by varying the extruder screw speed.

The material is divided into two categories for manufacturing the pellet. Acetal copolymer is chosen as one group, since the melting points of POM1, POM2, POM3, POM4 and POM5 is roughly at the same temperature. The other group includes polyethylene (PE), polypropylene (PP), polystyrene (PS), nylon 6 (PA 6) and acrylonitrile-butadiene-styrene (ABS). The operating conditions is dramatically change depending on the melting points of the materials.

In the development stage of the manufacturing system, several die orifice geometries were constructed and tested. To minimize cost, the die was designed such that only a small die insert had to be changed, and the same die body was used throughout. The design of the die body and inserts is illustrated in chapter three. The dies are readily interchangeable and changeover including temperature stabilization took only ten minutes. However, profile dies are not easy to design and in industry are made by trial and error. Rothemeyer [37] has explained some of the difficulties, the most significant being the difference in shape of the die and the extrudate cross-section due to die swelling. The die swelling is different at different points in the face of the die orifice due to the different local shear rates. The result is that the pellet has not only a different size than the die orifice, as is the case with pellets of circular cross-section, but also a different shape. This was extensively reported by Rothemeyer [37]. After many hours of trial and error, trying to make pellets with a multi-lobal cross-sections from die orifices with multi-lobal cross-sections, it was discovered that the easiest die orifice geometry with which to make multi-lobal pellets was multiple orifices. The pellets were then formed outside of the die, as in tube-on cable coating.

The pellets were manufactured on the Wayne extrusion compounding line, dried according to the manufacturer's recommended drying conditions, and stored in moisture-proof bags ready for testing in the shear cell. Each sample was clearly labelled with the pertinent information relevant to manufacture, the die used, the output rate and the extruder speed.

4.3 The Operating Conditions for Profile Extrusion

The operating conditions for the acetal copolymer are shown in Tables 4.4 - 10. According to the different profile die inserts, operating temperature varied for the acetal copolymer. The operating conditions for polyethylene (PE), polystyrene (PS) polypropylene (PP), nylon 6 (PA 6), and acrylonitrile-butadiene-styrene (ABS) are shown in Tables 4.11 - 17, respectively.

Table 4.1 Drying Conditions of the Polymer Feedstocks for Acetal Copolymer, Polyethylene, Polypropylene, Polystyrene, Nylon 6 and ABS.

No	Polymer Material	Temperature (°F)
1.	Acetal Copolymer U10-01 (POM1) M25 (POM2) M90 (POM3) M270 (POM4) M450 (POM5)	220 220 220 220 220
2.	Polyethylene (PE)	180
3.	Polypropylene (PP)	N/A
4.	Polystyrene (PS)	180
5.	Nylon 6 (PA 6)	180
6.	Acrylonitrile-butadiene- styrene (ABS)	N/A

Table 4.2 Material Resin & Codes.

No	Material	Abbreviation	Material Supplier	Trade name	Code
1.	Polyethylene	PE	Soltex	Portiflex	PE
2.	Polypropylene	PP	Soltex	P4D 0326-61	PP
3.	Polystyrene	PS	Dow	484-27W	PS
4.	Nylon 6	PA	Allied Chemical	(XPN,917, CLEAR)	PA 6
5.	Acrylonitrile- butadiene- styrene	ABS	Monsanto	248	ABS
6.	Acetal Copolymer	Celcon	Hoechst Celanese	U10-01 M25 M90 M270 M450	POM1 POM2 POM3 POM4 POM5

Table 4.3 Material Mechanical Properties.

No	Material	Density (Kg/m ³)	Tensile Modulus (GN/m ²)
1.	Polyethylene(PE)	950	0.8
2.	Polypropylene(PP)	905	1.3
3.	Polystyrene(PS)	1050	2.9
4.	Nylon 6(PA 6)	1140	0.7
5.	Acrylonitrile-butadiene- styrene (ABS)	1040	2.4
6.	Acetal Copolymer (Celcon)		
	U10-01	1190	3.6
	M25	1087	3.6
	M90	1042	3.6
	M270	1239	3.6
	M450	1265	3.6

Table 4.4 Operating Conditions of Profile Die A211 for Acetal Copolymer.

	Profile Die A211	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material U10-01	5rpm	440	450	280	11.7	105.3	3	6.0
	10rpm	440	450	280	30.0	269.9	6	8.0
	15rpm	435	450	280	44.8	403.1	8	10.0
	20rpm	430	450	280	60.9	548.0	11	11.0
Material M25	5rpm	440	450	290	9.4	93.4	7	1.0
	10rpm	440	450	285	18.8	162.7	11	2.0
	15rpm	440	450	280	28.6	265.1	14	2.5
	20rpm	440	450	280	40.6	353.5	16	3.0
Material M90	5rpm	440	450	280	16.1	112.1	13	2.0
	10rpm	440	455	280	32.1	301.7	17	3.5
	15rpm	440	455	280	43.0	414.8	20	4.5
Material M270	20rpm	440	455	280	61.1	564.6	24	6.0
	5rpm	440	460	260	9.9	135.7	13	0.2
	10rpm	440	460	260	27.0	215.0	18	1.0
	15rpm	440	460	270	38.5	298.6	23	1.5
Material M450	20rpm	435	460	270	47.5	392.9	26	2.0
	5rpm	440	460	260	15.5	81.1	26	0.2
	10rpm	440	460	255	26.5	226.1	31	0.5
	15rpm	435	460	250	34.8	289.9	38	1.2

Table 4.5 Operating Conditions of Profile Die A212 for Acetal Copolymer.

	Profile Die A212	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material U10-01	5rpm	430	455	285	15.6	142.4	3	4.0
	10rpm	430	450	285	31.7	289.4	6	8.0
	15rpm	440	450	290	45.3	413.5	8	10.5
	20rpm	440	450	290	55.4	505.7	10	12.0
Material M25	5rpm	440	450	285	9.3	92.9	6	0.5
	10rpm	440	450	290	16.2	161.9	10	1.0
	15rpm	440	450	290	26.4	263.8	13	2.0
	20rpm	440	450	290	35.2	351.8	15	2.5
Material M90	5rpm	445	450	290	10.7	111.5	12	2.0
	10rpm	440	450	290	28.8	300.2	16	3.0
	15rpm	440	450	290	39.6	412.8	19	4.0
	20rpm	440	460	290	53.9	561.9	22	5.0
Material M270	5rpm	450	445	295	15.4	135.0	14	0.2
	10rpm	445	450	290	24.4	213.9	18	0.5
	15rpm	440	450	285	33.9	297.2	22	1.0
	20rpm	440	460	285	44.6	391.0	25	2.0
Material M450	5rpm	440	450	290	9.4	80.7	26	0.1
	10rpm	440	455	295	26.2	225.0	31	0.3
	15rpm	440	455	290	33.6	288.5	35	1.0
	20rpm	440	460	290	44.2	379.6	38	1.5

Table 4.6 Operating Conditions of Profile Die A221 for Acetal Copolymer.

	Profile Die A221	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material U10-01	5rpm	440	460	290	12.7	226.4	3	4.0
	10rpm	445	460	295	31.6	563.4	5	6.0
	15rpm	450	460	300	42.3	754.2	7	8.0
	20rpm	450	460	300	51.5	918.2	9	10.0
Material M25	5rpm	425	450	280	7.8	152.2	4	1.0
	10rpm	430	450	285	15.9	310.3	6	2.0
	15rpm	435	455	290	23.1	450.9	7	2.5
	20rpm	440	460	295	34.1	665.6	9	3.5
Material M90	5rpm	440	450	280	15.9	323.7	7	1.0
	10rpm	440	460	290	30.3	617.0	13	3.0
	15rpm	450	460	290	40.1	816.5	18	4.0
	20rpm	450	460	300	60.3	1127.8	24	6.0
Material M270	5rpm	440	450	285	10.3	176.4	12	0.2
	10rpm	445	450	290	25.9	443.5	18	0.5
	15rpm	450	460	295	36.4	623.3	24	0.8
	20rpm	450	460	295	47.6	815.1	27	1.0
Material M450	5rpm	440	460	290	14.1	236.5	18	0.1
	10rpm	440	460	290	24.8	416.0	23	0.4
	15rpm	440	460	290	33.9	568.6	27	0.6
	20rpm	450	460	295	46.4	778.2	32	0.8

Table 4.7 Operating Conditions of Profile Die A231 for Acetal Copolymer.

	Profile Die A231	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material U10-01	5rpm	440	450	290	13.7	244.3	5	2.5
	10rpm	440	450	290	29.3	522.4	7	5.0
	15rpm	440	455	300	38.9	693.6	12	7.0
	20rpm	440	460	300	54.0	962.8	15	9.0
Material M25	5rpm	435	440	285	6.0	117.1	8	1.0
	10rpm	440	445	285	15.1	294.7	13	2.0
	15rpm	440	445	290	24.0	468.4	17	2.5
	20rpm	440	450	290	32.1	626.5	20	3.0
Material M90	5rpm	430	440	285	14.7	299.3	12	2.0
	10rpm	435	450	285	27.1	551.8	15	3.0
	15rpm	440	450	285	40.3	820.6	20	4.0
	20rpm	440	450	290	53.7	1093.4	25	5.0
Material M270	5rpm	440	450	290	10.3	176.4	14	0.2
	10rpm	440	450	290	23.4	400.7	20	1.2
	15rpm	440	450	300	33.5	573.7	26	1.5
	20rpm	440	450	300	44.3	758.6	36	2.0
Material M450	5rpm	440	450	300	8.3	139.2	17	0.1
	10rpm	440	450	300	19.9	333.8	25	0.3
	15rpm	440	450	300	28.9	484.7	32	1.0
	20rpm	440	460	300	37.4	627.3	38	1.5

Table 4.8 Operating Conditions of Profile Die A241 for Acetal Copolymer.

	Profile Die A241	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material U10-01	5rpm	440	450	290	14.8	78.2	4	4.0
	10rpm	440	450	290	33.6	177.5	6	6.0
	15rpm	450	460	295	45.8	241.9	8	8.0
	20rpm	450	460	300	63.3	334.4	10	10.0
Material M25	5rpm	430	440	290	8.1	46.8	4	1.0
	10rpm	430	450	295	22.5	130.1	6	2.5
	15rpm	430	450	300	32.2	186.2	10	3.0
	20rpm	440	460	300	43.2	249.8	13	4.0
Material M90	5rpm	435	450	290	16.5	99.5	5	1.0
	10rpm	440	455	290	31.9	192.5	10	2.0
	15rpm	440	455	295	46.3	279.3	14	3.5
	20rpm	440	460	300	60.9	367.4	16	4.5
Material M270	5rpm	435	450	300	16.8	85.2	6	0.5
	10rpm	440	450	300	38.3	194.3	10	2.0
	15rpm	440	450	300	46.4	235.4	14	3.0
	20rpm	440	460	300	63.6	322.7	20	3.5
Material M450	5rpm	440	460	300	12.8	63.6	10	0.2
	10rpm	440	460	300	25.5	126.7	18	0.4
	15rpm	440	460	300	43.4	215.7	22	0.6
	20rpm	440	460	305	50.1	249.0	26	0.8

Table 4.9 Operating Conditions of Profile Die A311 for Acetal Copolymer.

	Profile Die A311	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material U10-01	5rpm	430	450	285	11.4	135.5	3	2.5
	10rpm	440	450	285	25.8	306.7	5	4.5
	15rpm	440	450	285	37.9	450.5	7	6.0
	20rpm	440	455	285	54.8	651.4	9	8.0
Material M25	5rpm	440	450	290	7.8	101.5	7	1.0
	10rpm	440	455	290	15.1	1996.5	9	1.5
	15rpm	440	460	290	23.2	301.9	11	2.5
	20rpm	440	460	290	33.3	433.3	13	3.5
Material M90	5rpm	440	460	290	16.8	228.0	12	1.5
	10rpm	440	460	290	26.8	363.8	15	3.0
	15rpm	440	460	290	40.3	547.0	18	4.0
	20rpm	440	460	290	55.0	746.6	21	5.0
Material M270	5rpm	440	460	290	13.2	150.7	15	0.5
	10rpm	440	460	290	24.1	275.1	20	1.5
	15rpm	440	460	290	35.4	404.1	25	2.0
	20rpm	440	460	290	47.2	538.8	28	2.5
Material M450	5rpm	440	460	290	10.1	112.9	20	0.2
	10rpm	440	460	290	22.6	252.7	26	0.5
	15rpm	445	460	295	32.9	367.9	32	1.5
	20rpm	445	460	295	41.5	464.0	36	2.0

Table 4.10 Operating Conditions of Profile Die A411 for Acetal Copolymer.

	Profile Die A411	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material U10-01	5rpm	430	460	280	14.3	127.5	3	6.0
	10rpm	440	460	285	25.9	230.9	5	9.5
	15rpm	440	460	285	38.3	341.4	7	10.5
	20rpm	440	460	285	55.8	494.4	9	12.0
Material M25	5rpm	440	460	290	10.6	103.4	4	0.5
	10rpm	440	460	290	15.7	153.2	6	1.5
	15rpm	440	460	290	24.3	237.2	8	2.0
	20rpm	440	460	290	34.0	331.8	10	2.5
Material M90	5rpm	430	450	295	17.0	173.1	16	2.0
	10rpm	435	450	295	30.2	307.5	20	3.0
	15rpm	440	455	295	40.6	433.7	25	4.0
	20rpm	445	460	295	55.6	566.0	28	6.0
Material M270	5rpm	435	450	300	13.4	114.7	20	0.4
	10rpm	435	455	300	24.3	208.1	24	1.0
	15rpm	440	455	300	35.8	306.5	28	2.0
	20rpm	440	460	300	47.4	405.8	34	2.5
Material M450	5rpm	440	460	295	10.5	88.1	28	0.2
	10rpm	440	460	295	23.0	192.9	32	0.5
	15rpm	440	460	295	33.5	280.9	36	0.8
	20rpm	440	460	300	41.8	350.5	40	1.5

Table 4.11 Operating Conditions of Profile Die A211 for PE, PP, PA 6, ABS and PS.

	Profile Die A211	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material PE	5rpm	490	500	300	10.2	115.0	12	3.0
	10rpm	490	510	300	24.5	276.2	15	4.5
	15rpm	490	510	300	38.5	434.0	18	6.0
	20rpm	490	510	300	53.0	597.4	21	6.5
Material PP	5rpm	480	500	280	12.2	144.4	17	0.5
	10rpm	480	500	280	21.8	257.9	20	1.5
	15rpm	480	500	280	31.6	373.9	23	2.0
	20rpm	480	500	280	40.9	483.9	26	3.0
Material Nylon 6	5rpm	520	535	320	14.3	134.3	16	3.0
	10rpm	520	535	320	23.5	220.7	20	6.0
	15rpm	520	540	320	35.2	330.6	23	8.0
	20rpm	525	540	320	47.2	443.3	25	10.0
Material ABS	5rpm	485	495	365	13.1	134.9	15	1.0
	10rpm	485	495	365	30.7	316.1	20	2.0
	15rpm	485	495	365	40.6	418.0	28	3.0
	20rpm	485	495	365	55.8	574.5	32	4.0
Material PS	5rpm	530	540	375	13.0	132.6	22	1.0
	10rpm	530	540	375	24.8	252.9	25	3.0
	15rpm	530	540	375	36.0	367.1	28	3.5
	20rpm	535	540	375	49.8	507.9	31	4.0

Table 4.12 Operating Conditions of Profile Die A212 for PE, PP, PA 6, ABS and PS.

	Profile Die A212	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material PE	5rpm	490	500	300	10.4	117.2	10	4.0
	10rpm	500	500	300	23.5	264.9	14	6.0
	15rpm	500	500	300	34.3	386.6	19	7.0
	20rpm	500	510	300	50.7	571.5	23	7.5
Material PP	5rpm	480	500	280	10.8	127.8	13	0.5
	10rpm	480	500	280	20.2	236.6	19	2.0
	15rpm	480	500	280	29.2	345.5	24	2.5
	20rpm	480	500	280	39.8	470.9	29	3.5
Material PS	5rpm	510	540	320	14.4	135.3	15	3.0
	10rpm	520	540	320	23.0	216.0	21	6.0
	15rpm	520	540	320	35.5	333.5	23	10.0
	20rpm	520	540	320	42.5	399.2	25	11.0
Material Nylon 6	5rpm	530	540	340	13.0	109.1	16	2.0
	10rpm	530	540	345	24.8	214.2	20	3.5
	15rpm	530	540	345	36.0	326.3	24	4.0
	20rpm	535	540	345	49.8	453.8	28	5.5

Table 4.13 Operating Conditions of Profile Die A221 for PE, PP, PA 6, ABS and PS.

	Profile Die A221	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material PE	5rpm	490	500	295	12.5	279.2	14	4.0
	10rpm	490	500	295	23.9	533.8	17	5.5
	15rpm	490	500	295	32.7	730.3	21	6.5
	20rpm	490	500	295	44.9	1022.8	24	7.5
Material PP	5rpm	480	490	280	9.8	229.7	14	1.0
	10rpm	480	490	280	17.4	407.9	22	1.5
	15rpm	480	490	280	26.3	616.6	27	2.0
	20rpm	480	490	280	36.6	858.0	32	3.0
Material Nylon 6	5rpm	525	540	350	9.8	182.4	11	4.0
	10rpm	530	540	350	20.0	372.2	13	7.0
	15rpm	530	540	350	29.6	550.9	15	9.0
	20rpm	530	540	350	38.0	707.2	17	11.0
Material ABS	5rpm	480	490	360	11.0	242.8	21	2.0
	10rpm	480	490	360	27.8	567.1	25	3.0
	15rpm	480	490	360	40.4	824.2	27	4.0
	20rpm	480	490	360	53.7	1095.5	32	5.0
Material PS	5rpm	540	550	370	12.9	242.5	14	2.0
	10rpm	540	550	370	24.8	493.0	26	3.0
	15rpm	540	550	370	34.5	697.1	32	4.0
	20rpm	540	550	370	46.4	937.6	41	5.0

Table 4.14 Operating Conditions of Profile Die A231 for PE, PP, PA 6, ABS and PS.

	Profile Die A231	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material PE	5rpm	490	500	300	14.2	317.1	15	4.0
	10rpm	490	500	300	26.1	582.9	18	6.0
	15rpm	490	500	300	38.1	850.9	21	7.0
	20rpm	490	500	300	51.2	1143.5	24	8.0
Material PP	5rpm	480	490	280	9.2	215.7	19	0.5
	10rpm	480	490	280	20.7	485.3	24	2.0
	15rpm	480	490	280	29.1	682.2	28	2.5
	20rpm	480	490	280	38.9	912.0	34	3.5
Material Nylon 6	5rpm	520	530	320	11.4	212.2	12	5.0
	10rpm	520	530	320	24.6	457.8	14	7.0
	15rpm	520	530	320	35.3	657.0	16	8.0
	20rpm	520	530	320	47.4	882.2	20	9.0
Material ABS	5rpm	480	490	355	12.2	248.9	17	1.5
	10rpm	480	490	355	26.6	542.7	25	2.5
	15rpm	480	490	355	38.7	789.5	32	3.5
	20rpm	480	490	355	53.2	1085.3	40	4.5
Material PS	5rpm	535	545	360	9.0	181.9	21	2.0
	10rpm	535	545	360	22.8	460.7	24	3.5
	15rpm	535	550	360	33.1	668.8	29	4.5
	20rpm	535	550	360	46.8	945.7	37	6.0

Table 4.15 Operating Conditions of Profile Die A241 for PE, PP, PS, PA 6 and ABS.

	Profile Die A241	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material PE	5rpm	500	510	310	11.1	73.5	11	2.0
	10rpm	500	510	310	26.3	174.0	14	3.0
	15rpm	500	510	300	40.5	268.0	17	3.5
	20rpm	500	510	300	52.9	350.1	20	4.0
Material PP	5rpm	485	495	280	10.1	70.2	20	0.5
	10rpm	480	495	280	20.5	140.4	23	2.0
	15rpm	480	495	280	30.6	212.6	25	2.5
	20rpm	480	495	280	41.1	285.5	27	3.5
Material PS	5rpm	520	540	320	12.6	69.5	8	4.0
	10rpm	520	540	320	29.7	163.8	11	6.0
	15rpm	520	540	330	41.6	229.4	14	9.0
	20rpm	520	540	330	50.3	277.4	18	10.0
Material Nylon 6	5rpm	485	495	370	9.8	59.2	12	1.0
	10rpm	485	495	370	27.5	166.2	15	2.0
	15rpm	485	495	370	40.1	242.4	18	3.0
	20rpm	485	495	370	56.6	342.1	21	3.5
Material ABS	5rpm	535	545	365	14.7	88.0	12	2.0
	10rpm	535	545	365	23.3	139.5	15	3.0
	15rpm	535	545	370	33.9	203.0	20	4.0
	20rpm	535	545	370	46.5	278.4	24	5.0

Table 4.16 Operating Conditions of Profile Die A311 for PE, PP, PA 6 and PS.

	Profile Die A311	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material PE	5rpm	500	510	300	12.6	187.6	14	3.0
	10rpm	500	510	300	23.9	355.8	17	4.0
	15rpm	500	510	300	34.8	518.1	20	5.5
	20rpm	500	510	300	47.4	705.7	23	6.5
Material PP	5rpm	485	490	270	10.8	168.8	21	1.0
	10rpm	485	490	270	18.5	289.1	25	2.0
	15rpm	480	490	270	29.3	457.9	29	3.0
	20rpm	480	490	270	39.0	609.5	33	4.0
Material Nylon 6	5rpm	535	550	330	13.2	163.8	18	4.0
	10rpm	535	550	330	23.7	294.1	21	7.0
	15rpm	535	550	330	32.0	397.0	23	9.0
	20rpm	530	550	330	43.3	537.2	25	11.5
Material PS	5rpm	535	545	365	11.5	154.9	16	2.0
	10rpm	535	545	365	19.4	261.3	20	3.5
	15rpm	535	545	365	33.5	451.3	24	4.5
	20rpm	535	545	365	44.4	598.1	28	5.5

Table 4.17 Operating Conditions of Profile Die A411 for PE and PP.

	Profile Die A411	Temperature			Mass flow rate (g/min)	Shear rate (1/s)	Pelletizer speed (rpm)	DC Motor Current (amperes)
		Front (°F)	Middle (°F)	Die (°F)				
Material PE	5rpm	490	500	310	12.4	138.5	8	3.0
	10rpm	490	500	310	26.8	299.3	11	4.0
	15rpm	490	500	310	36.9	412.0	13	5.0
	20rpm	490	500	310	49.1	548.3	16	6.0
Material PP	5rpm	485	495	280	91	106.7	16	1.0
	10rpm	485	495	280	21.0	246.2	18	2.0
	15rpm	485	495	280	30.1	352.8	21	2.5
	20rpm	485	495	280	38.9	456.0	24	3.5

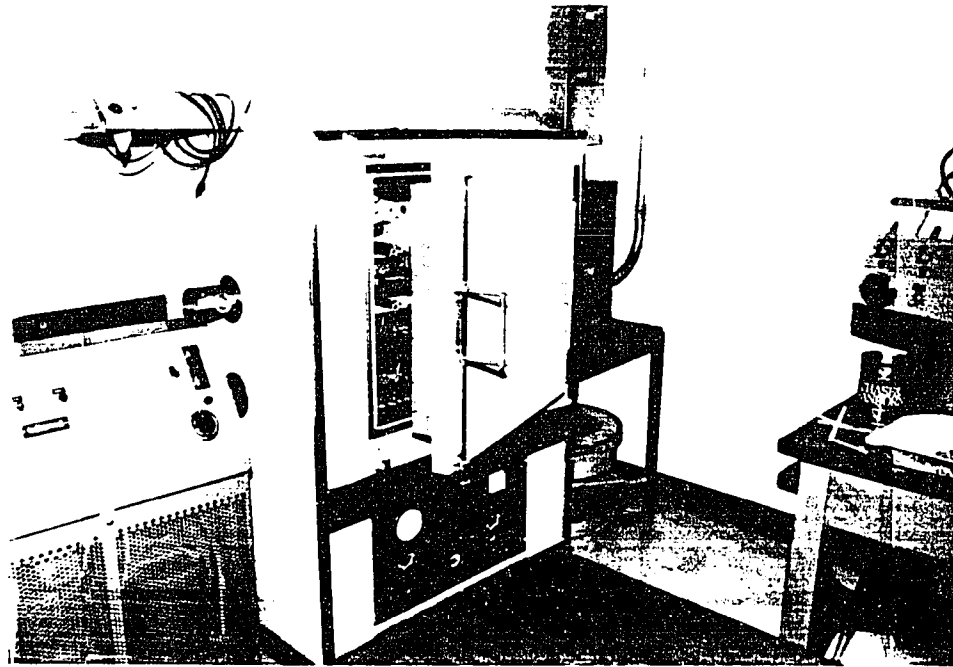


Figure 4.1 Drying Oven Manufactured by Blue M. Electric, Co.

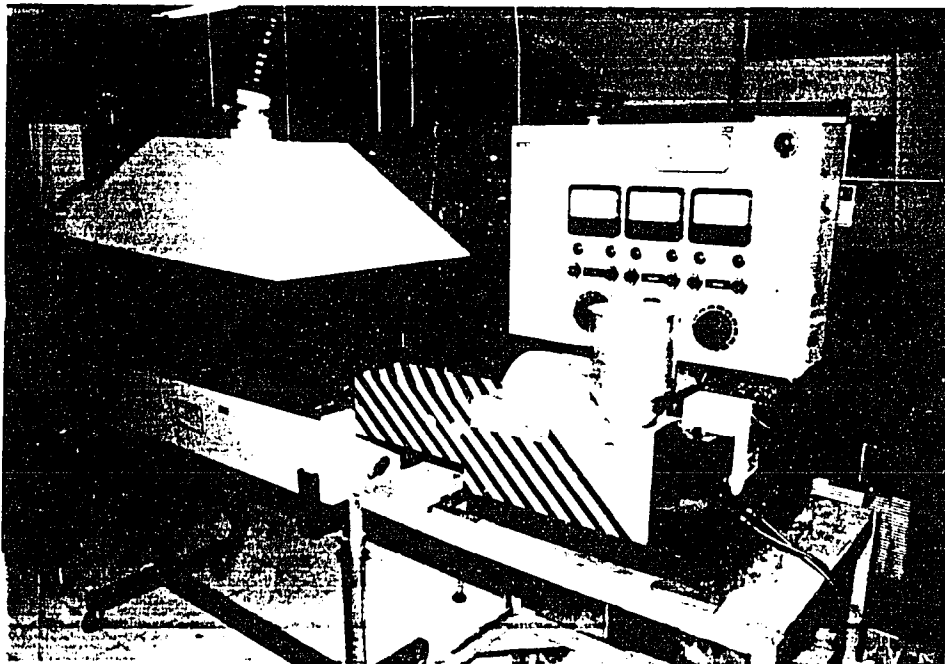


Figure 4.2 Extruder Manufactured by Wayne Tool and Die, Co.

CHAPTER 5

MECHANISM OF INTERPARTICULATE FRICTION IN POLYMERIC PARTICULATE CONTINUA

5.1 Mechanics of Friction

The interparticular friction between solid and solid is of great importance in polymer processing. Friction is the tangential resistance offered to the sliding of one solid over another. The values of the friction coefficients are in general determined empirically. The interparticulate friction coefficients of particulate materials may be measured in a number of ways. The most common method is the use of a "shear cell", or "shear tester". The principles of operation of these devices are described in great detail by Jenike [25], Carr and Walker [10], Schwedes [43], Roberts [36]. Jenike [25] developed an experimental apparatus, known as a shear cell for measuring the shear properties of particulate solids. It consists of a stationary base and a moving ring. Loads are applied to the ring causing shear in the particulate continuum. The limiting friction coefficient is the interparticulate friction coefficient. The theoretical development of statics of particulate solids commences with the work of Coulomb [15]. There are some concepts in elementary statics that are essential for the understanding of the behavior of particulate solid. It shall be dealing with a condition of static equilibrium that also holds at the limiting condition of incipient flow, that is, The interparticulate friction coefficient μ is defined as:

$$\mu = \frac{S}{N} \quad (5.1)$$

where,

S = the mean tangential frictional force

and N = the normal force applied perpendicular to the plane of shear

The Eq. (5.1) is known as Amonton's law [1]. It indicates that frictional resistance is proportional to the normal force.

5.2 Agglomeration

The term agglomeration may vary in meaning between different industries and different fields of research. In this work, it describes the forming of an aggregate from the individual particles, such as, the building up clusters from polymeric pellets during conveying. Agglomeration is undesirable when it happens in a free flowing system, but it is desirable for pelleting, and similar processes. In either case, it is important to understand the physical mechanisms involved [33]. Agglomeration occurs because of the binding forces exceed the disruptive or break-up forces between the particles [52]. Bowden and Tabor [6] proposed that solid-solid forces are significantly amplified by increases in pressure and temperature, which induce simultaneously an increase in contact area. Agglomeration greatly depends on the particulate material. There are two different kinds of material, which display different relationship among the processes.

The first kind of material is referred to as cohesive. If the intrinsic shear strength under zero consolidation load is large. Using Amonton's friction law given by Eq. (5.1), the yield locus at incipient failure can be written as,

$$\tau = (\tan\phi)\sigma + c \quad (5.2)$$

where c is the coefficient of cohesion. It is simply the intercept of the internal yield locus on the shear axis as shown on Figure 5.1. A cohesive particulate system gains strength when pressure is applied. Consequently, the relation between the normal

stress and the shear stress is a function of the consolidation pressure and consolidation time.

Another kind of material, termed cohesionless is used to described those granular materials whose intrinsic shear strength under zero consolidation load ($\sigma=0$) is negligible. In this case the yield locus shown in Figure 5.2 for plastic failure given by,

$$\tau = (\tan\phi)\sigma \quad (5.3)$$

where,

τ = shear stress

ϕ = the angle of internal friction

and σ = normal stress

In plasticating processes, including extrusion, particulate pellets are agglomerated and compacted prior to melting. The mechanical properties of agglomerates control the deformation and rupture of the particulate system. The interparticulate friction coefficient plays an important role in the behavior of the particulate system.

5.3 Interparticulate Strength

The strength of the packed particles is dominated by the fractional density. The variation in tensile strength with fractional density and particle size can be approximated from [2,3,8,11,19]. It is formulated as below:

$$\sigma_t = \frac{Cf^n P_c F_c}{D^2} \quad (5.4)$$

where,

σ_t = tensile strength

C = factor dependent on the particle shape

- f =the fractional density
 P_c =the packing coordination
 n =an exponent typically near unity
 F_c =the cohesive bond strength between particle
 and D =the particle diameter

The packing density is important because it controls the number of contacts per unit volume. Beyond these factors, the strength is also sensitive to the particle shape and size distribution. The more irregular the particle shape, the higher the strength at a given fractional density. Various relations have been proposed between the shear strength τ and the normal stress σ , such as, derived from [13,31,32,45].

that is,

$$\tau^n = F_c \left(1 + \frac{\sigma}{\sigma_t} \right) \quad (5.5)$$

where,

- n =the shear index
 and F_c =the cohesive strength of the pellets

The cohesive strength is approximately twice the interparticle tensile strength. The shear index, n , ranges between one and two. For large spherical particles it approaches two. It can be approximated as follows,

$$n = 1 + \frac{0.5}{D^{2/3}} \quad (5.6)$$

where,

- D =the particle diameter in millimeters

Particle compaction creates bonding planes and increases the interlocking at the interfaces, greatly increasing the interparticulate strength. The process of

compaction initially causes local deformation by flattening surface. With continued pressurization, there occurs a transition from a loose particle mass to a higher packing density, with a high volumetric population of interparticulate contacts, resulting in greater strength. The effect of the particle shape is mixed in the degree of mechanical interlocking. Mechanical interlocking of the particles increases for the non-circular, irregular particle shapes. Therefore, the pellets with multi-lobal cross-sections had a tendency to lock each other more tightly than the pellets with circular cross-sections under the same pressure conditions.

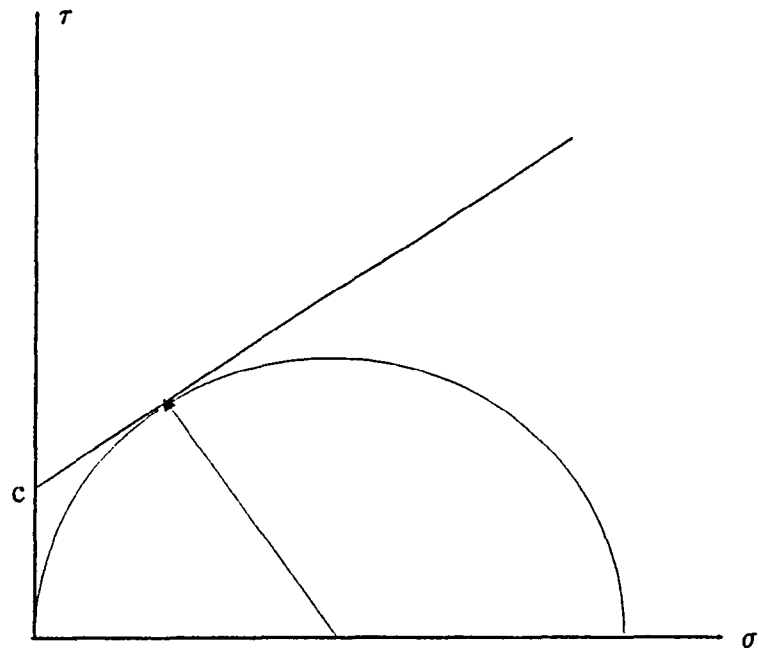


Figure 5.1 The Yield Locus of Cohesive System.

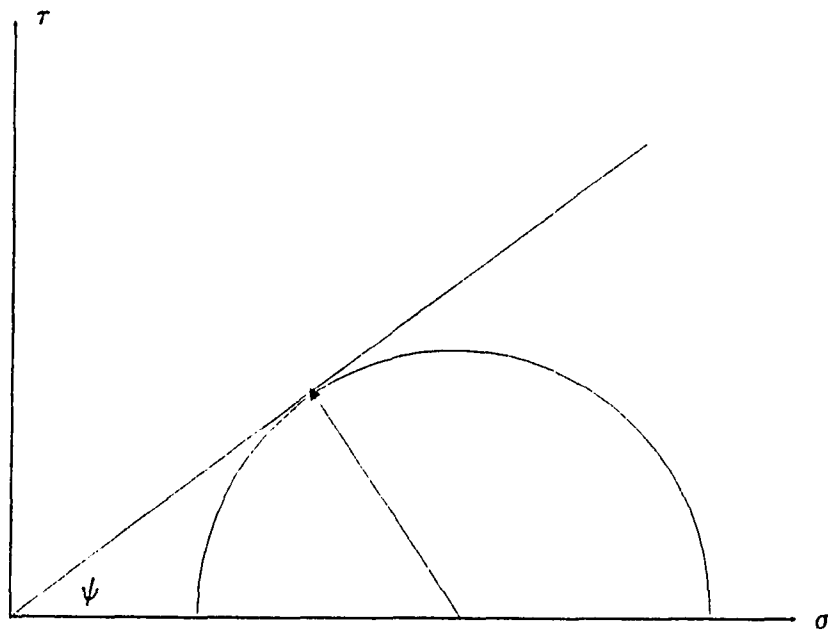


Figure 5.2 The Yield Locus of Noncohesive System.

CHAPTER 6

TEST APPARATUS AND TEST PROCEDURE FOR THE MEASUREMENT OF THE INTERPARTICULATE FRICTION COEFFICIENT

6.1 Test Apparatus

The original experimental test apparatus used for the measurement of the IPFC was developed by Chen [12]. The system is similar to the Jenike shear cell [25]. It is composed of five pieces with an upper ring, a low ring, a cover, a pulley, and a connecting cable. Due to the limitations of the design, it was not possible to measure the exact value of the IPFC. This can be remedied by using a direct shear cell apparatus. A photograph is shown in Figure 6.1. The test shear cell is mounted on a table, it contains the shear box housing, the upper moving ring, the cover and the load cell on one side. On the other side, it contains the gear box with a hand wheel for controlling the pushing rod, which connects to the strain gages for detection of the horizontal force at the shear plane. The direct shear cell arrangement is schematically shown in Figure 6.2. The shear box housing is fixed on the base of shear cell frame. The moving ring is placed on the top of the ring in the shear box housing. The cover holds the sample in the shear box during shear testing. The applied shear force is derived from the pushing stud by rotating the hand wheel. A strain gage is placed on the compressive ring to detect the applied shear force. In performing the test, the sample is loaded in the shear cell, and then the normal force is applied on the cover. The pushing stud applies the shear force to the moving ring, and when motion begins the induced strain is measured using a strain gage, recorded, and converted to a shear force.

6.2 Test Procedure

The direct shear cell arrangement is described as above. It is a static test, but is valid in its application to plasticating extrusion since the break-up of the solid bed is with respect to a static co-ordinate reference frame convected in the solid bed.

The polymeric pellets are packed into the shear cell and then sheared under the chosen normal force, which is applied to the top of the shear cell. The shear force is then applied to the moving ring, and when motion begins the induced strain is measured by using a strain gage. It records the scale indicator shown on the strain gage, which is then converted to a shear force. The interparticulate friction coefficient, μ , is defined as the ratio of the shear force to the normal force, as motion commences, that is,

$$\mu = \frac{S}{N} \quad (6.1)$$

where,

S is the shear force which causes motion,

and N is the normal force applied.

The behavior of the polymeric pellets can be investigated at other chosen stress conditions, by increasing the normal stress to the desired value and then reshearing. Each test was repeated five times to ensure accuracy. The material can readily be returned to the original prepared state by increasing the normal load from 20.5kPa to 45.2kPa.

6.3 V-Blender

A tumbler mixer is used to mix the pellets of non-circular cross-sections with surfactants in weight percentage from 0.25% to 2%. The mixer, a totally enclosed vessel rotating about an axis, causes the particles within the mixer to tumble over each other on the mixer surface. Rotation can be effected by placing the cylinder on

driving rollers. In most other cases, the vessel is attached to a drive shaft and supported on one or two bearings. The vessel is shaped like the V as shown in Figure 6.3.

6.4 Method of Calculation for IPFC

The acting force on the shear force is shown in Figure 6.4, where a contact is assumed between the ring and the base. Some of the forces work around the whole circumference of the ring. The horizontal friction force F_h in this situation originates from two sources,

1. The weight of the ring W_r
2. The silo effect in the upper ring, which causes a part of the vertical force N on the cover to be transmitted by friction to the wall W_f .

The force balance of the system is,

$$T - F_h = S \quad (6.2)$$

$$F_h = \mu_2 F_v \quad (6.3)$$

$$F_v = W_r + W_f \quad (6.4)$$

$$W_f = \mu_1 N \quad (6.5)$$

$$F_h = \mu_2 (W_r + N \mu_1) \quad (6.6)$$

$$T - \mu_2 (W_r + N \mu_1) = S \quad (6.7)$$

where,

μ_1 = friction coefficient between polymer and steel,

μ_2 = friction coefficient between ring and base,

F_h = horizontal friction force between ring and base, N,

F_v = vertical contact force between ring and base, N,

N = total vertical force on the cover, N,

S = real shearing force at shearing plane, N,

T = total externally applied horizontal force, N,

W_r = vertical force due to weight of ring, N,

W_f = vertical friction force between ring and material inside, due to silo effect, N.

The friction coefficient, μ_1 , between the polymer and steel is dependent on the material. The friction coefficient, μ_1 , data of acetal copolymer is found from the typical properties of acetal copolymer [53]. The friction coefficient, μ_1 , data of polyethylene, polypropylene, polystyrene, nylon 6 and ABS are found from Egan Machinery Co. [22]. The values, μ_1 , are listed in Table 6.1.

The friction coefficient, μ_2 , between the ring and base is dependent on the material of shear cell. It can be calibrated by pushing the upper shear cell by measuring the scale indicated on the strain gage, and then converting to the value μ_2

6.5 Validation of the Test Results

In order to confirm the satisfactory operation of the shear cell some statistical tests were conducted. The cell was set up forty times for the same feedstock, and the friction force was measured. The mean and standard deviation for the forty data points were calculated, and based on these values the minimum number of sample tests required to determine a true average was determined from Blank [5]. The procedure is as follow.

Consider the $(1-\alpha)$ 100 percent confidence interval for a population mean m , as given,

$$m = X + Z_{\alpha/2} \frac{\sigma}{\sqrt{n}} \quad (6.8)$$

The term $Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$ is bound on the estimation error that is achieved with probability $(1-\alpha)$, planning the sample size to estimate m , There are a number of

reasons for trying to keep the sample size small. The reasons for sampling in the first place, the cost of data collection and processing, and the time needed to acquire data. On the other hand, the sample must be large enough to achieve the goals, the desire for reliable and accurate estimation, the need to meet contractual obligations, and to satisfy industry and government test standards.

Consider the problem of choosing the sample size for estimating a population mean m , using the mean X of a random sample, the probability is $(1-\alpha)$ that the estimation error will not exceed $Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$. Suppose the decision maker determines that this bound should not exceed a value B . Then it is easy to determine the minimum sample size needed to achieve this accuracy. The $Z_{\alpha/2} = Z_{0.025} = 1.96$, $B = 0.05$, $\sigma = 0.053$.

$$Z_{\alpha/2} \frac{\sigma}{\sqrt{n}} \leq B \quad (6.9)$$

$$n \geq \left(Z_{\alpha/2} \frac{\sigma}{B} \right)^2 \quad (6.10)$$

$$n \geq \left(1.96 \frac{0.053}{0.05} \right)^2 \quad (6.11)$$

$$n \geq 4.32 \quad (6.12)$$

It was determined that five tests were required to make an accurate estimation of the interparticulate friction coefficient in the direct shear cell. This procedure was therefore carried out in all of the test results taken. Namely, the values of the interparticulate friction coefficients were averaged from the five results.

Table 6.1 The Friction Coefficients of the Polymer for Acetal Copolymer, Polyethylene, Polypropylene, Polystyrene, Nylon 6, and ABS on Steel Surface.

No	Polymer Material	Friction Coefficient μ_2
1.	Acetal Copolymer U10-01(POM1) M25(POM2) M90((POM3) M270(POM4) M450(POM5)	0.15 0.15 0.15 0.15 0.15
2.	Polyethylene(PE)	0.24
3.	Polypropylene(PP)	0.32
4.	Polystyrene(PS)	0.25
5.	Nylon 6(PA 6)	0.28
6.	Acrylonitrile-butadiene- styrene(ABS)	0.36

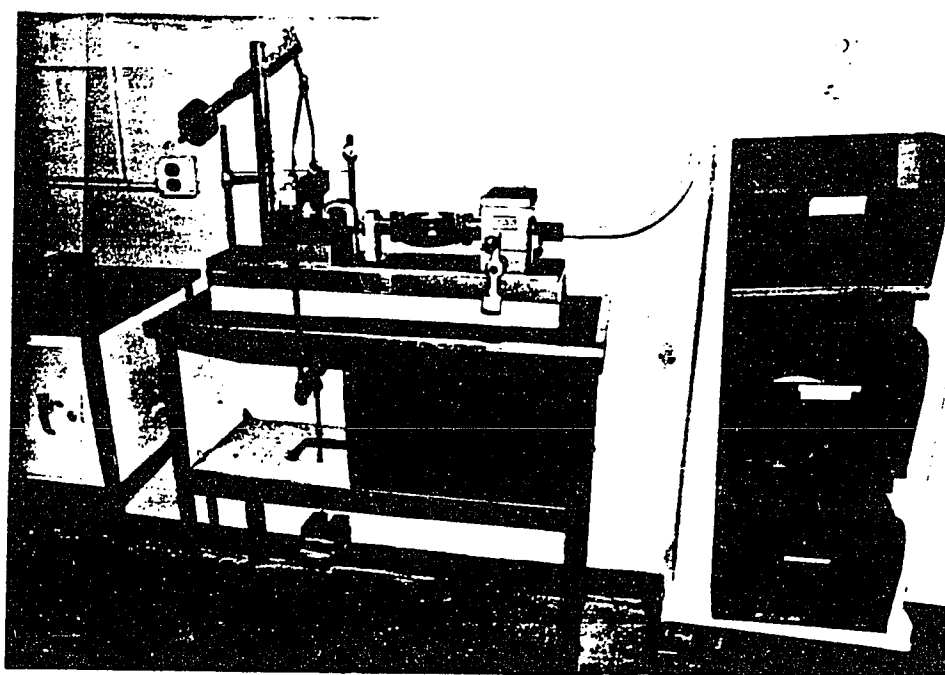


Figure 6.1 Direct Shear Cell Apparatus.

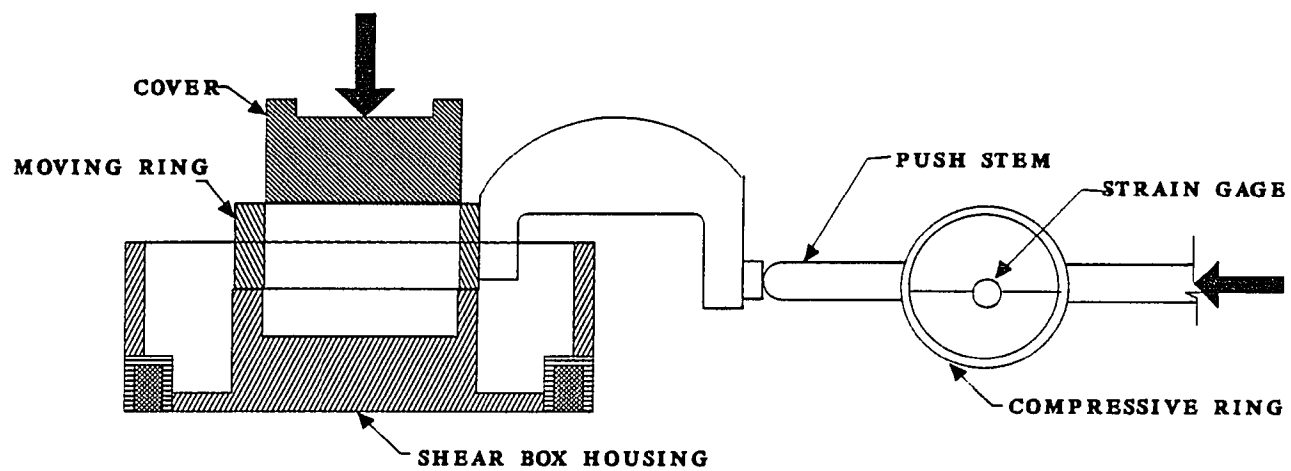


Figure 6.2 Schematic Diagram of the Shear Cell for the Measurement of the Interparticulate Friction Coefficient.

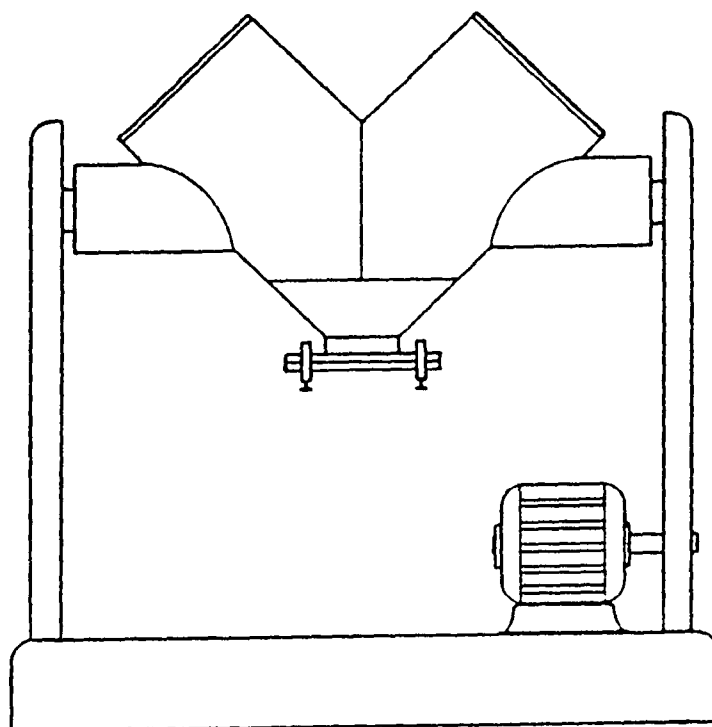


Figure 6.3 V-Blender.

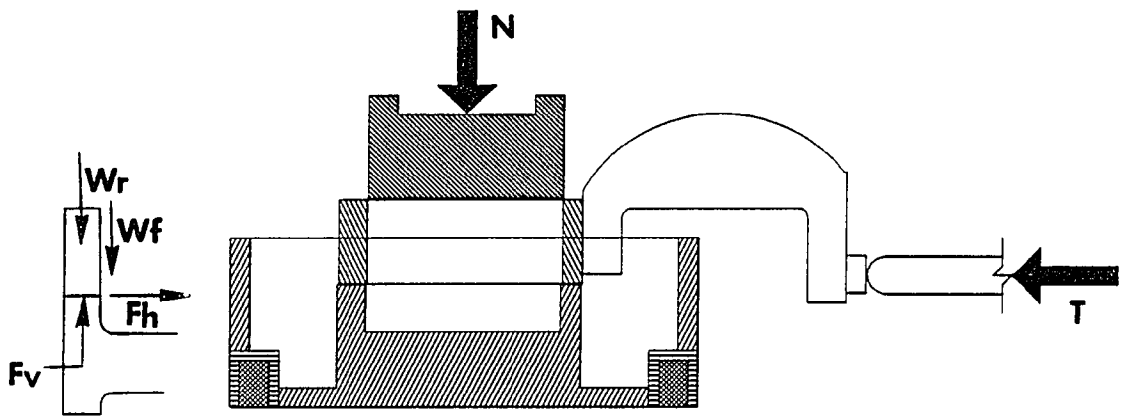


Figure 6.4 Acting Force on Shear Cell.

CHAPTER 7

EXPERIMENTAL RESULTS FOR THE INTERPARTICULATE FRICTION COEFFICIENT

In order to obtain a control datum, pellets with a circular cross-section, manufactured from the materials listed in Table 4.3 were first tested. The results for the measurement of the interparticulate friction coefficients, using the procedure described in chapter six are presented here. The pellets used in the tests with different profiled cross-sections were all manufactured using the specific die inserts, and designate by the code for the die inserts. For example, the bilobal pellets of polyethylene was manufactured by using the die insert A211 (A201-01). The pellet is classified as A211 of PE bilobal pellets.

The of X-axis is the normal pressure (Pascal) obtained by dividing the normal load (N) by the cross-sectional area of the shear cell (m^2), and the Y-axis is the IPFC obtained as in chapter six. Therefore, IPFC as a function of pressure for circular, bilobal, trilobal and quadrilobal cross-sections was plotted for each test. The results are described in the following sections.

7.1 Pellets with Circular Cross-Sections

The pellets with a circular cross-section for all five acetal copolymer samples were first tested. The results are presented in Figure 7.1. The only variables introduced were the pressure, the extruder screw speed, and the melt indices of the polymers from which the pellets were manufactured. Interparticulate friction coefficients for U10-01 (POM1) from 0.25 to 0.31 were recorded. Interparticulate friction coefficients for M25 (POM2) from 0.15 to 0.19 were recorded.

Interparticulate friction coefficients for M90 (POM3) from 0.17 to 0.24 were recorded. Interparticulate friction coefficients for M270 (POM4) from 0.16 to 0.185 were recorded. Interparticulate friction coefficients for M450 (POM5) from 0.15 to 0.17 were recorded. These values are very similar to the published data by [53]. Each result is based on an average of five measurements in accordance with the statistical determinations made in the chapter six.

The pellets with a circular cross-section of materials for polyethylene (PE), polypropylene (PP), polystyrene (PS), nylon 6 (PA 6), and acrylonitrile-butadiene-styrene (ABS) were also tested. The results are presented in Figure 7.2. Interparticulate friction coefficients for polyethylene from 0.25 to 0.275 were recorded. Interparticulate friction coefficients for polypropylene from 0.22 to 0.24 were recorded. Interparticulate friction coefficients for polystyrene from 0.23 to 0.29 were recorded. Interparticulate friction coefficients for nylon 6 from 0.265 to 0.29 were recorded. Interparticulate friction coefficients for acrylonitrile-butadiene-styrene from 0.16 to 0.19 were recorded. Each result is based on an average of five measurements in accordance with the statistical determinations made in the chapter six.

7.2 Pellets with Bilobal Cross-Sections

First, the die, A211 (A201-01), was installed on the extruder and pellets were manufactured at different extruder screw speeds ranging from 5 rpm to 20 rpm for each of the five samples of acetal copolymer. Samples of the pellets were collected for later testing, in accordance with the procedure described in chapter four. Then, this procedure was repeated for dies A212 (A201-02), A221 (A202-01), A231 (A203-01), A241 (A204-01), A311 (A301-01) and A411 (A401-01). Each of the samples was then placed in the shear cell and the interparticulate friction coefficient was measured as a function of normal pressure.

Figures 7.3 - 7.7 show the IPFC as a function of pressure of all bilobal dies for acetal copolymer grade U10-01 (POM1). The value of the IPFC is presented as described here. Figure 7.3 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A211. The value of the IPFC is approximate 0.382 to 0.459. Figure 7.4 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A212. The value of the IPFC is approximate 0.355 to 0.448. Figure 7.5 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221 for. The value of the IPFC is approximate 0.398 to 0.0.480. Figure 7.6 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231 for. The value of the IPFC is approximate 0.32 to 0.45. Figure 7.7 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.33 to 0.485.

Figures 7.8 - 7.12 show the IPFC as a function of pressure of all bilobal die for acetal copolymer grade M25 (POM2). The value of the IPFC is presented as described here. Figure 7.8 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A211. The value of the IPFC is approximate 0.35 to 0.42. Figure 7.9 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A212. The value of the IPFC is approximate 0.31 to 0.43. Figure 7.10 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221. The value of the IPFC is approximate 0.32 to 0.395. Figure 7.11 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231. The value of the IPFC is approximate 0.22 to 0.34. Figure 7.12 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.34 to 0.52.

Figures 7.13 - 7.17 show the IPFC as a function of pressure of all bilobal die for acetal copolymer grade M90 (POM3). The value of the IPFC is presented as described here. Figure 7.13 shows the IPFC as a function of pressure for pellets with

bilobal cross-sections of die A211. The value of the IPFC is approximate 0.34 to 0.42. Figure 7.14 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A212. The value of the IPFC is approximate 0.33 to 0.43. Figure 7.15 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221. The value of the IPFC is approximate 0.375 to 0.445. Figure 7.16 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231. The value of the IPFC is approximate 0.245 to 0.32. Figure 7.17 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.34 to 0.42.

Figures 7.18 - 7.22 show the IPFC as a function of pressure of all bilobal die for acetal copolymer grade M270 (POM4). The value of the IPFC is presented as described here. Figure 7.18 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A211. The value of the IPFC is approximate 0.31 to 0.40. Figure 7.19 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A212. The value of the IPFC is approximate 0.30 to 0.45. Figure 7.20 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221. The value of the IPFC is approximate 0.36 to 0.46. Figure 7.21 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231. The value of the IPFC is approximate 0.17 to 0.25. Figure 7.22 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.23 to 0.42.

Figures 7.23 - 7.27 show the IPFC as a function of pressure of all bilobal die for acetal copolymer grade M450 (POM5). The value of the IPFC is presented as described here. Figure 7.23 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A211. The value of the IPFC is approximate 0.33 to 0.43. Figure 7.24 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A212. The value of the IPFC is approximate 0.33 to 0.43. Figure 7.25

shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221. The value of the IPFC is approximate 0.385 to 0.455. Figure 7.26 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231. The value of the IPFC is approximate 0.17 to 0.235. Figure 7.27 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.35 to 0.44.

Second, with the same procedure described as above, the die, A201-01, was installed on the extruder and pellets were manufactured at different extruder screw speeds ranging from 5 rpm to 20 rpm for polyethylene (PE), polypropylene (PP), polystyrene (PS), nylon 6 (PA 6), and acrylonitrile-butadiene-styrene (ABS). Samples of the pellets were collected for later testing, in accordance with the procedure described in chapter four. Then, this procedure was repeated for dies A201-02, A202-01, A203-01, A204-01, A301-01, and A401-01. Each of the samples was then placed in the shear cell and the interparticulate friction coefficient was measured as a function of normal pressure.

Figures 7.28 - 7.32 show the IPFC as a function of pressure of all bilobal die for polyethylene (PE). The value of the IPFC is presented as described here. Figure 7.28 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A211. The value of the IPFC is approximate 0.26 to 0.345. Figure 7.29 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A212. The value of the IPFC is approximate 0.29 to 0.35. Figure 7.30 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221. The value of the IPFC is approximate 0.31 to 0.37. Figure 7.31 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231. The value of the IPFC is approximate 0.295 to 0.36. Figure 7.32 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.32 to 0.395.

Figures 7.33 - 7.37 show the IPFC as a function of pressure of all bilobal die for polypropylene (PP). The value of the IPFC is presented as described here. Figure 7.33 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A211. The value of the IPFC is approximate 0.275 to 0.32. Figure 7.34 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A212. The value of the IPFC is approximate 0.24 to 0.285. Figure 7.35 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221. The value of the IPFC is approximate 0.28 to 0.33. Figure 7.36 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231. The value of the IPFC is approximate 0.26 to 0.315. Figure 7.37 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.325 to 0.395.

Figures 7.38 - 7.42 show the IPFC as a function of pressure of all bilobal die for polystyrene (PS). The value of the IPFC is presented as described here. Figure 7.38 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A211. The value of the IPFC is approximate 0.278 to 0.37. Figure 7.39 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A212. The value of the IPFC is approximate 0.27 to 0.35. Figure 7.40 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221. The value of the IPFC is approximate 0.39 to 0.475. Figure 7.41 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231. The value of the IPFC is approximate 0.28 to 0.36. Figure 7.42 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.32 to 0.395.

Figures 7.43 - 7.47 show the IPFC as a function of pressure of all bilobal die for nylon 6 (PA 6). The value of the IPFC is presented as described here. Figure 7.43 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die

A211. The value of the IPFC is approximate 0.29 to 0.37. Figure 7.44 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A212. The value of the IPFC is approximate 0.29 to 0.335. Figure 7.45 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221. The value of the IPFC is approximate 0.295 to 0.375. Figure 7.46 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231. The value of the IPFC is approximate 0.28 to 0.355. Figure 7.47 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.325 to 0.390.

Figures 7.48 - 7.51 show the IPFC as a function of pressure of all bilobal die except A212 for acrylonitrile-butadiene-styrene (ABS). The value of the IPFC is presented as described here. Figure 7.48 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A211. The value of the IPFC is approximate 0.25 to 0.31. Figure 7.49 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A221. The value of the IPFC is approximate 0.21 to 0.28. Figure 7.50 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A231. The value of the IPFC is approximate 0.18 to 0.245. Figure 7.51 shows the IPFC as a function of pressure for pellets with bilobal cross-sections of die A241. The value of the IPFC is approximate 0.205 to 0.31.

7.3 Pellets with Trilobal Cross-Sections

Next, pellets with trilobal cross-sections were manufactured using the profile die A301-01 as described in Table 3.1 and tested in the direct shear cell.

Figures 7.52 - 7.56 show the IPFC as a function of pressure of trilobal die at four different extruder screw speeds ranging from 5 rpm to 20 rpm for each of the five samples of acetal copolymer. The value of the IPFC is presented as described here. Figure 7.52 shows the IPFC as a function of pressure for pellets with trilobal

cross-sections of die A311 for acetal copolymer grade U10-01 (POM1). The value of the IPFC is approximate 0.33 to 0.45. Figure 7.53 shows the IPFC as a function of pressure for pellets with trilobal cross-sections of die A311 for acetal copolymer grade M25 (POM2). The value of the IPFC is approximate 0.205 to 0.28. Figure 7.54 shows the IPFC as a function of pressure for pellets with trilobal cross-sections of die A311 for acetal copolymer grade M90 (POM3). The value of the IPFC is approximate 0.22 to 0.29. Figure 7.55 shows the IPFC as a function of pressure for pellets with trilobal cross-sections of die A311 for acetal copolymer grade M270 (POM4). The value of the IPFC is approximate 0.205 to 0.255. Figure 7.56 shows the IPFC as a function of pressure for pellets with trilobal cross-sections of die A311 for acetal copolymer grade M450 (POM5). The value of the IPFC is approximate 0.18 to 0.275.

Figures 7.57 - 7.60 show the IPFC as a function of pressure of trilobal die at four different extruder screw speeds ranging from 5 rpm to 20 rpm for polyethylene, polypropylene, polystyrene and nylon 6.. The value of the IPFC is presented as described here. Figure 7.57 shows the IPFC as a function of pressure for pellets with trilobal cross-sections of die A311 for polyethylene. The value of the IPFC is approximate 0.30 to 0.345. Figure 7.58 shows the IPFC as a function of pressure for pellets with trilobal cross-sections of die A311 for polypropylene. The value of the IPFC is approximate 0.25 to 0.295. Figure 7.59 shows the IPFC as a function of pressure for pellets with trilobal cross-sections of die A311 for polystyrene. The value of the IPFC is approximate 0.25 to 0.295. Figure 7.60 shows the IPFC as a function of pressure for pellets with trilobal cross-sections of die A311 for nylon 6. The value of the IPFC is approximate 0.315 to 0.38.

7.4 Pellets with Quadrilobal Cross-Sections

Next, pellets with quadrilobal cross-sections were manufactured using the profile die A401-01 as described in Table 3.1 and tested in the direct shear cell.

Figures 7.61 - 7.65 show the IPFC as a function of pressure of quadrilobal die at four different extruder screw speeds ranging from 5 rpm to 20 rpm for each of the five samples of acetal copolymer. The value of the IPFC is presented as described here. Figure 7.61 shows the IPFC as a function of pressure for pellets with quadrilobal cross-sections of die A411 for acetal copolymer grade U10-01 (POM1). The value of the IPFC is approximate 0.334 to 363. Figure 7.62 shows the IPFC as a function of pressure for pellets with quadrilobal cross-sections of die A411 for acetal copolymer grade M25 (POM2). The value of the IPFC is approximate 0.195 to 0.235. Figure 7.63 shows the IPFC as a function of pressure for pellets with quadrilobal cross-sections of die A411 for acetal copolymer grade M90 (POM3). The value of the IPFC is approximate 0.255 to 0.29. Figure 7.64 shows the IPFC as a function of pressure for pellets with quadrilobal cross-sections of die A411 for acetal copolymer grade M270 (POM4). The value of the IPFC is approximate 0.20 to 0.275. Figure 7.65 shows the IPFC as a function of pressure for pellets with quadrilobal cross-sections of die A411 for acetal copolymer grade M450 (POM5). The value of the IPFC is approximate 0.20 to 0.225.

Figures 7.66 - 7.67 show the IPFC as a function of pressure of quadrilobal die at four different extruder screw speeds ranging from 5 rpm to 20 rpm for polyethylene (PE), polypropylene (PP). The value of the IPFC is presented as described here. Figure 7.66 shows the IPFC as a function of pressure for pellets with quadrilobal cross-sections of die A411 for polyethylene. The value of the IPFC is approximate 0.335 to 0.365. Figure 7.67 shows the IPFC as a function of pressure for pellets with quadrilobal cross-sections of die A411 for polypropylene. The value of the IPFC is approximate 0.305 to 0.345.

7.5 Pellets with Consolidation Pressure and Consolidation Time

Using the apparatus and procedure described in chapter six, results for the IPFC were measured over extensive pressure ranges. The pellets consolidated at 126.3 kPa prior to testing. Figure 7.68 shows the IPFC as a function of pressure for pellets were manufactured from polyethylene using die A211. The value of the IPFC is 0.238 to 0.323.

The pellets also consolidated at 126.3 kPa for several different time periods. Figure 7.69 shows the IPFC as a function of consolidation time for pellets manufactured using die A211. The value of the IPFC is 0.32 to 0.36.

7.6 Pellets with Surface Lubricant and Additive

The zinc stearate, mica clay, and polyester powder (PBT) were added into the pellets with circular cross-sections and bilobal cross-sections.

Figure 7.70 shows the IPFC as a function of pressure for pellets with circular cross-sections of acetal copolymer grade M90 (POM3) by adding zinc stearate in weight percentage from 0.25% to 1.0%. The value of the IPFC is 0.119 to 0.233. Figure 7.71 shows the IPFC as a function of pressure for pellets with bilobal cross-sections manufactured using die A211 from acetal copolymer grade M90 (POM3) by adding zinc stearate in weight percentage from 0.25% to 1.0%. The value of the IPFC is 0.128 to 0.218. Figure 7.72 shows the IPFC as a function of pressure for the pellets manufactured using die A212 from acetal copolymer grade M90 (POM3) by adding zinc stearate in weight percentage from 0.25% to 1.0%. The value of the IPFC is 0.18 to 0.236.

Figure 7.73 shows the IPFC as a function of pressure for pellets with circular cross-sections of nylon 6 (PA 6) by adding mica clay in weight percentage from 0.5% to 2.0%. The value of the IPFC is 0.304 to 0.368. Figure 7.74 shows the IPFC as a function of pressure for pellets with bilobal cross-sections manufactured using die

A241 from nylon 6 (PA 6) by adding mica clay in weight percentage from 0.25% to 1.0%. The value of the IPFC is 0.35 to 0.43.

Figure 7.75 shows the IPFC as a function of pressure for pellets with circular cross-sections of acetal copolymer grade M90 (POM3) by adding polyester (PBT) powder in weight percentage from 0.5% to 2.0%. The value of the IPFC is 0.257 to 0.313. Figure 7.76 shows the IPFC as a function of pressure for pellets with bilobal cross-sections manufactured using die A212 from acetal copolymer grade M90 (POM3) by adding polyester (PBT) powder in weight percentage from 0.5% to 2.0%. The value of the IPFC is 0.248 to 0.383.

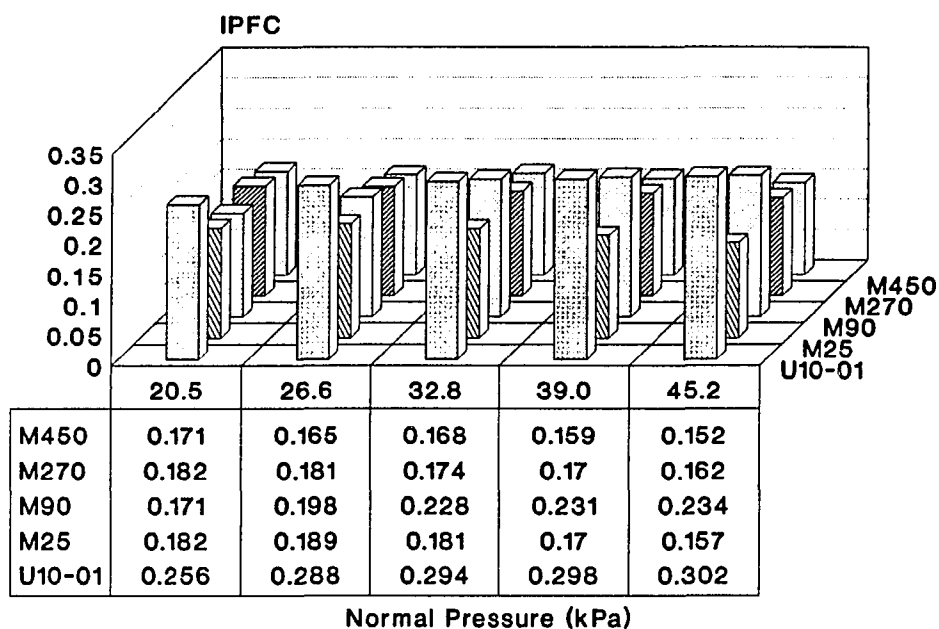


Figure 7.1 IPFC of Cylindrical for Pellets With Circular Cross-Sections (a) U-10, (b) M-25, (c) M-90, (d) M-270, (e) M-450.

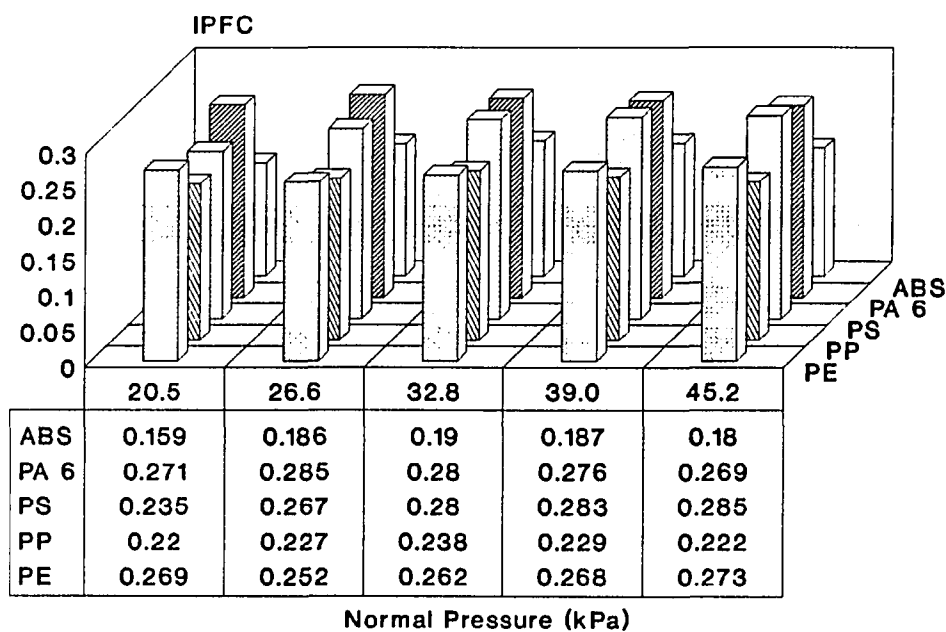


Figure 7.2 IPFC of Cylindrical for Pellets With Circular Cross-Sections (a) PE, (b) PP, (c) PS, (d) PA 6, (e) ABS.

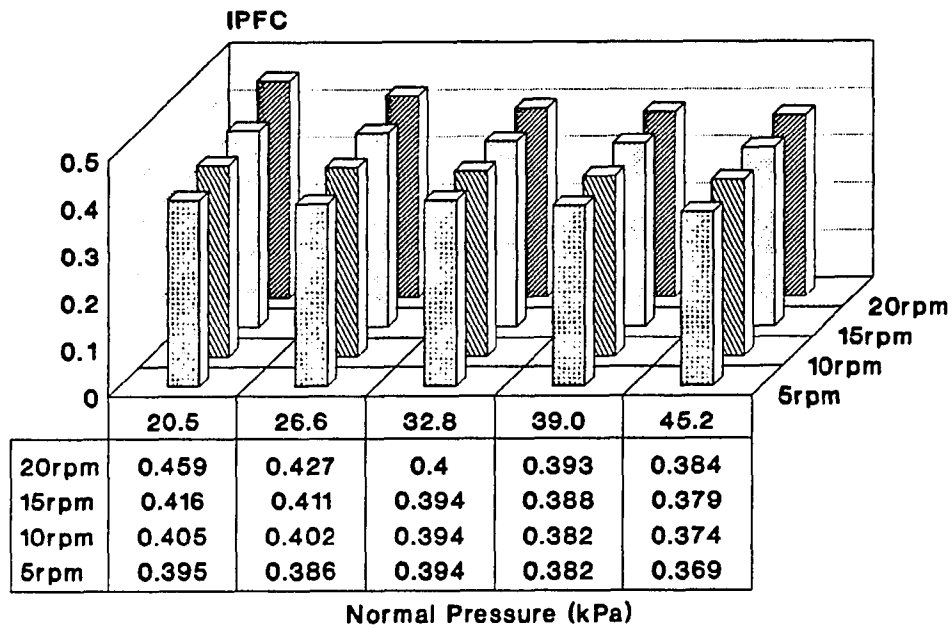


Figure 7.3 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM1.

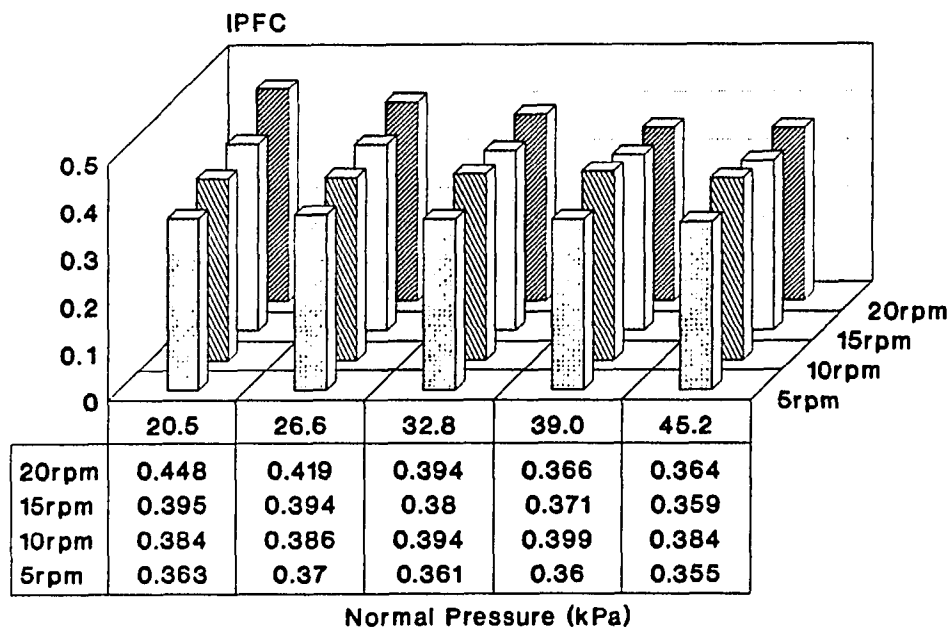


Figure 7.4 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM1

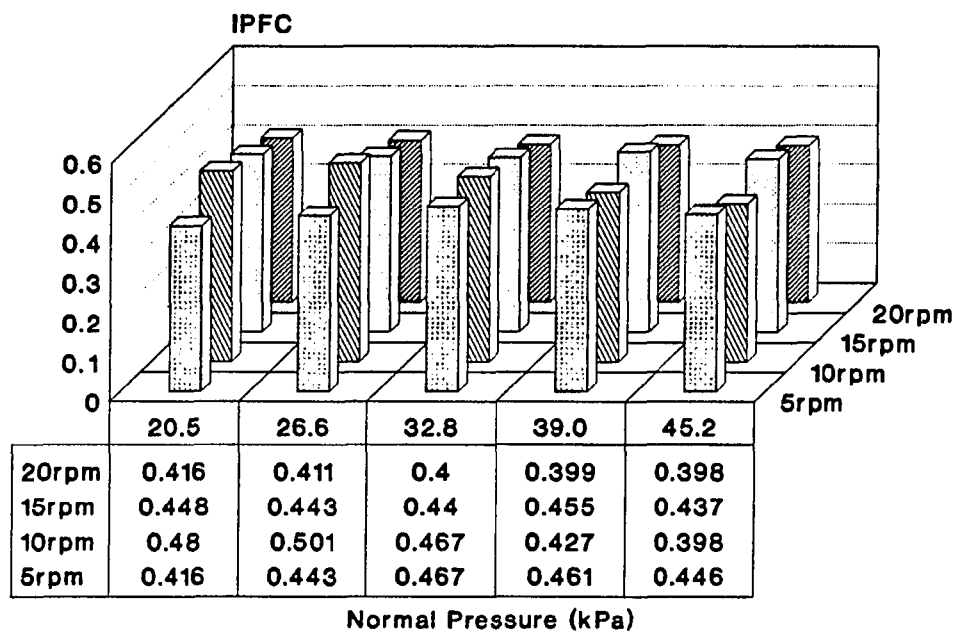


Figure 7.5 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM1.

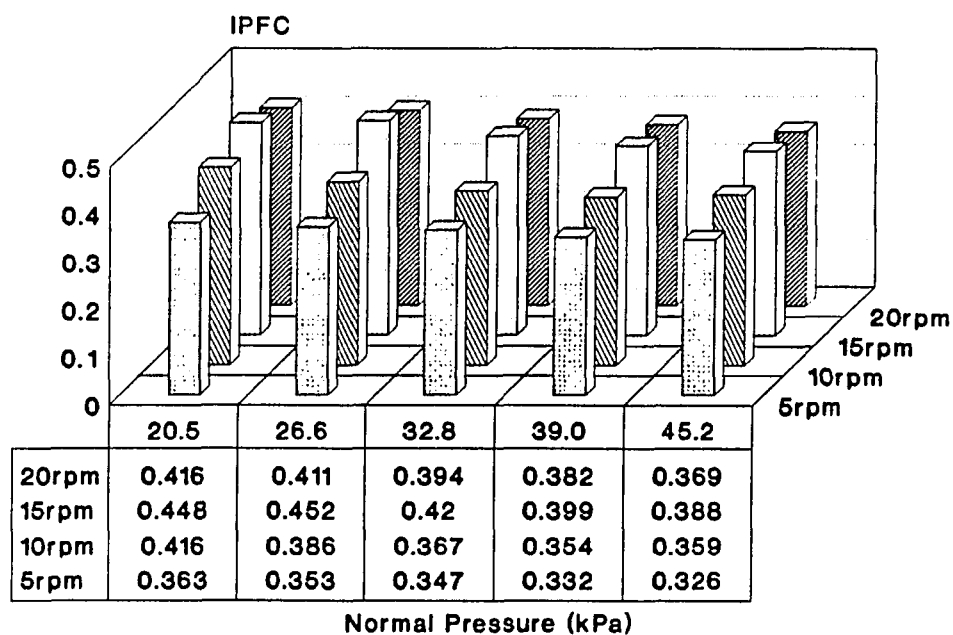


Figure 7.6 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM1.

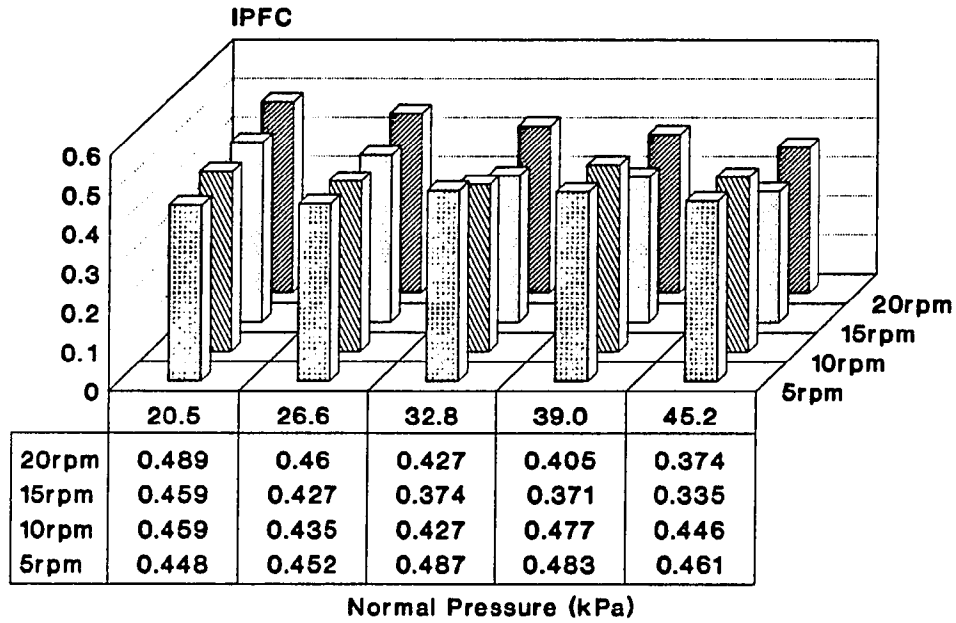


Figure 7.7 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM1.

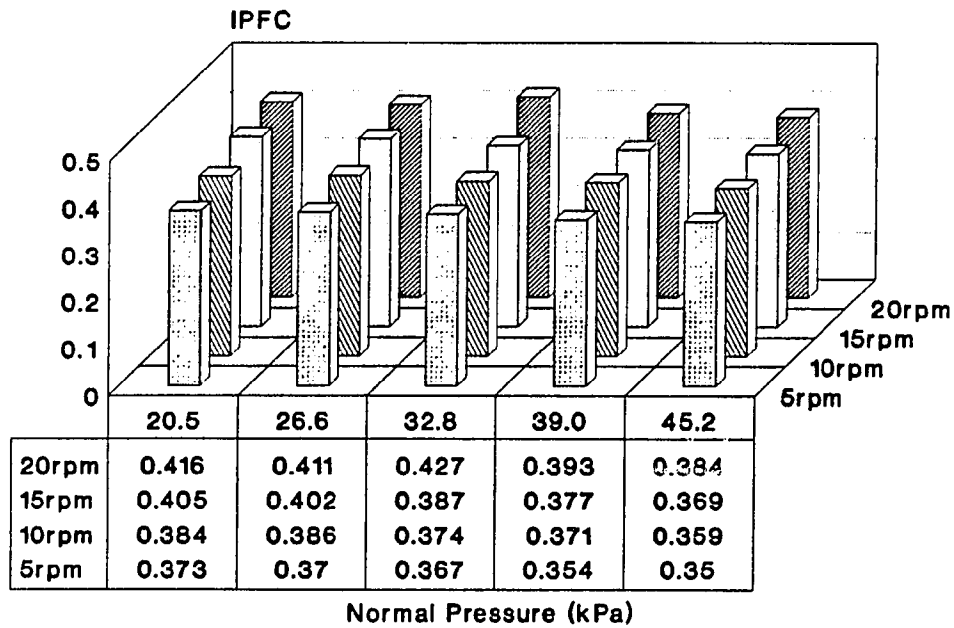


Figure 7.8 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM2

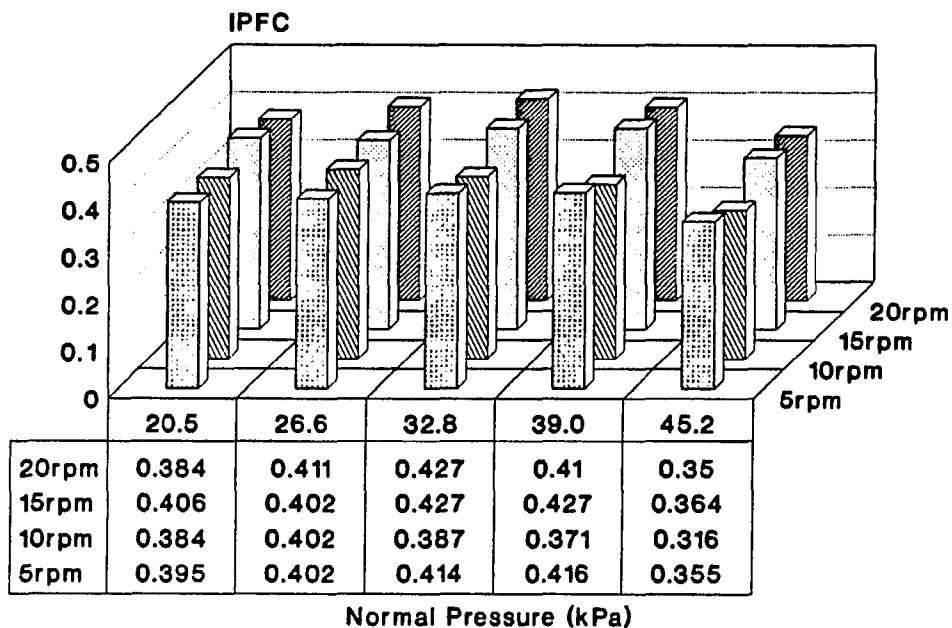


Figure 7.9 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM2 .

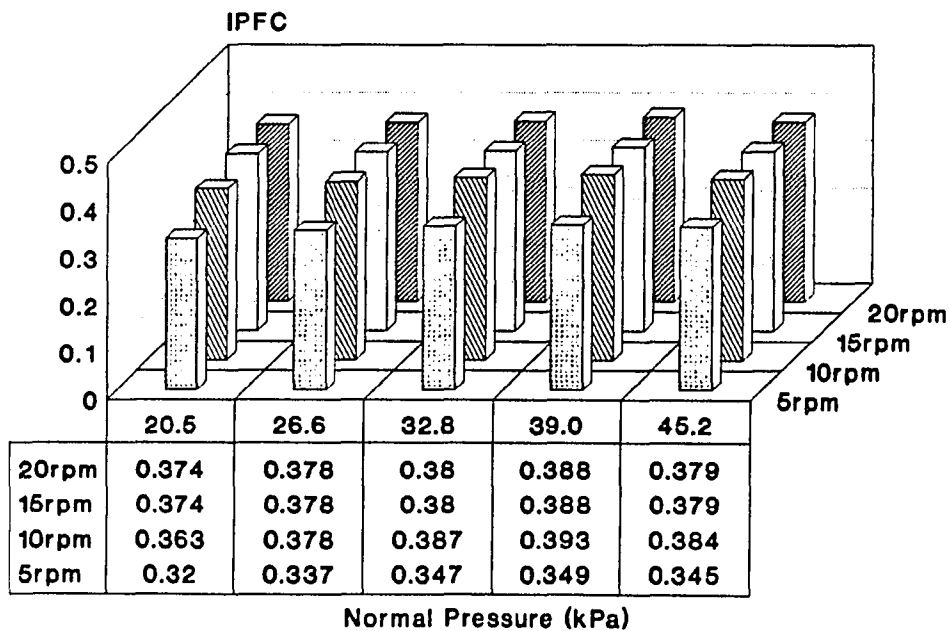


Figure 7.10 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM2.

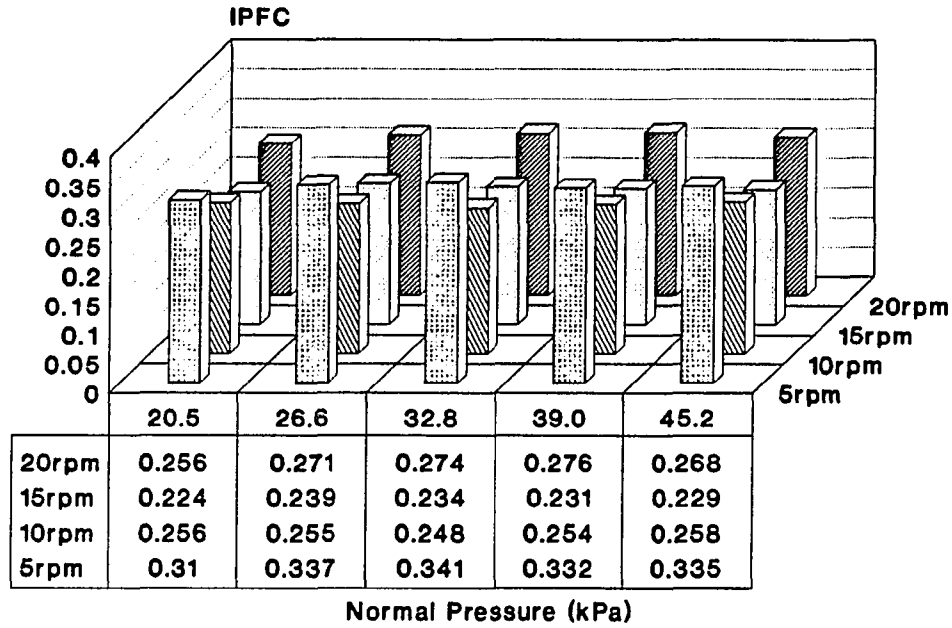


Figure 7.11 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM2.

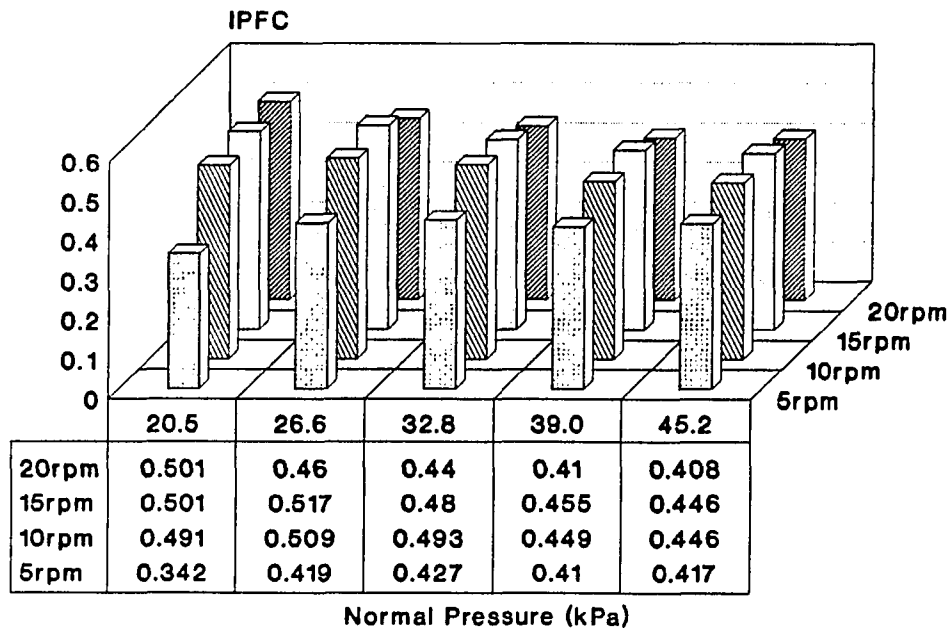


Figure 7.12 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM2.

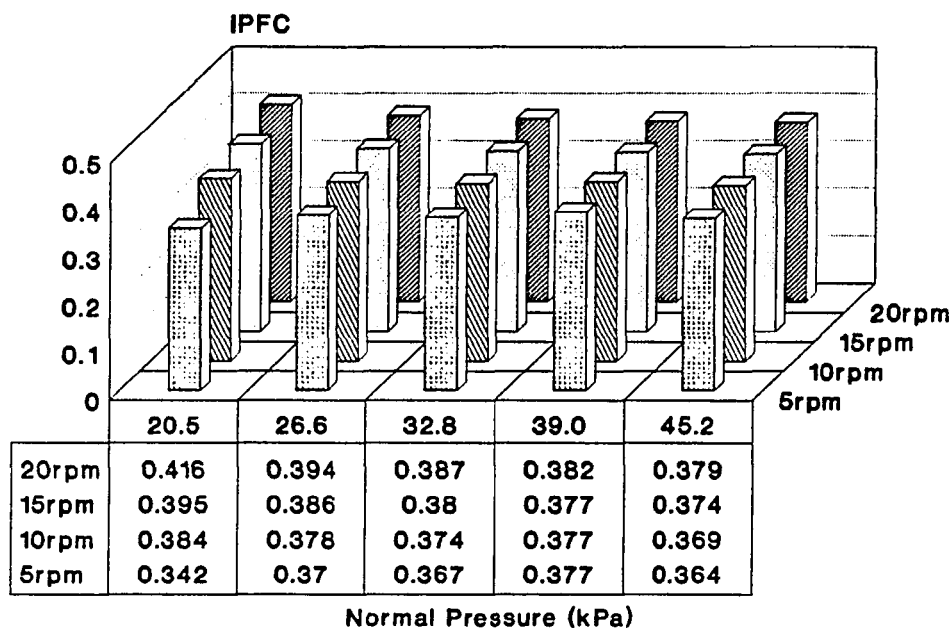


Figure 7.13 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM3.

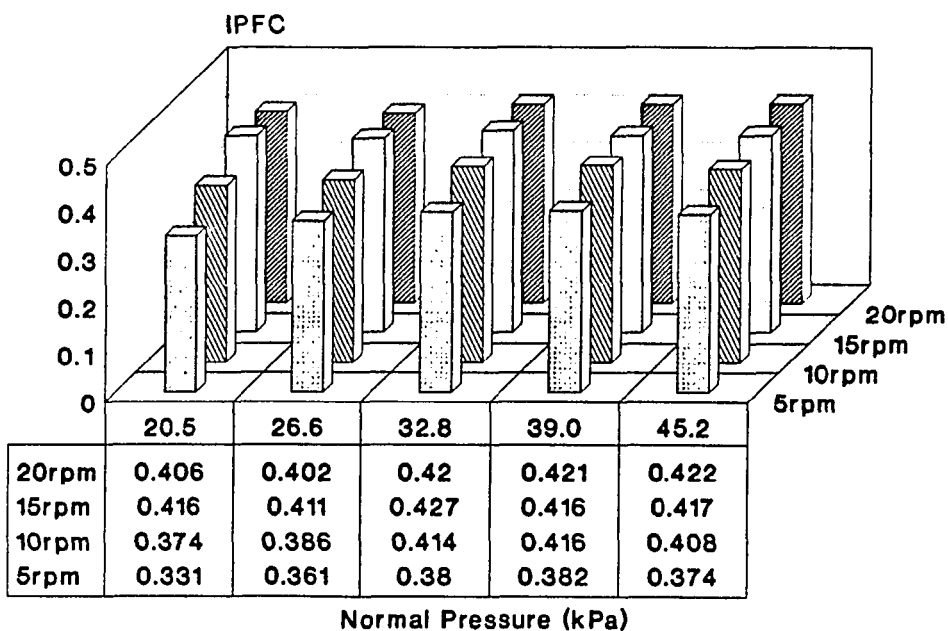


Figure 7.14 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM3.

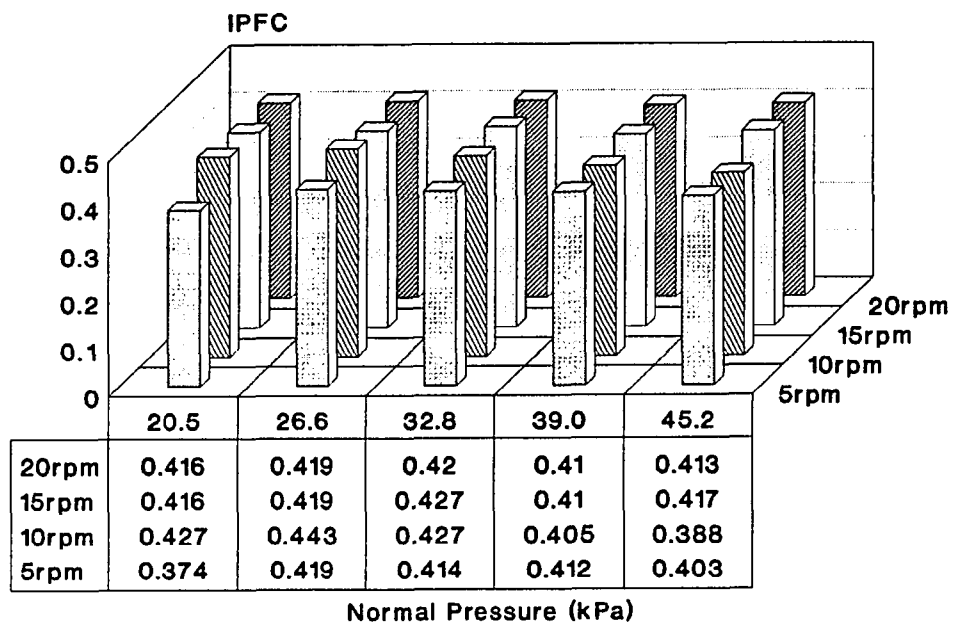


Figure 7.15 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM3.

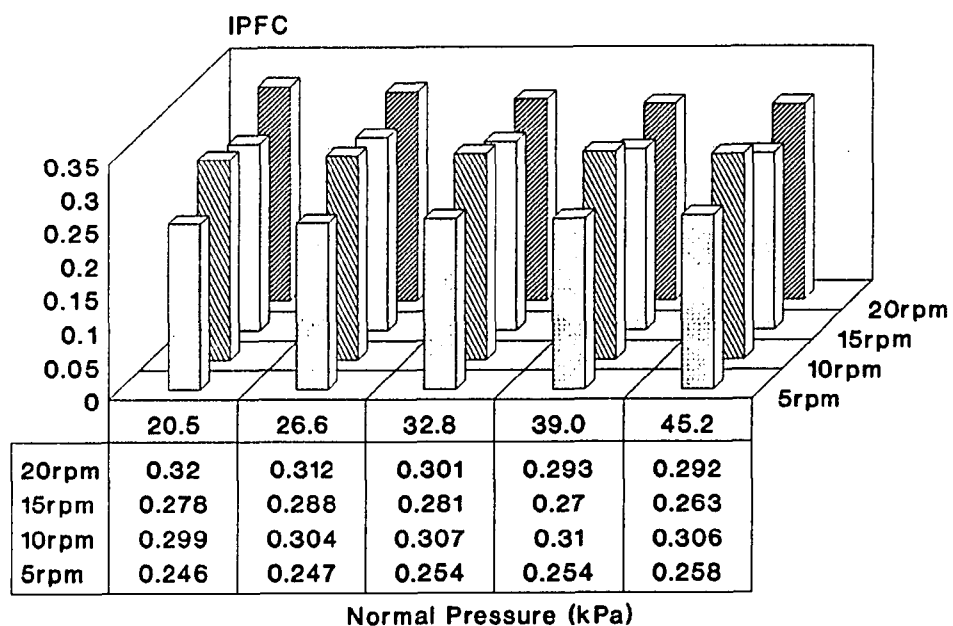


Figure 7.16 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM3.

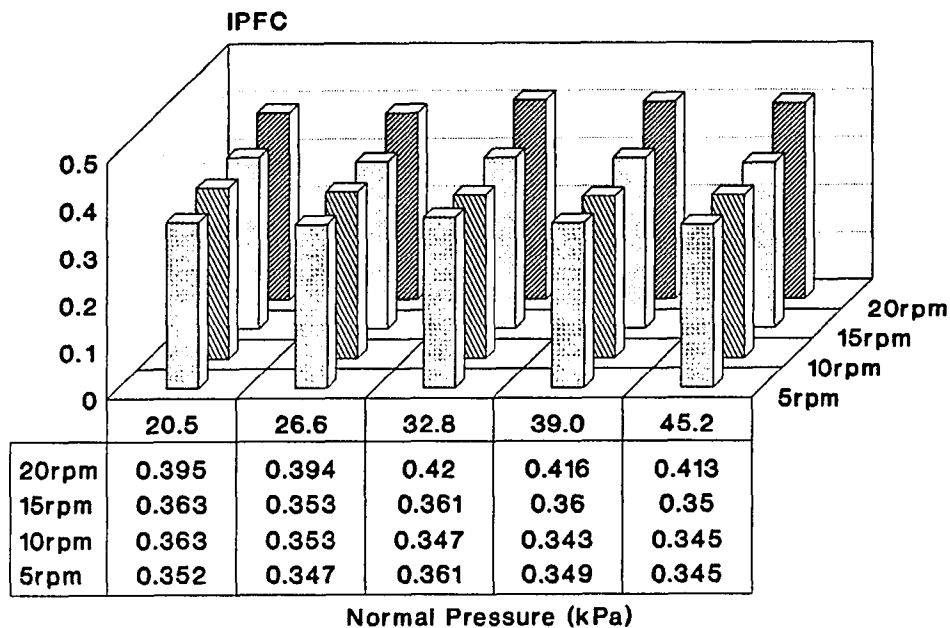


Figure 7.17 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM3.

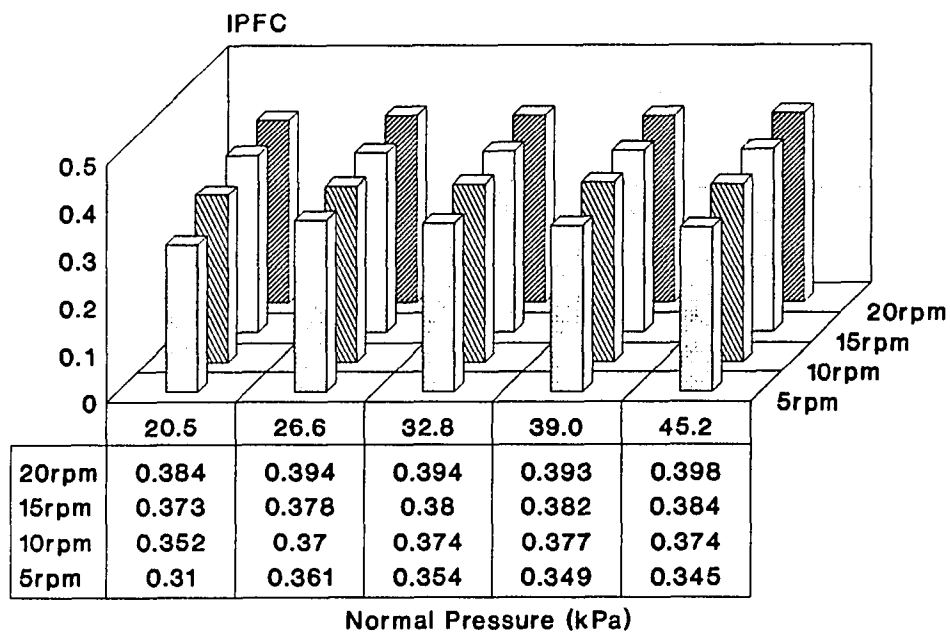


Figure 7.18 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM4.

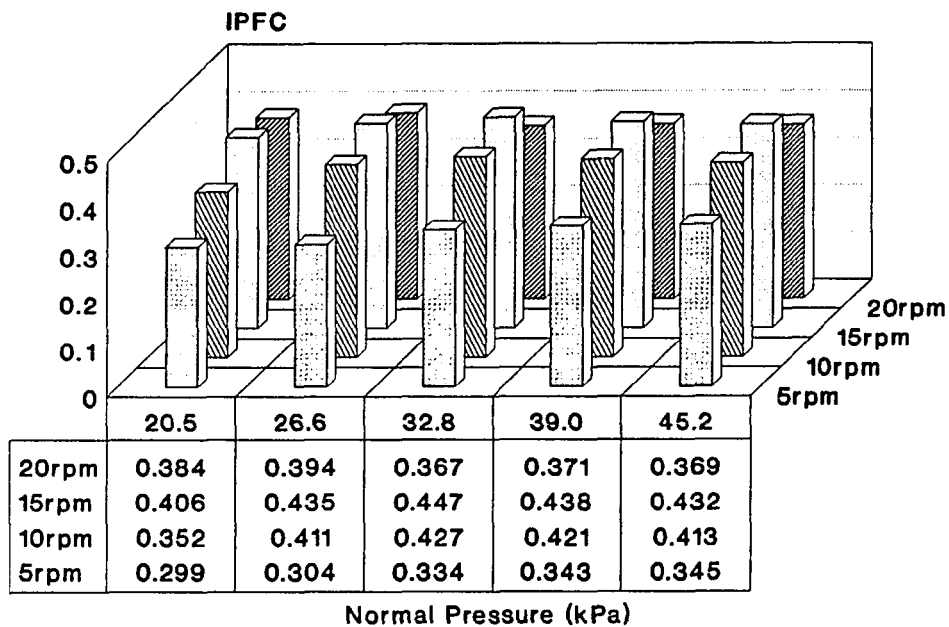


Figure 7.19 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM4.

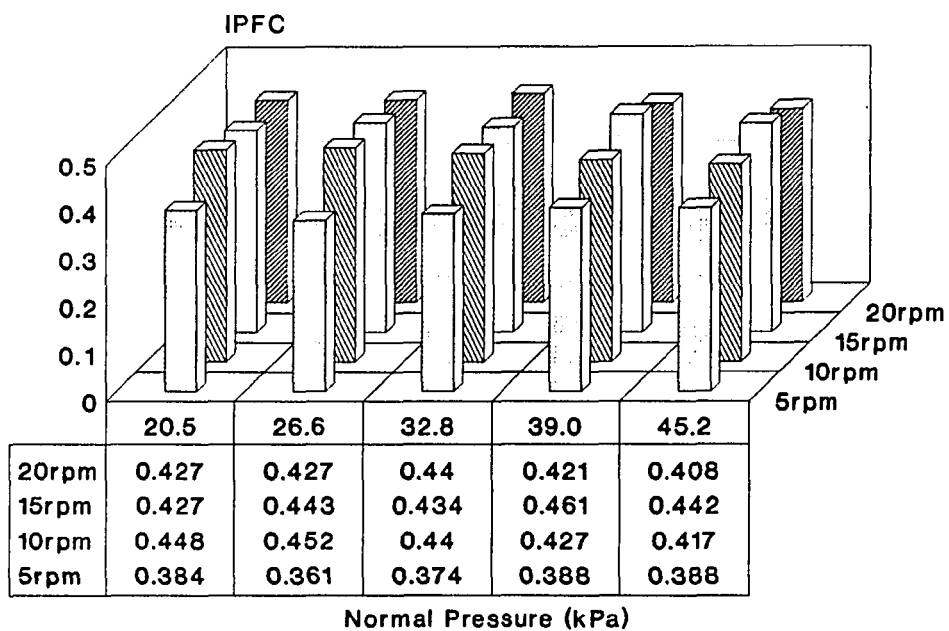


Figure 7.20 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM4.

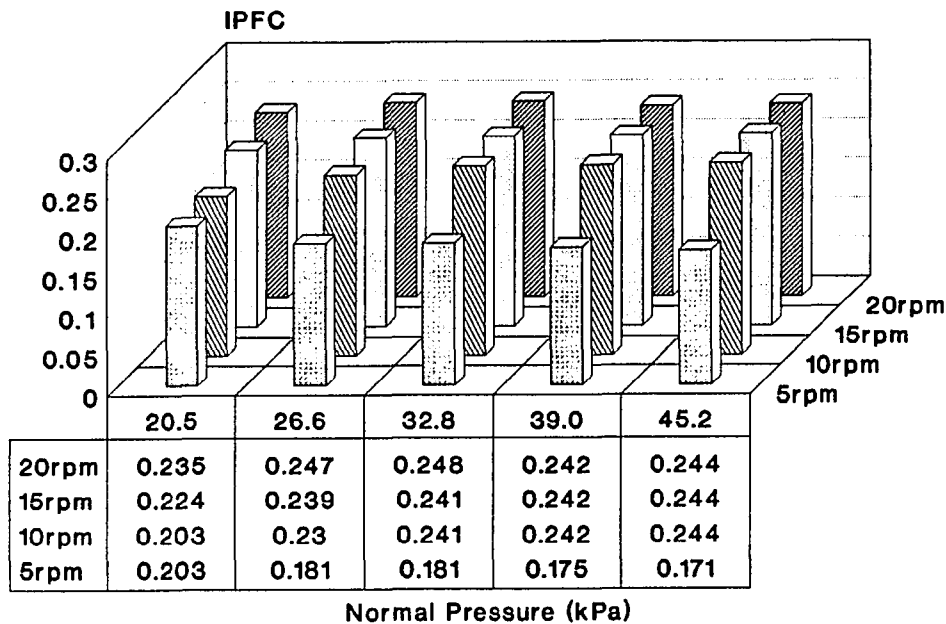


Figure 7.21 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM4.

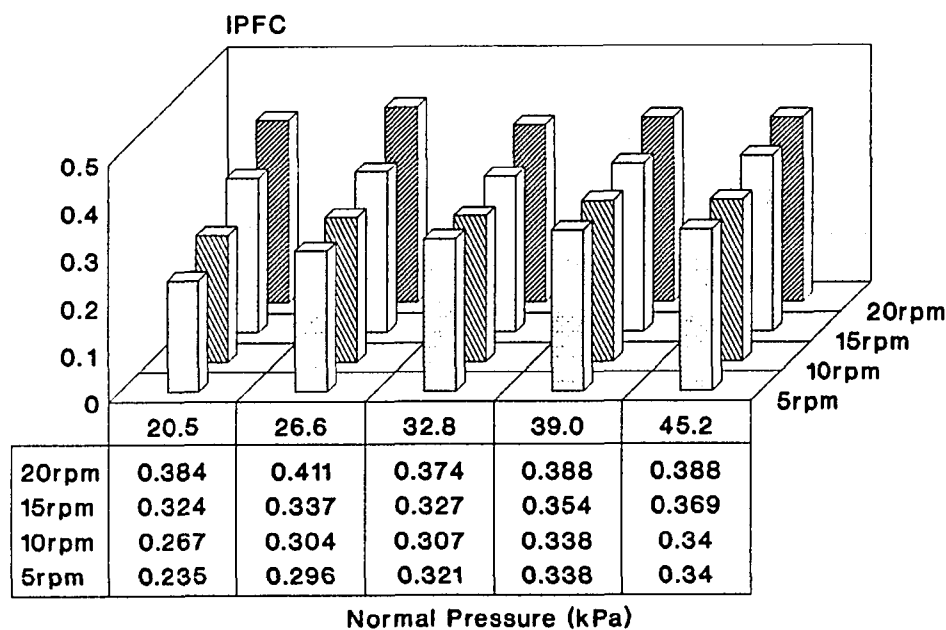


Figure 7.22 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM4.

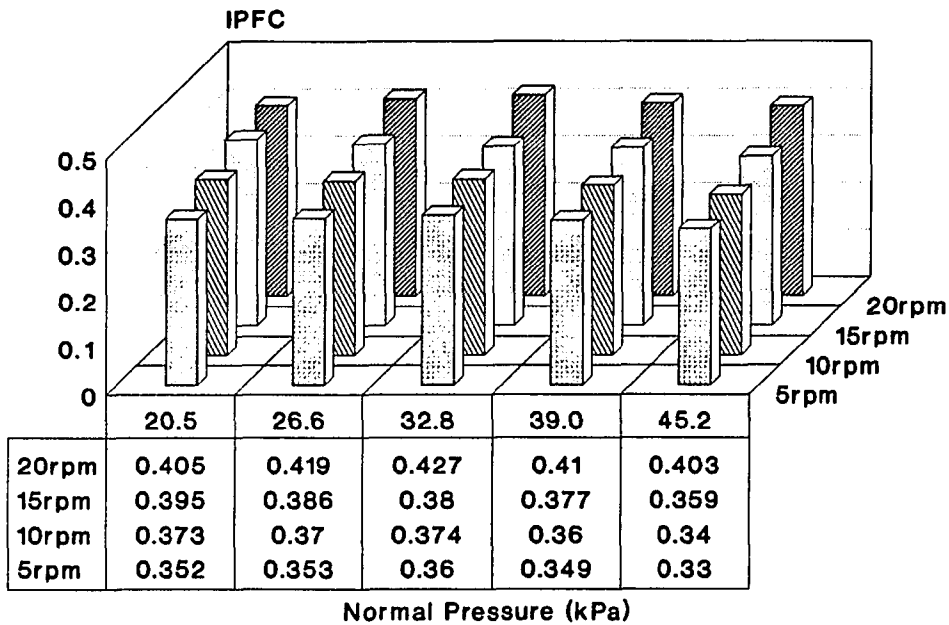


Figure 7.23 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM5.

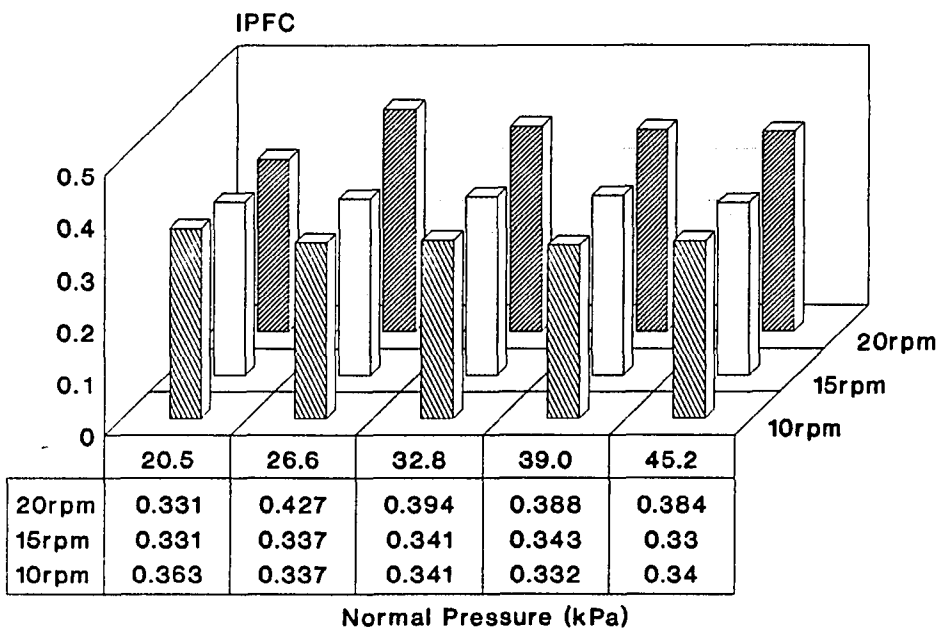


Figure 7.24 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM5.

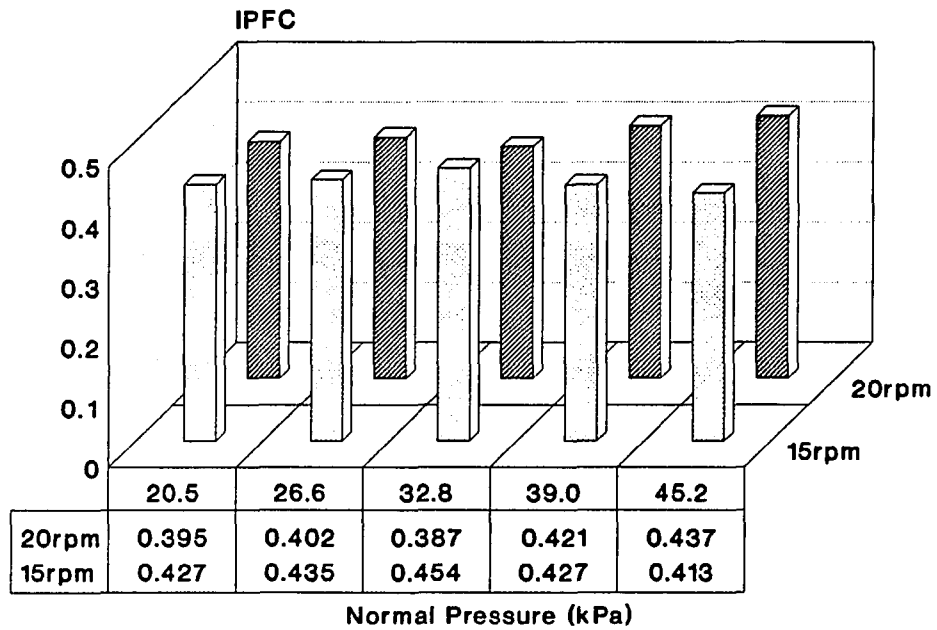


Figure 7.25 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM5.

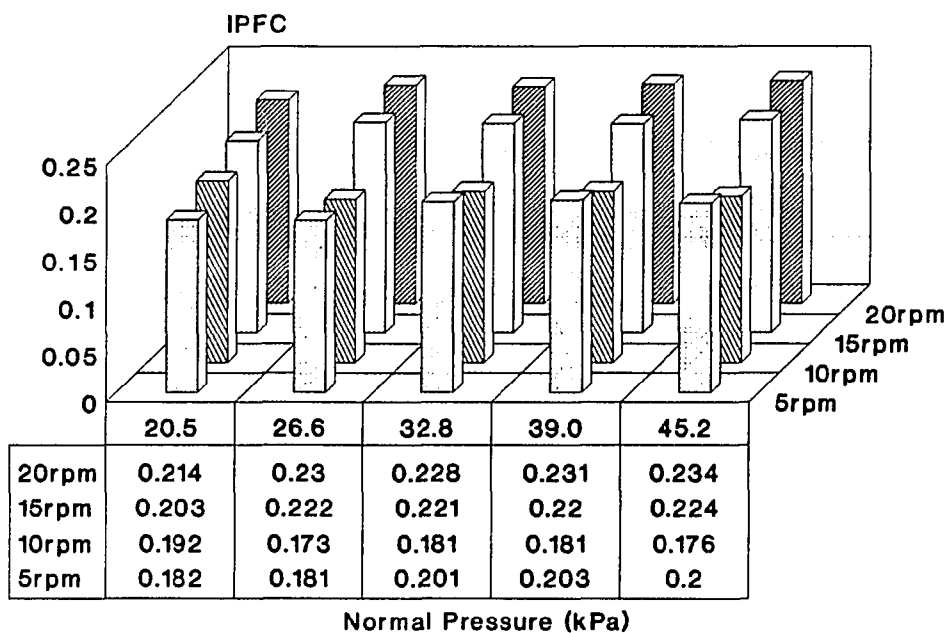


Figure 7.26 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM5.

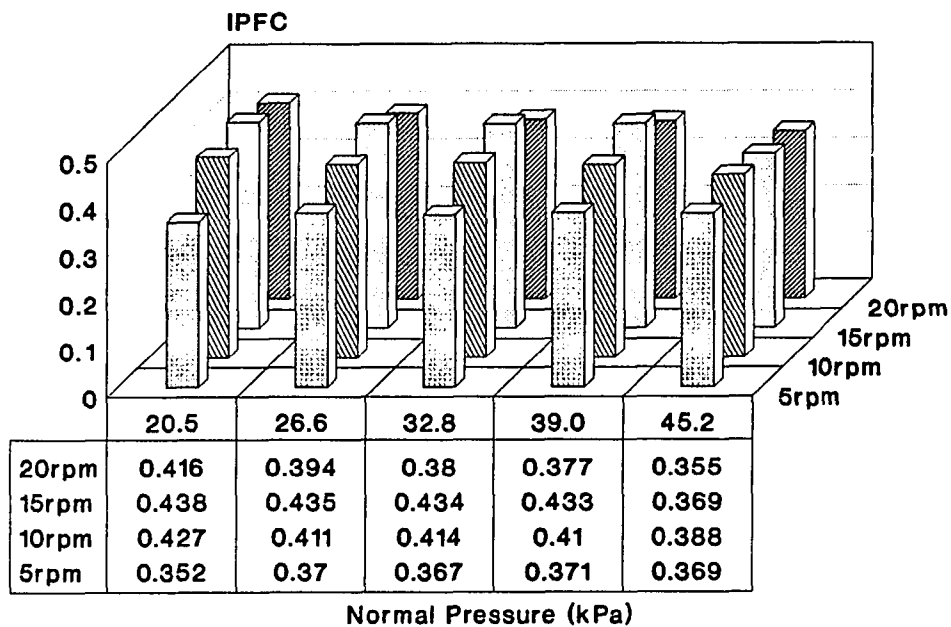


Figure 7.27 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM5.

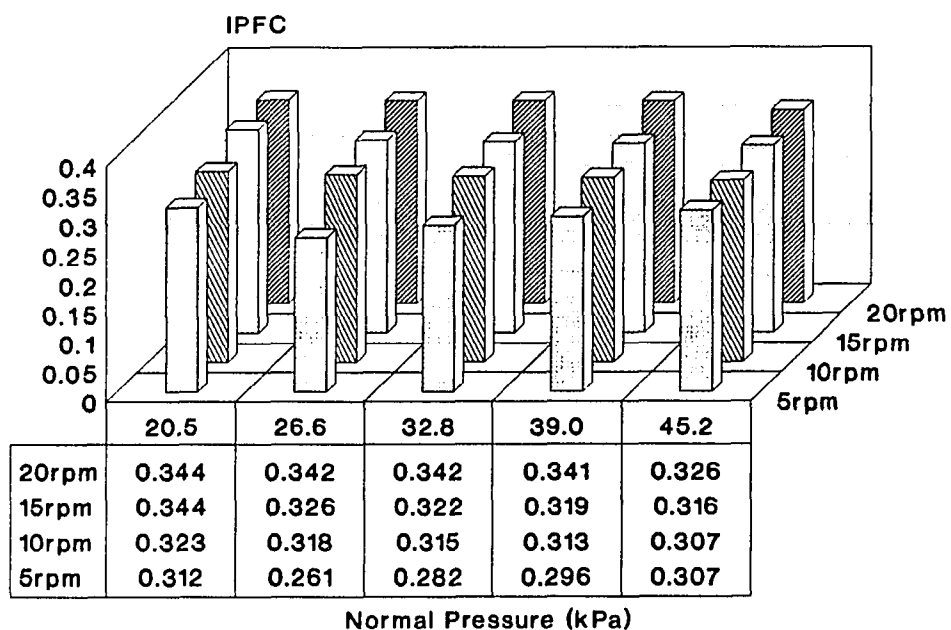


Figure 7.28 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PE.

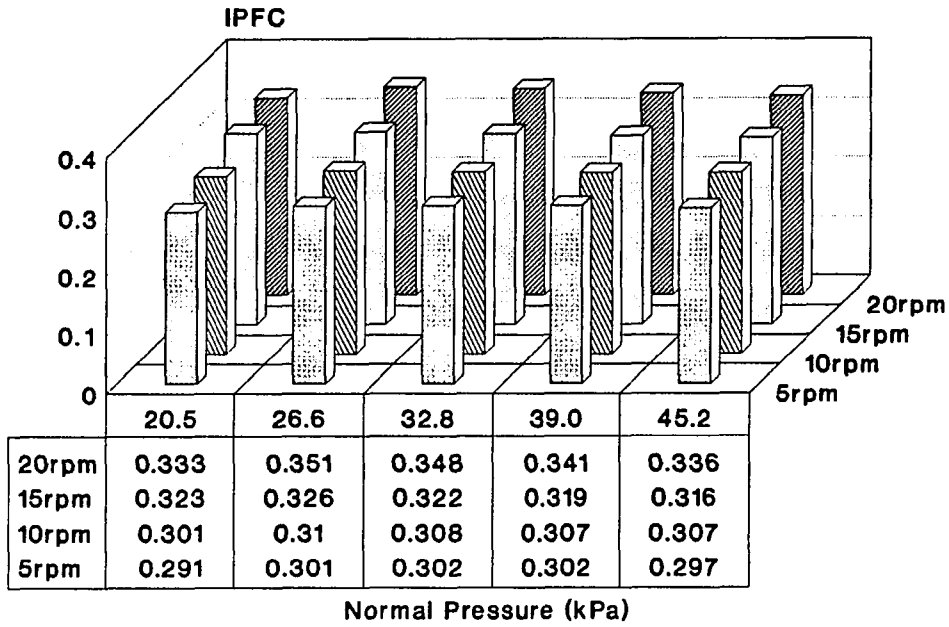


Figure 7.29 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PE.

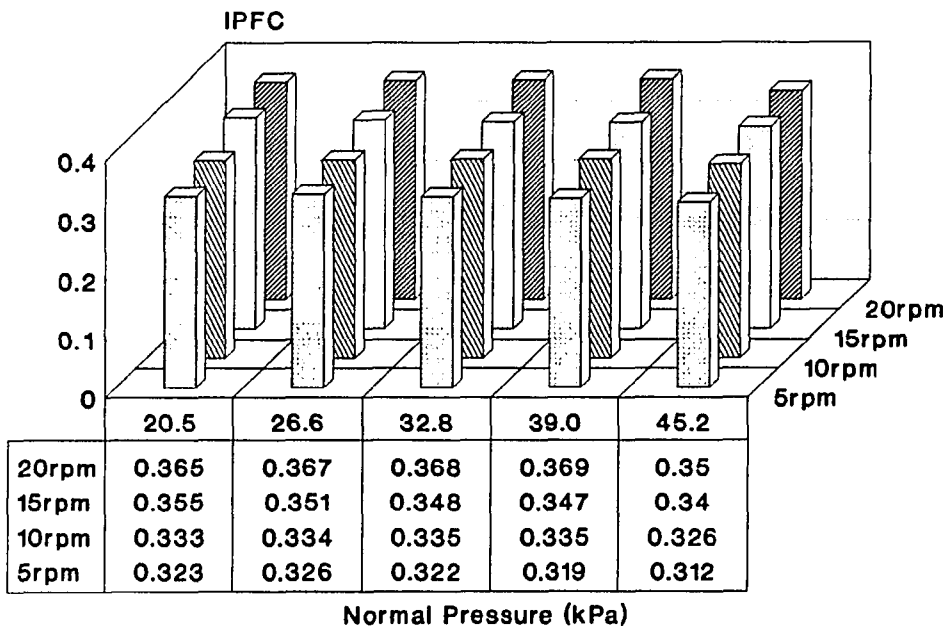


Figure 7.30 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PE.

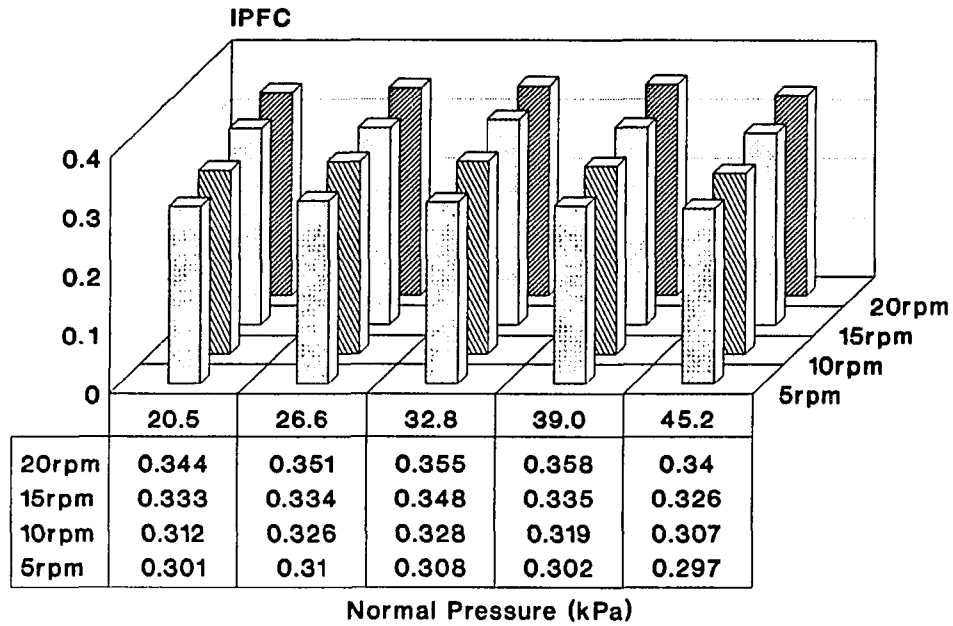


Figure 7.31 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PE.

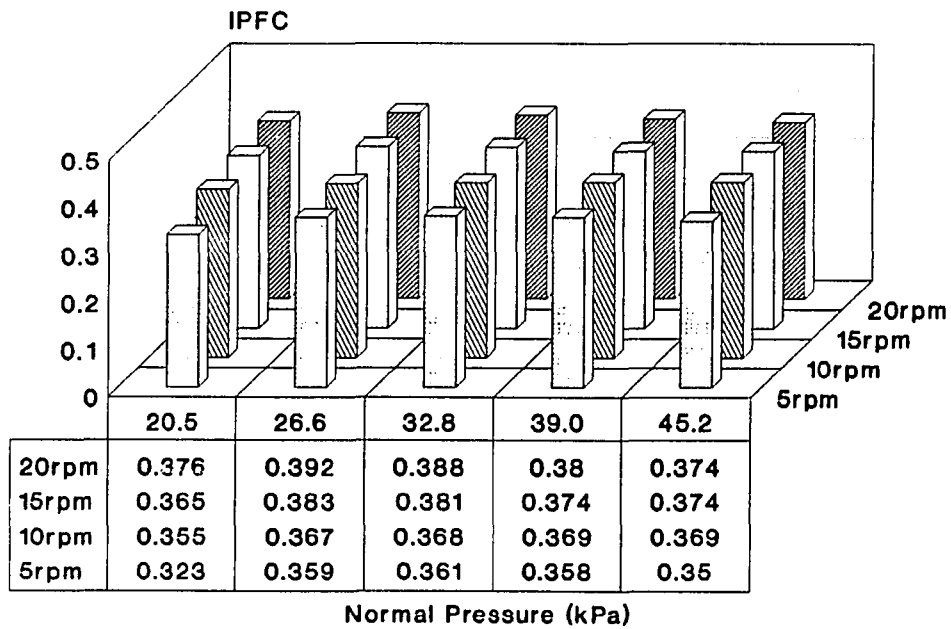


Figure 7.32 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PE.

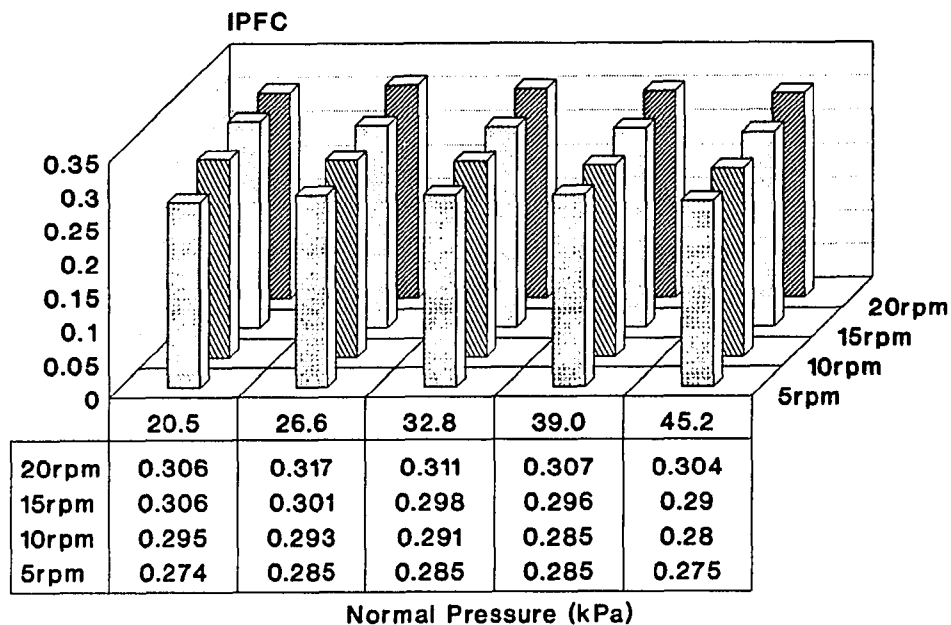


Figure 7.33 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PP.

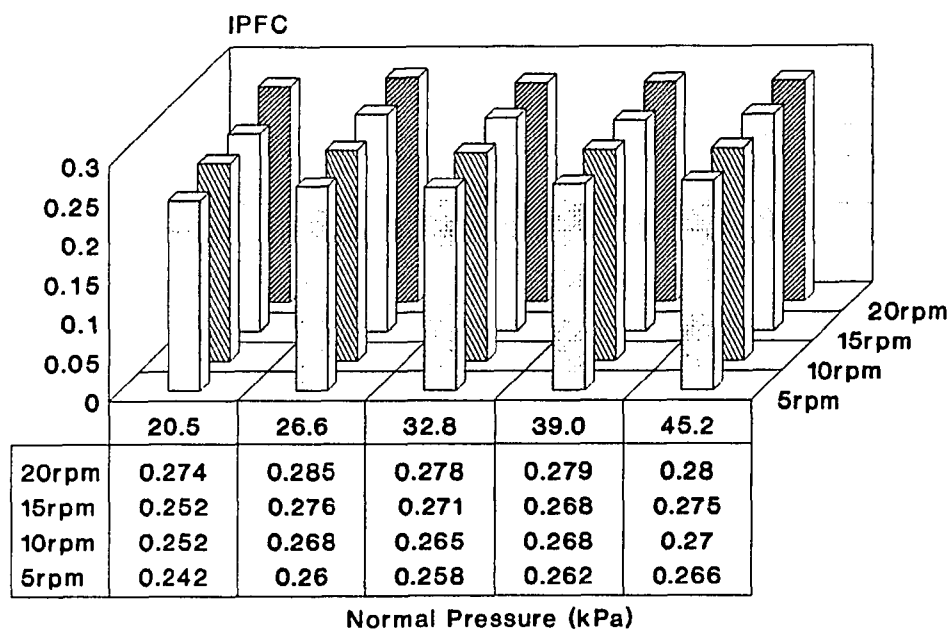


Figure 7.34 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PP.

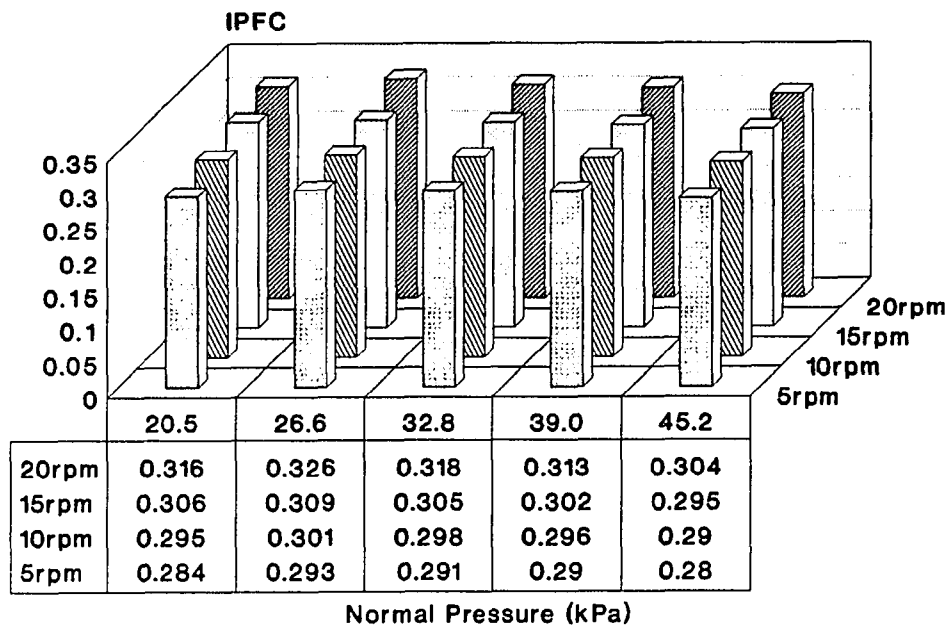


Figure 7.35 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PP.

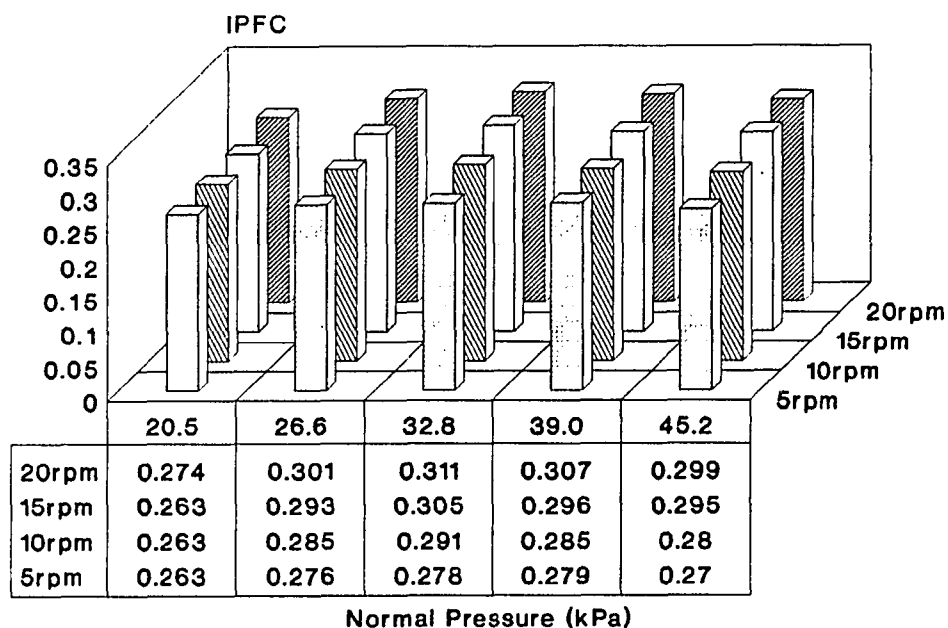


Figure 7.36 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PP.

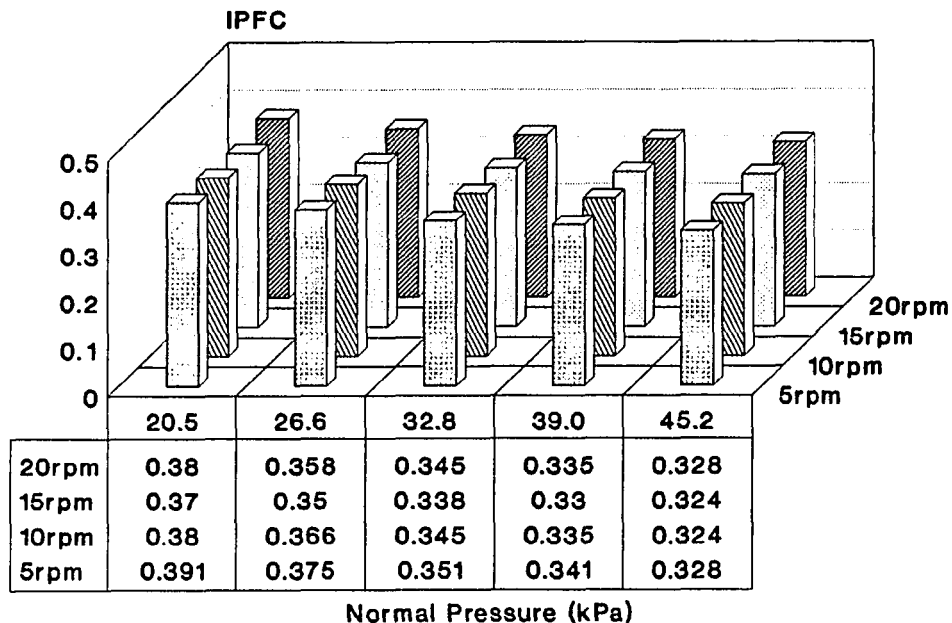


Figure 7.37 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PP.

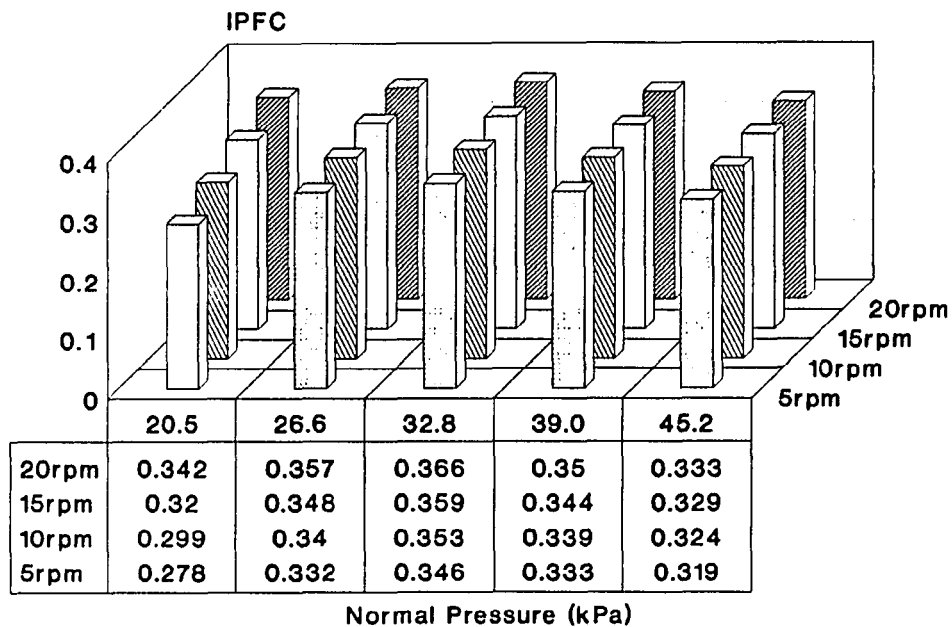


Figure 7.38 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PS.

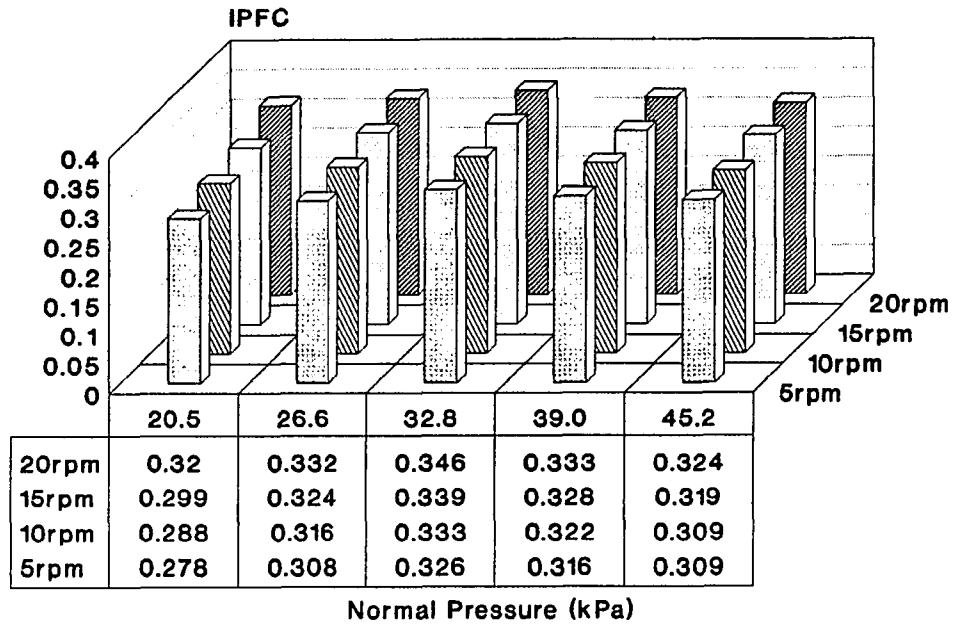


Figure 7.39 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PS.

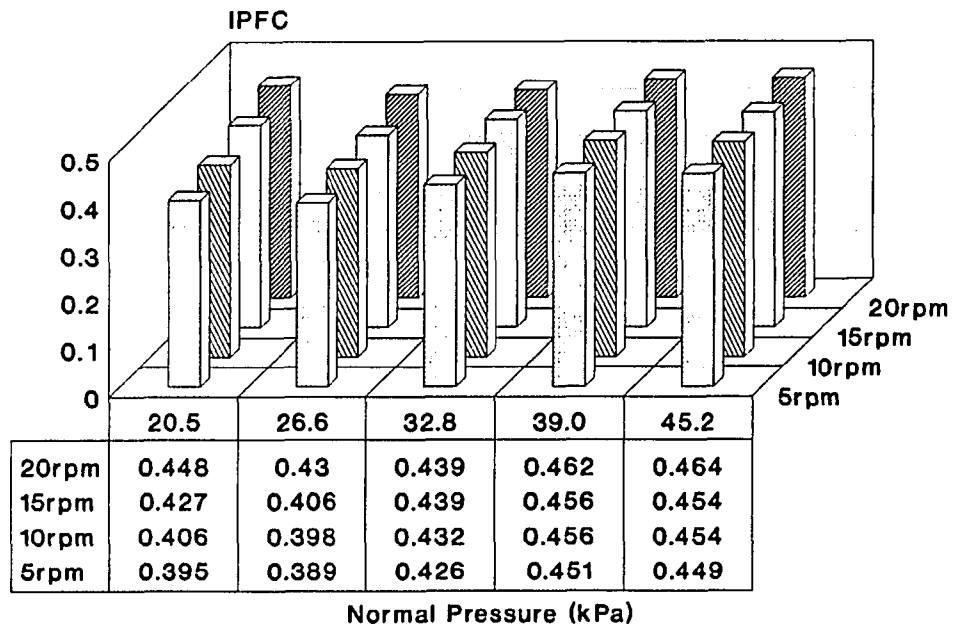


Figure 7.40 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PS.

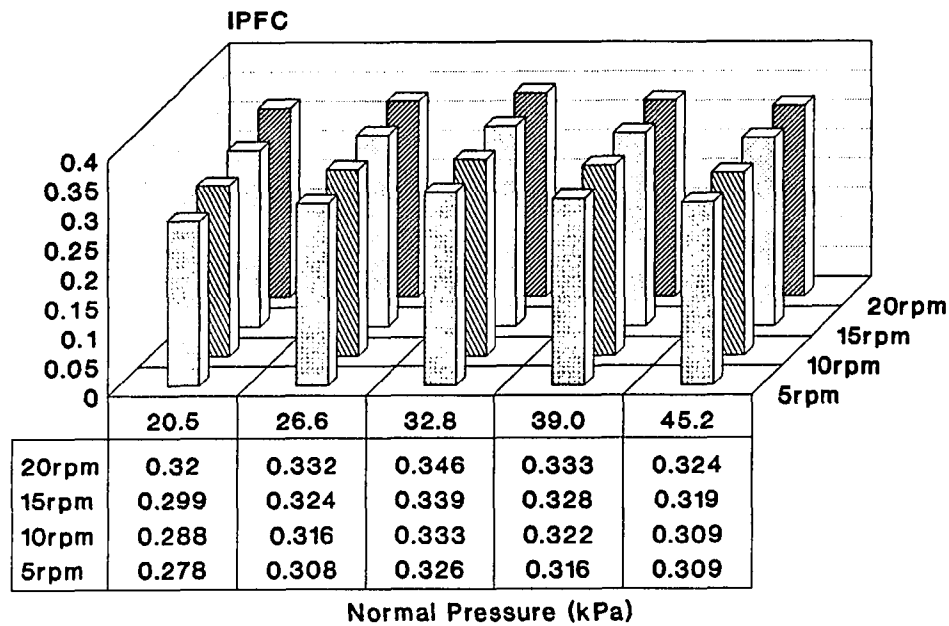


Figure 7.41 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PS.

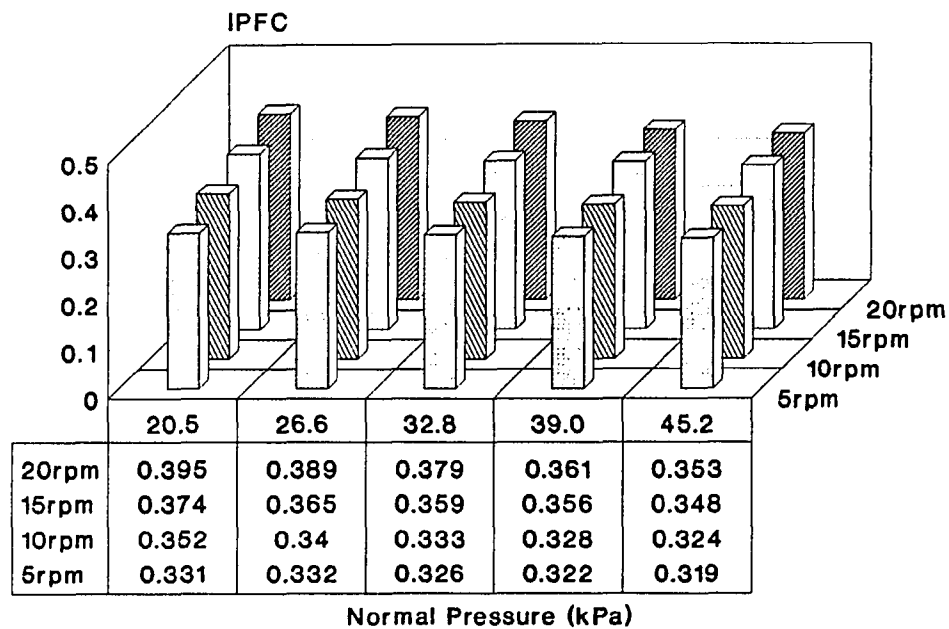


Figure 7.42 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PS.

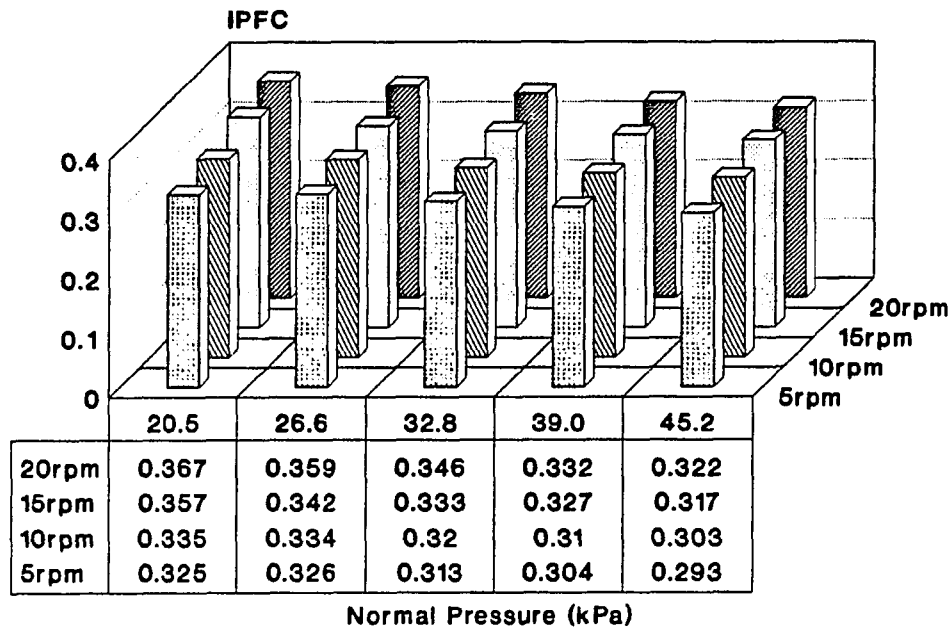


Figure 7.43 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PA 6.

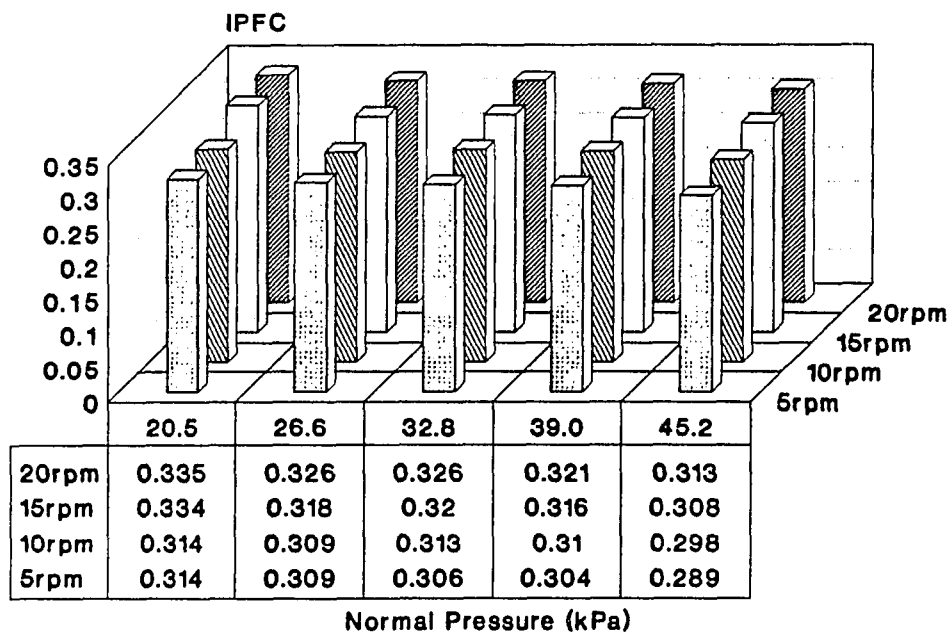


Figure 7.44 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PA 6.

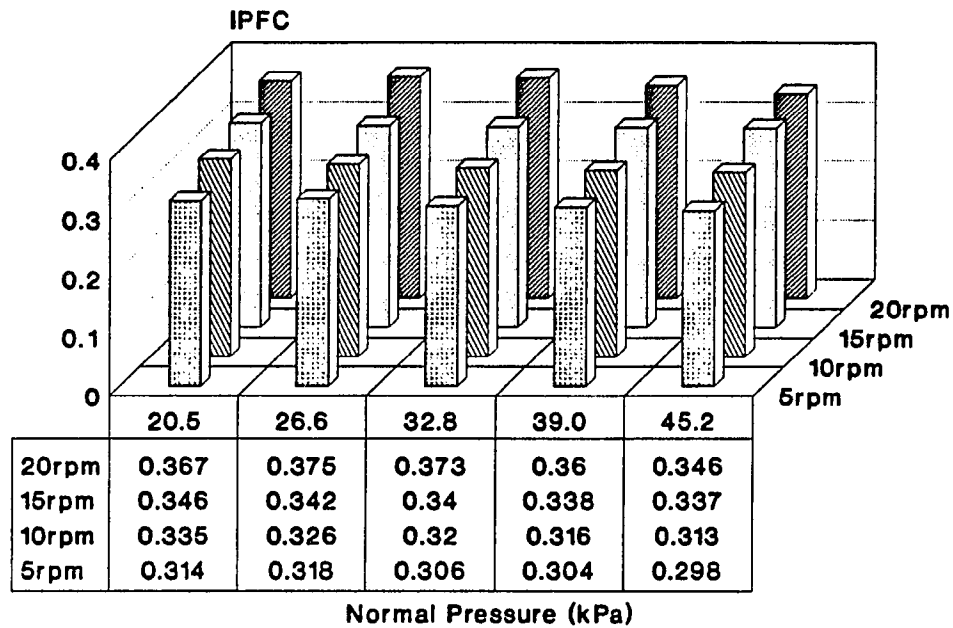


Figure 7.45 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PA 6.

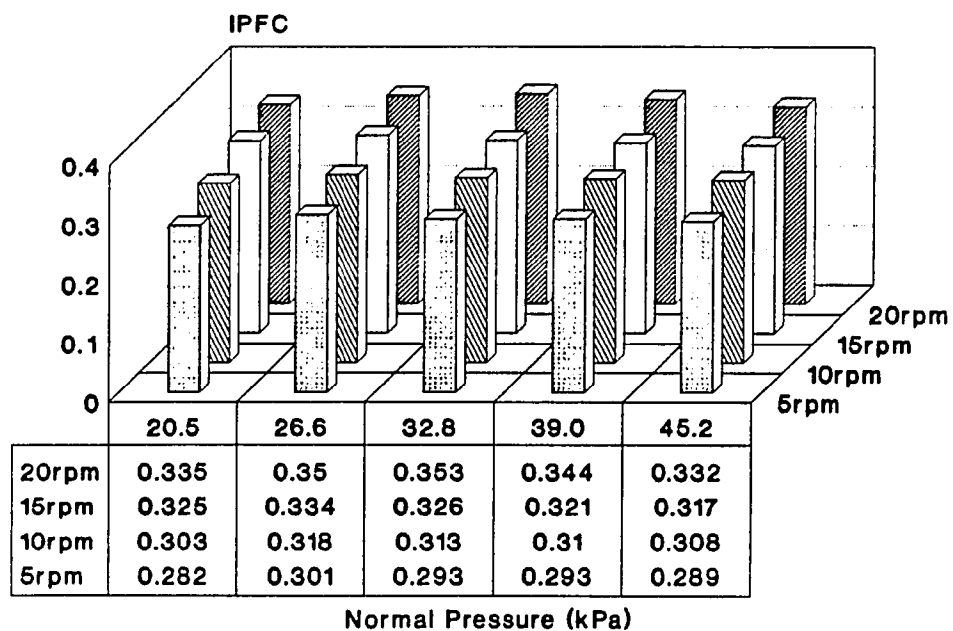


Figure 7.46 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PA 6.

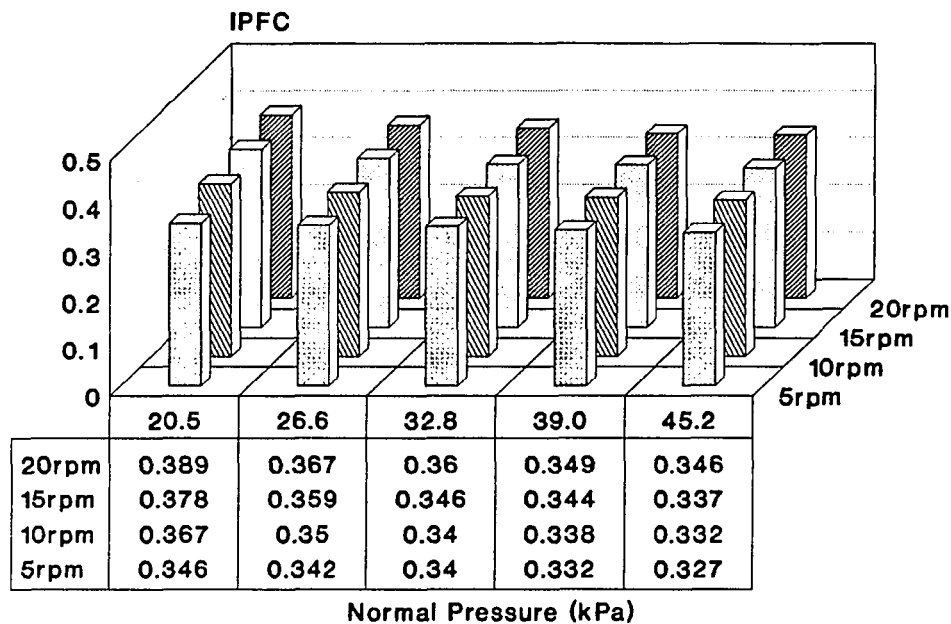


Figure 7.47 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PA 6.

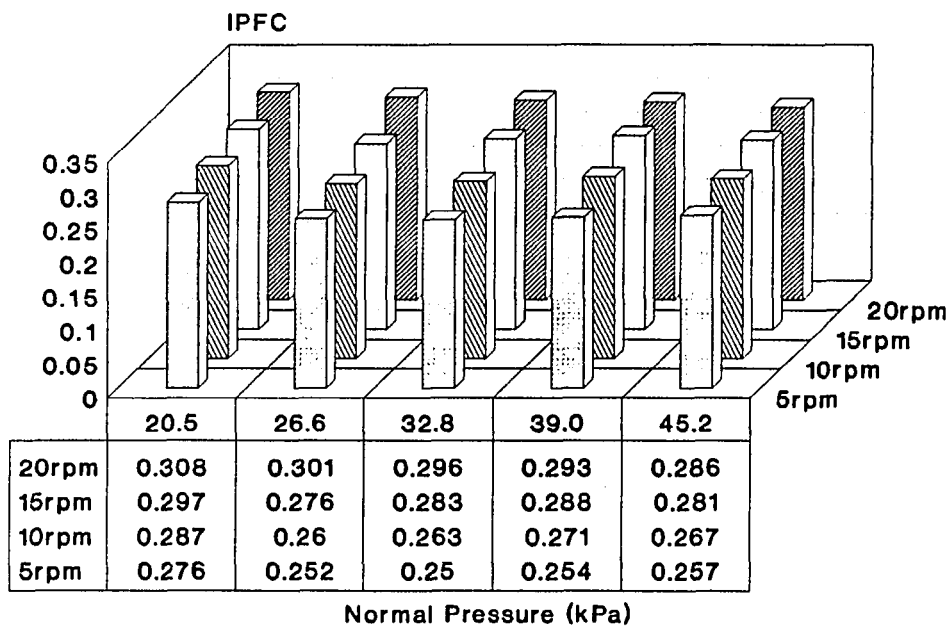


Figure 7.48 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for ABS.

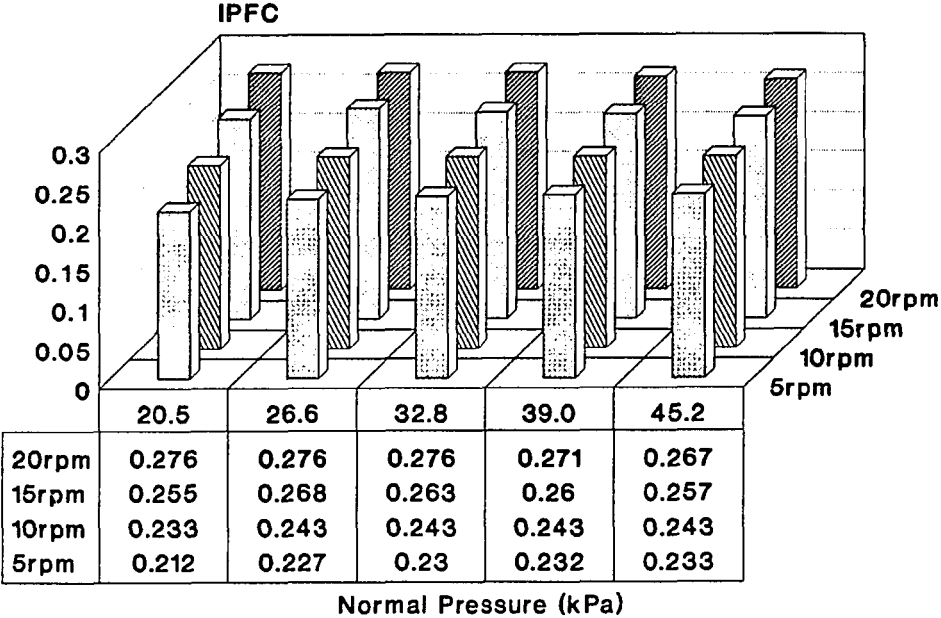


Figure 7.49 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for ABS.

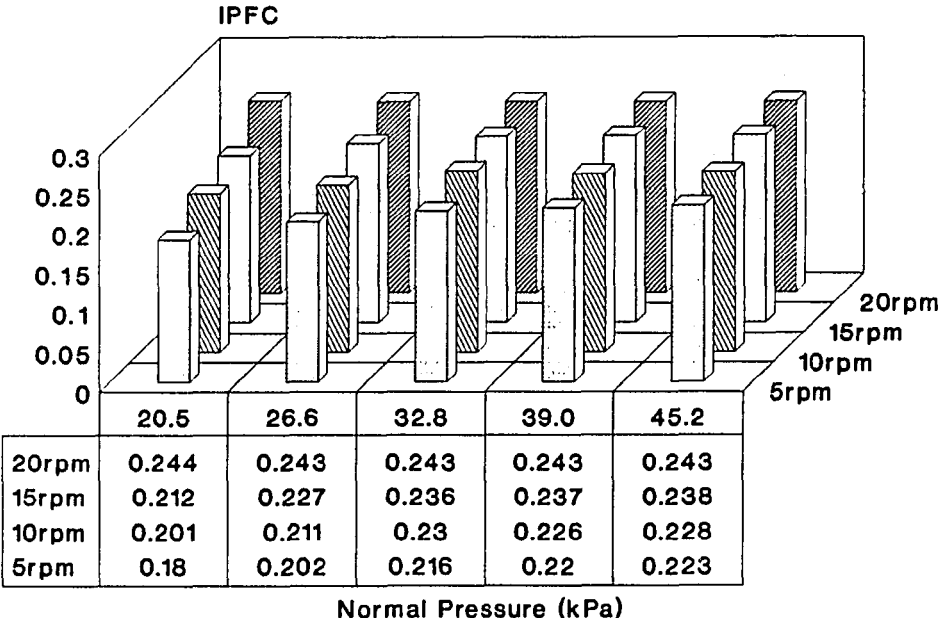


Figure 7.50 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for ABS.

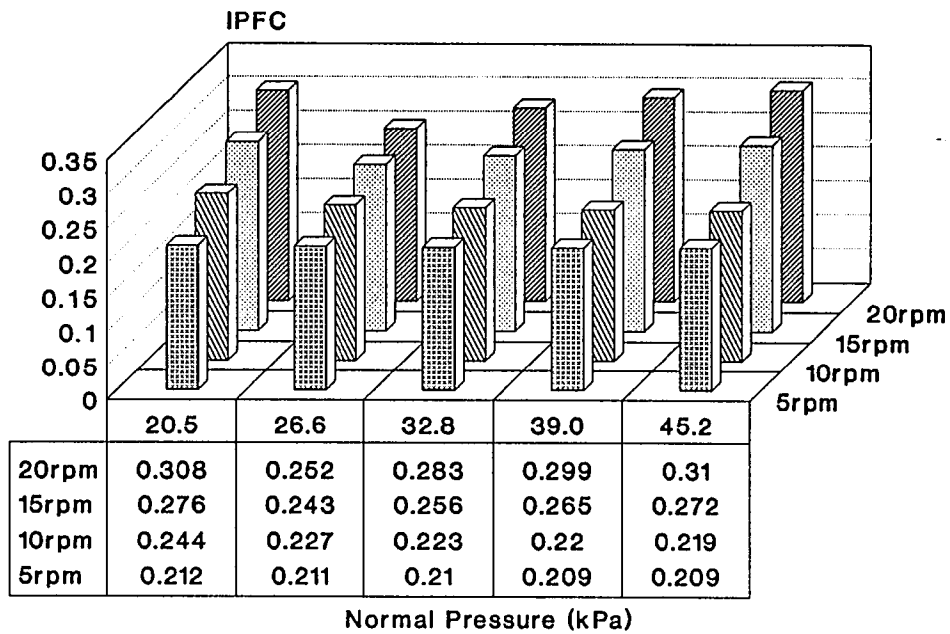


Figure 7.51 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for ABS.

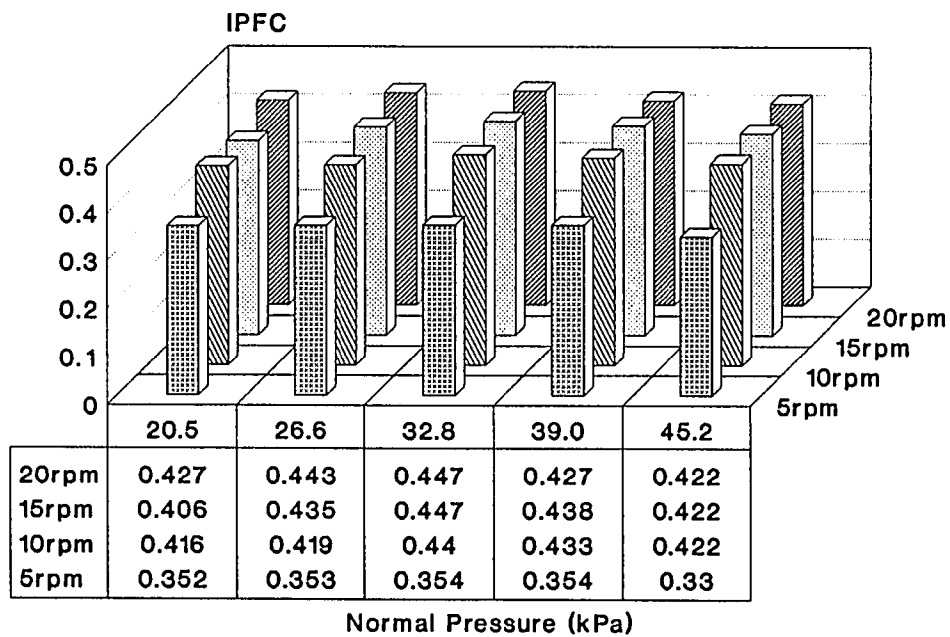


Figure 7.52 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM1.

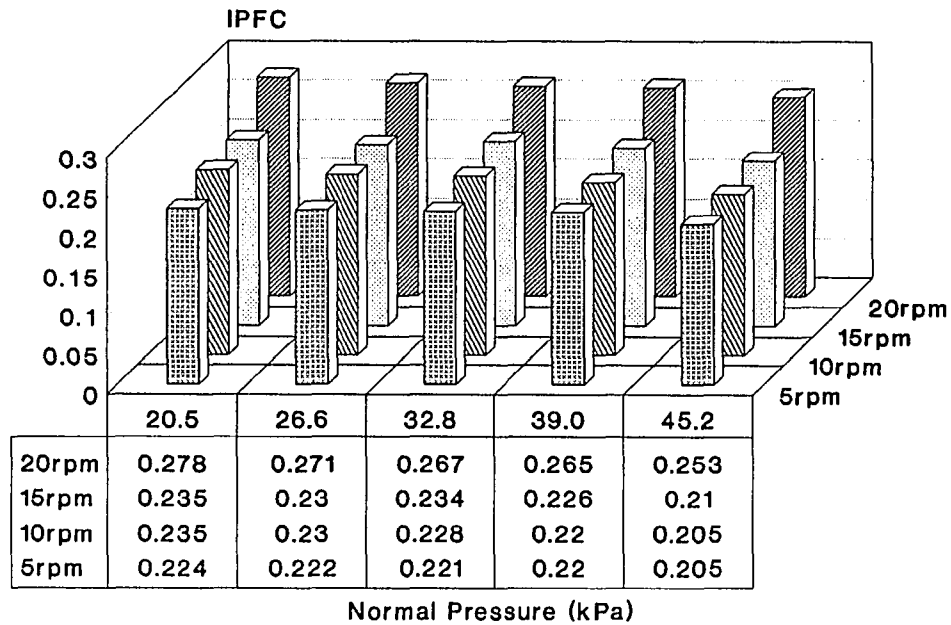


Figure 7.53 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM2.

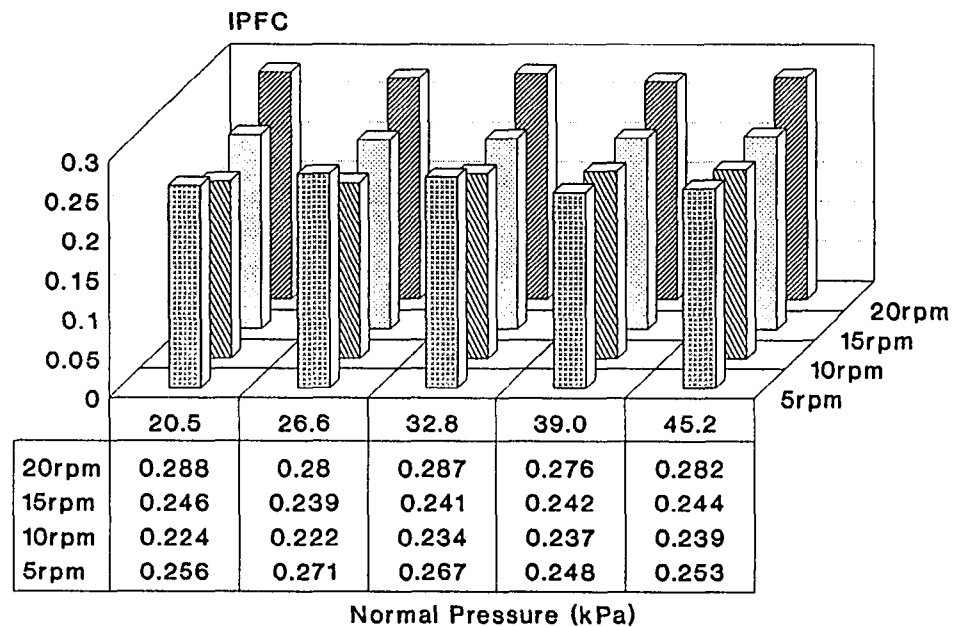


Figure 7.54 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM3.

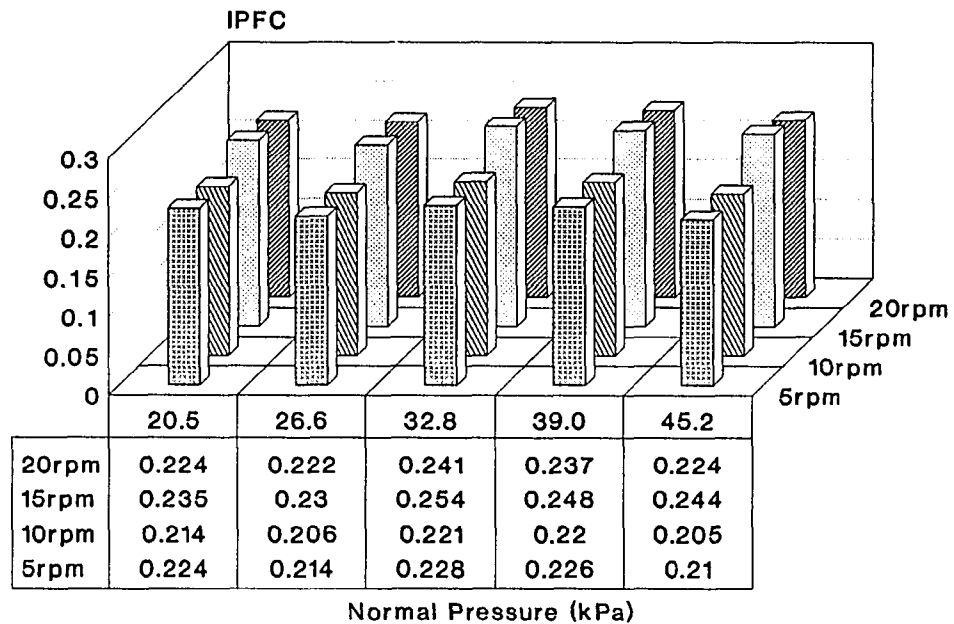


Figure 7.55 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM4.

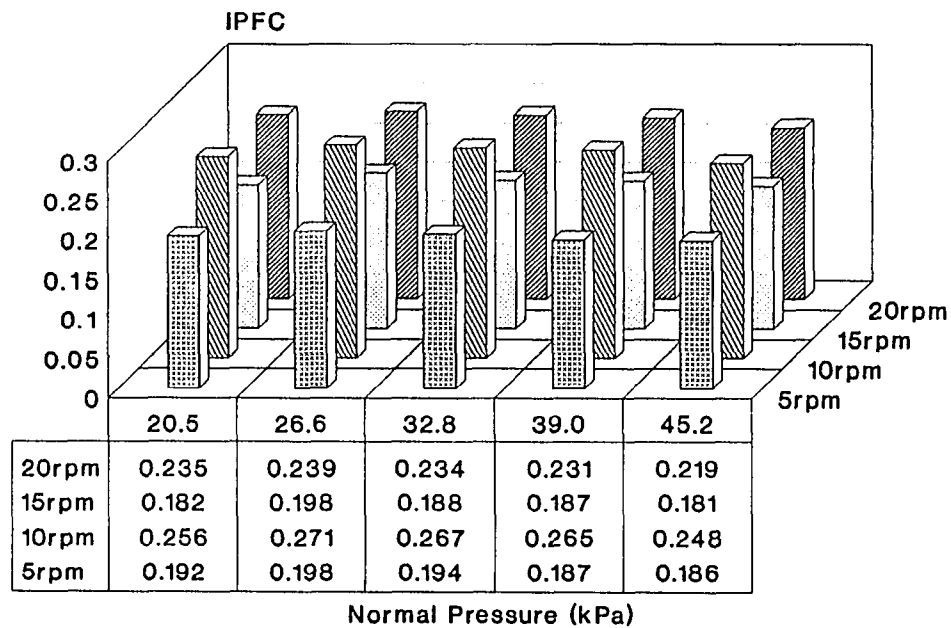


Figure 7.56 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM5.

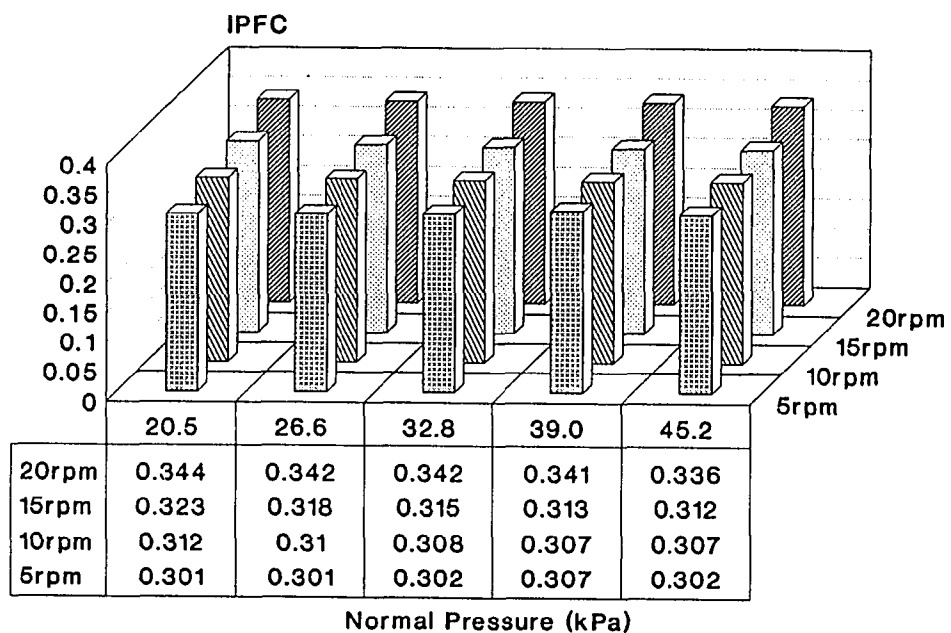


Figure 7.57 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PE.

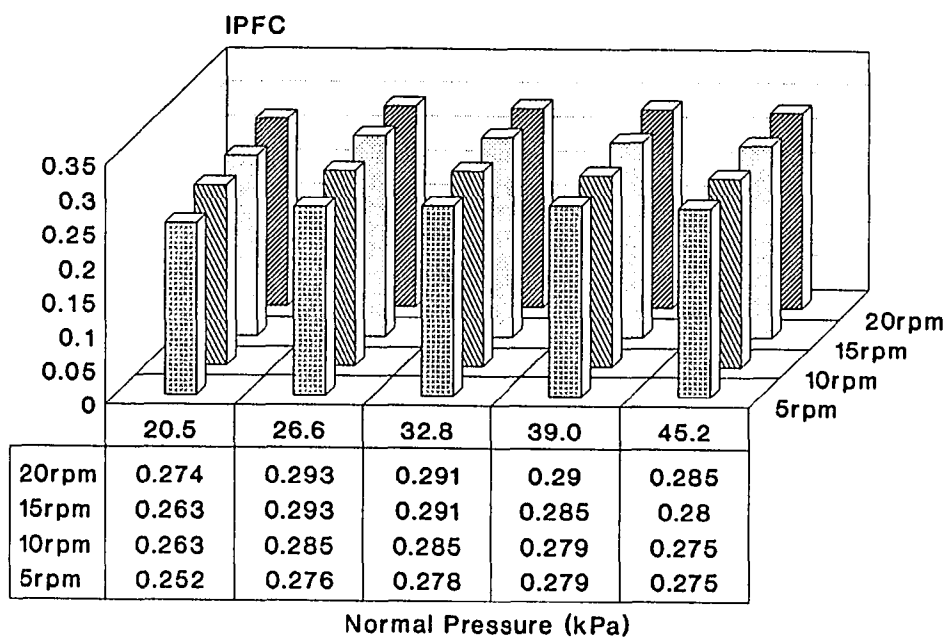


Figure 7.58 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PP.

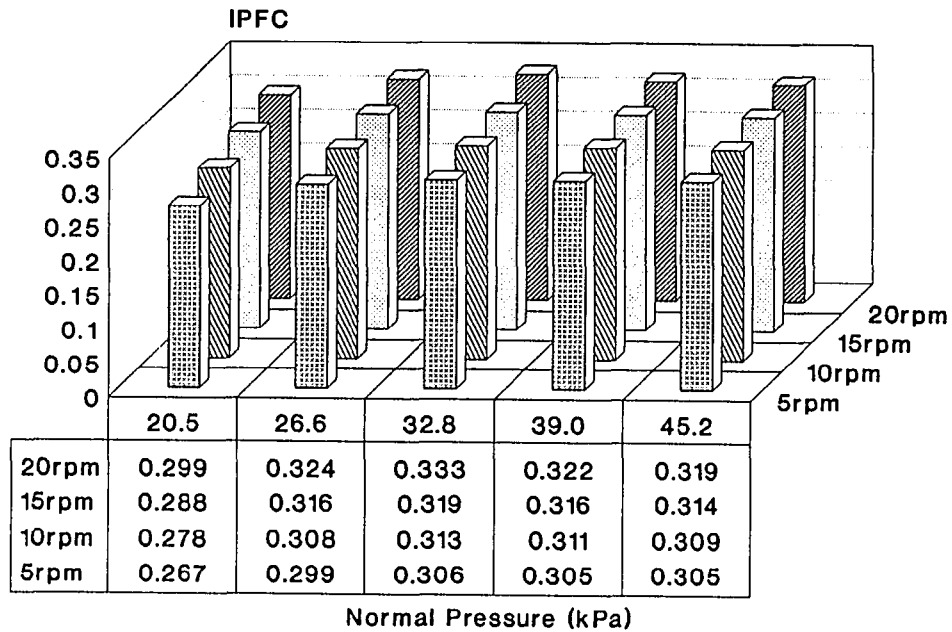


Figure 7.59 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PS.

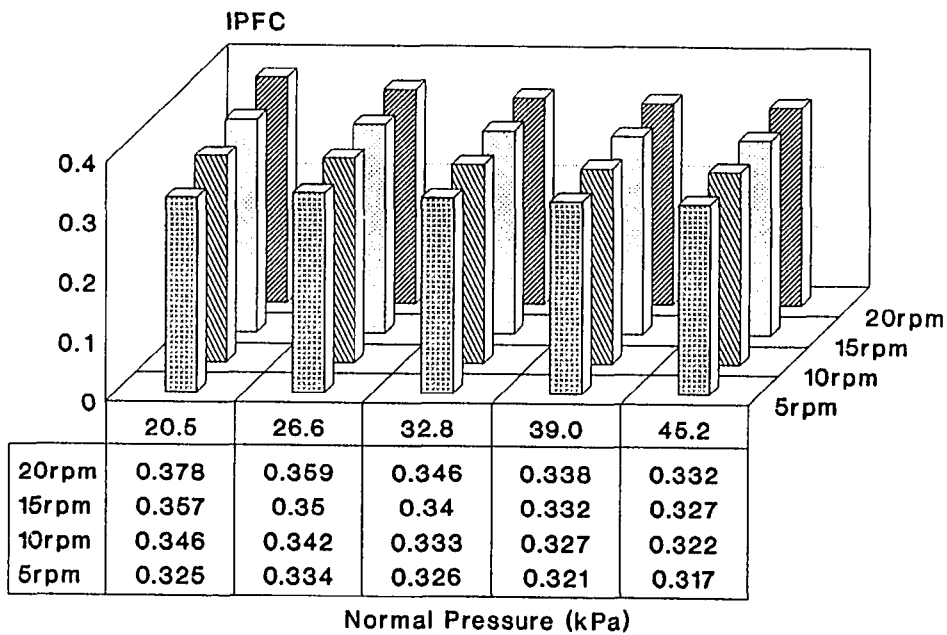


Figure 7.60 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PA 6.

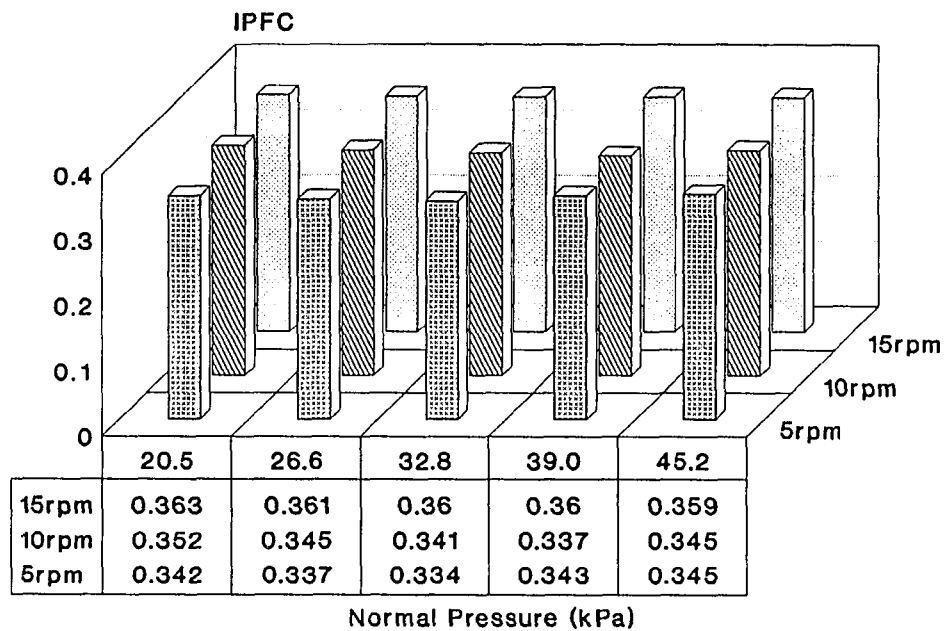


Figure 7.61 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM1.

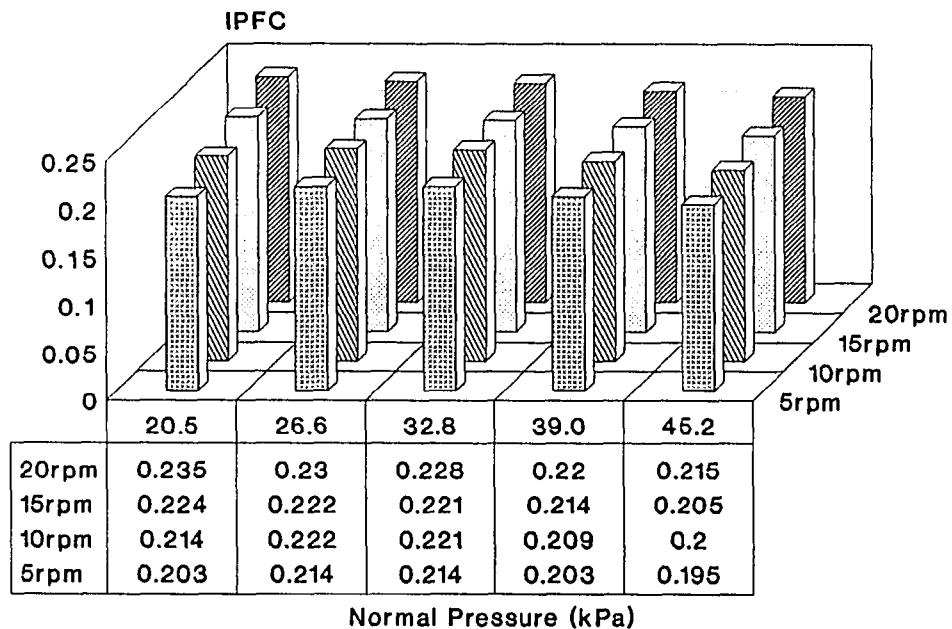


Figure 7.62 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM2.

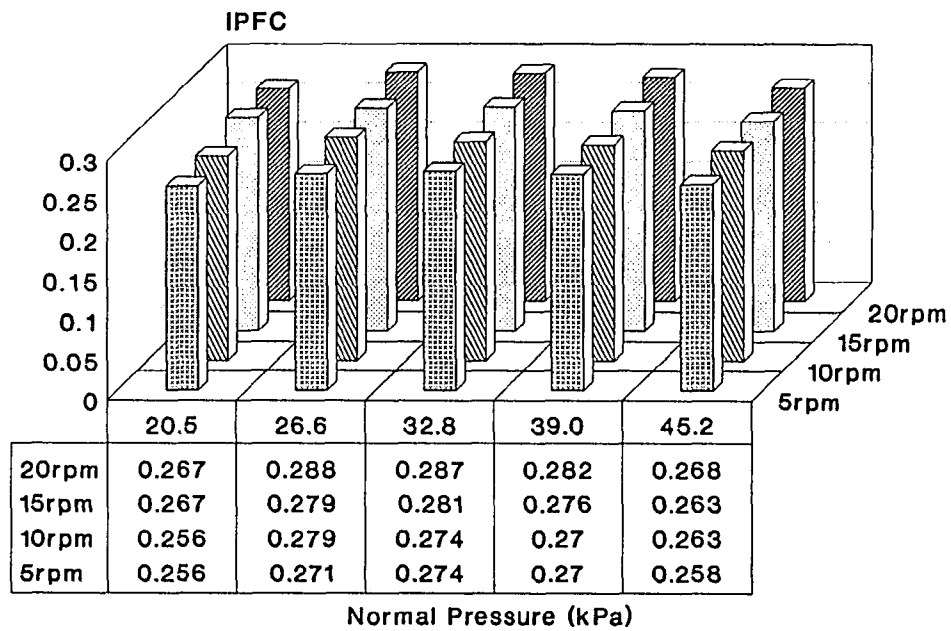


Figure 7.63 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM3.

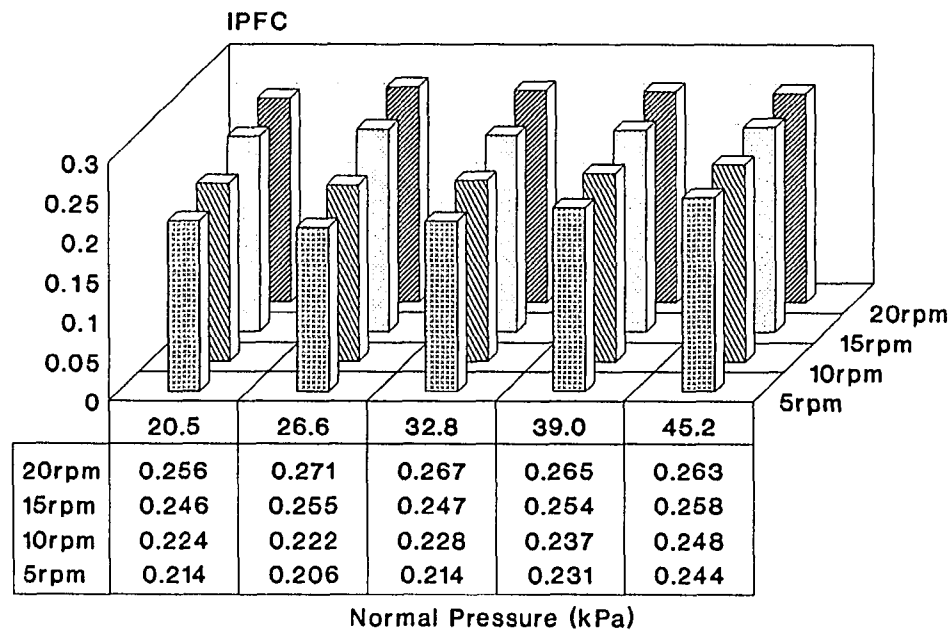


Figure 7.64 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM4.

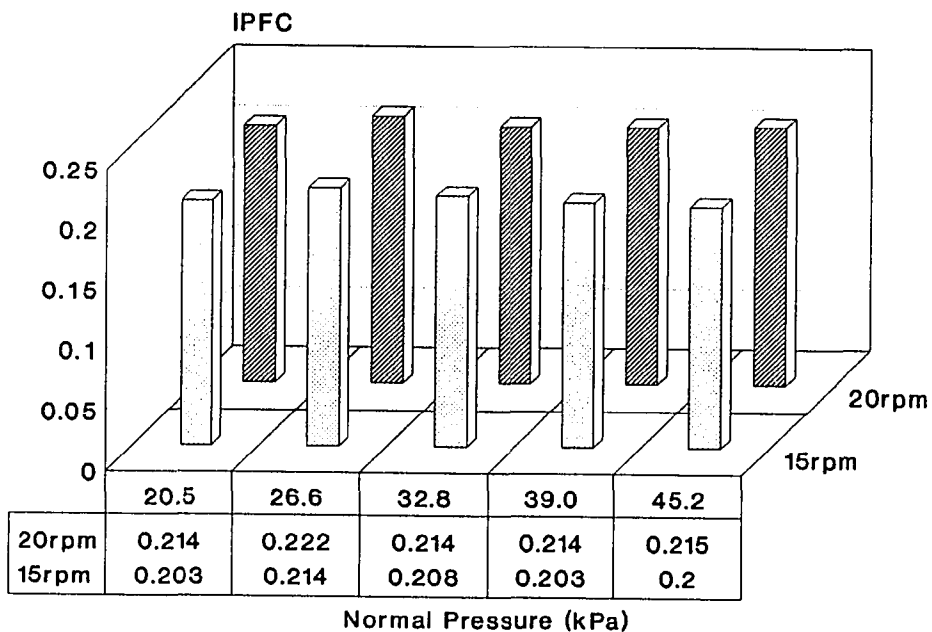


Figure 7.65 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM5.

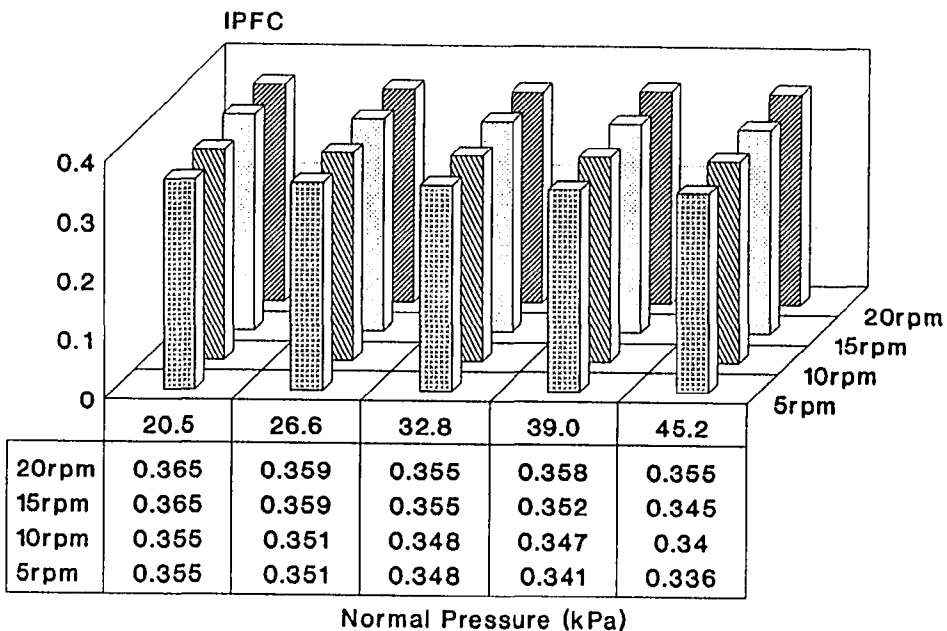


Figure 7.66 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for PE.

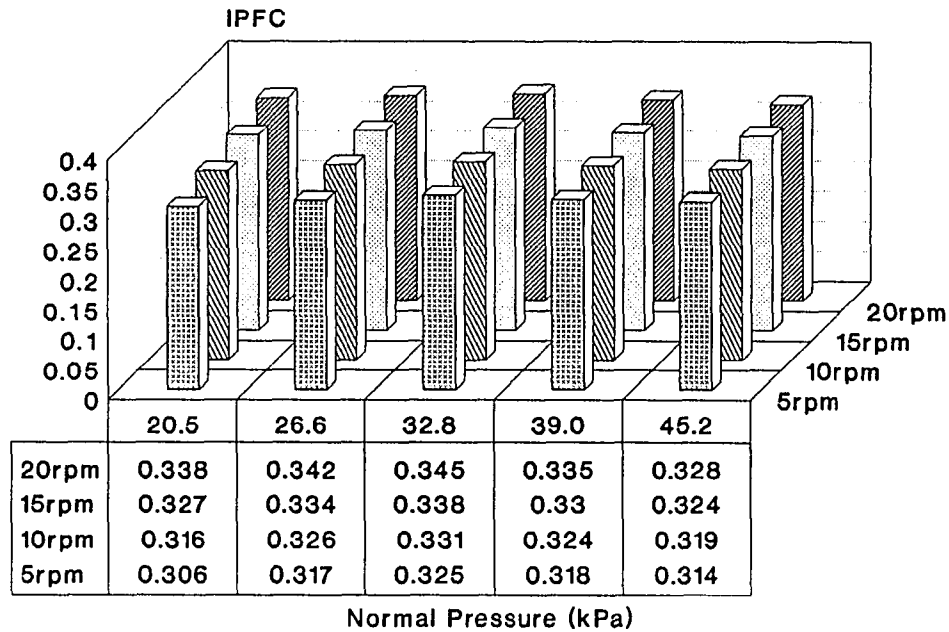


Figure 7.67 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for PP.

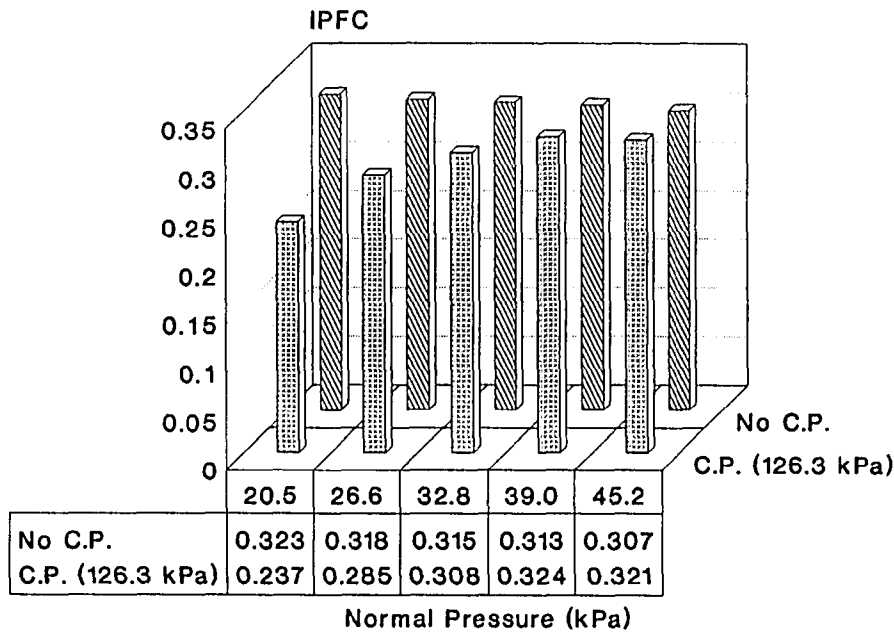


Figure 7.68 IPFC for the Pellets Manufactured Using Die A211 with Consolidation Pressure as a Function of Normal Pressure for PE.

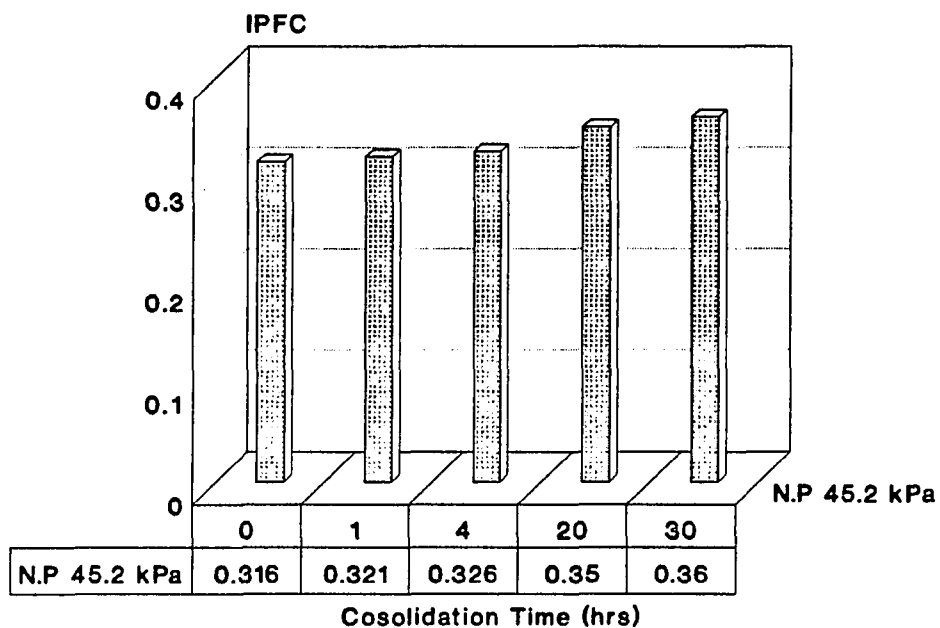


Figure 7.69 IPFC for the Pellets Manufactured Using Die A211 with Consolidation Time as a Function of Normal Pressure for PE.

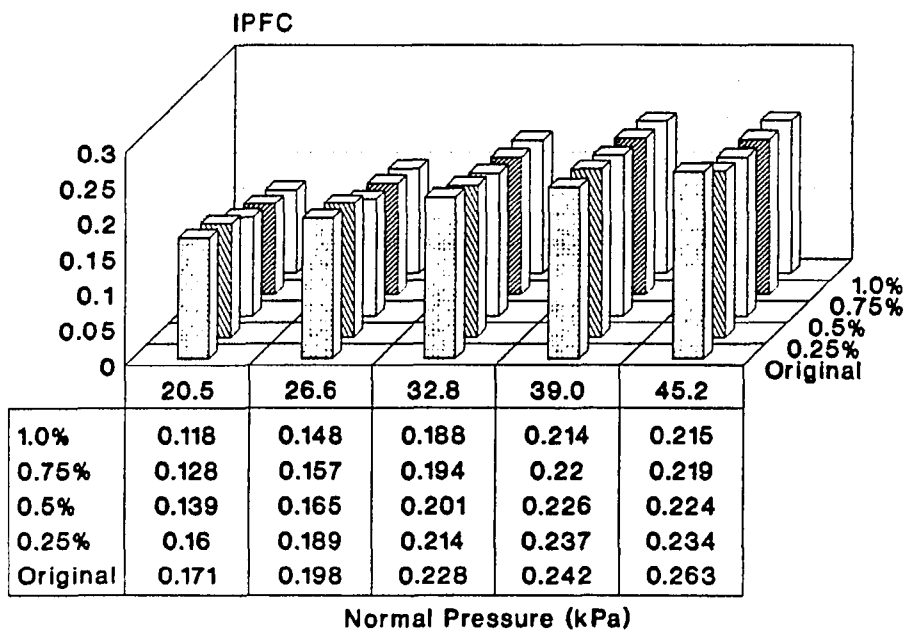


Figure 7.70 IPFC for Pellets with Circular Cross-Sections with Zinc Stearate as a Function of Normal Pressure for POM3.

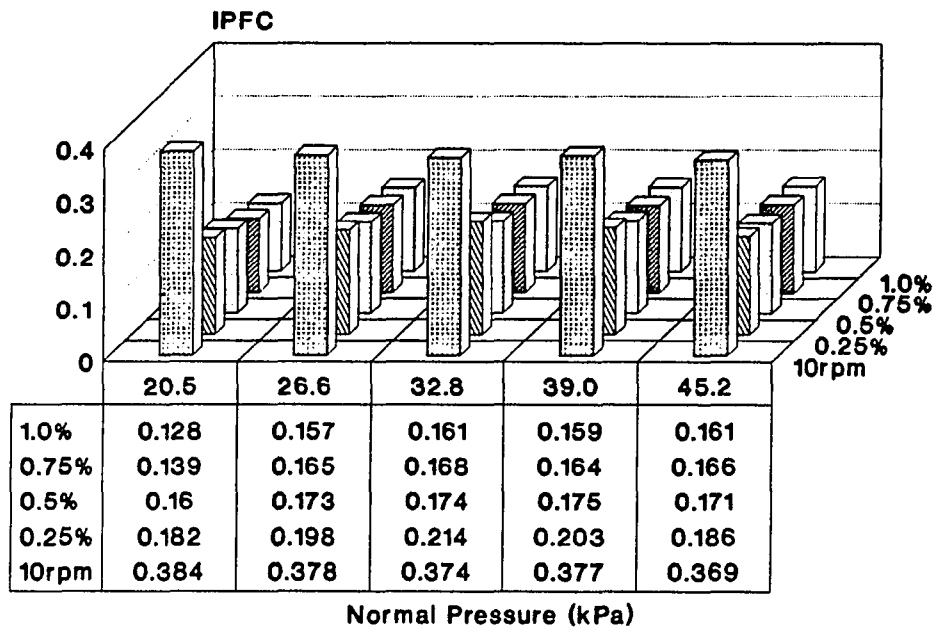


Figure 7.71 IPFC for Pellets Manufactured Using Die A211 with Zinc Stearate as a Function of Normal Pressure for POM3.

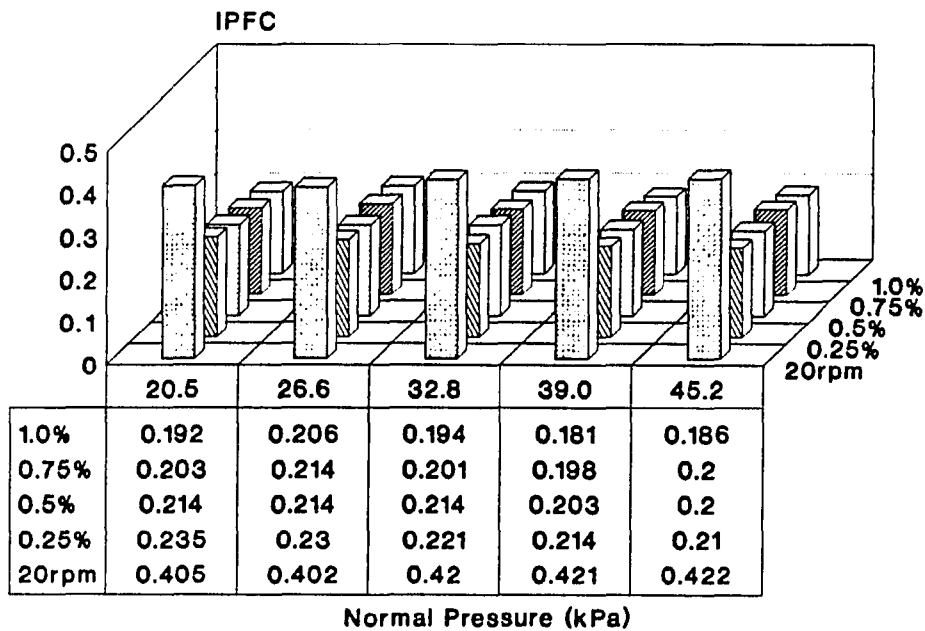


Figure 7.72 IPFC for Pellets Manufactured Using Die A212 with Zinc Stearate as a Function of Normal Pressure for POM3.

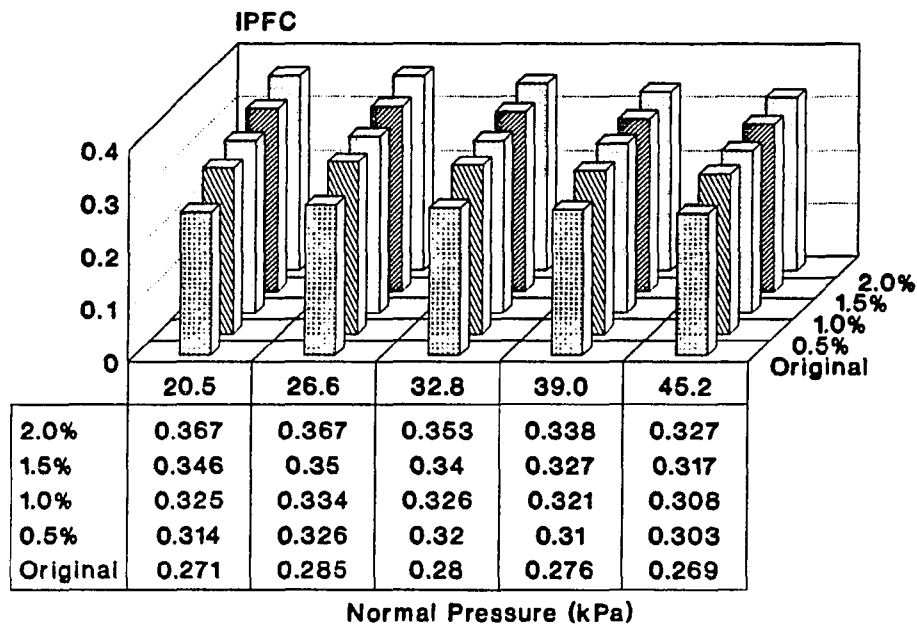


Figure 7.73 IPFC for Pellets with Circular Cross-Section with Mica Clay as a Function of Normal Pressure for PA 6.

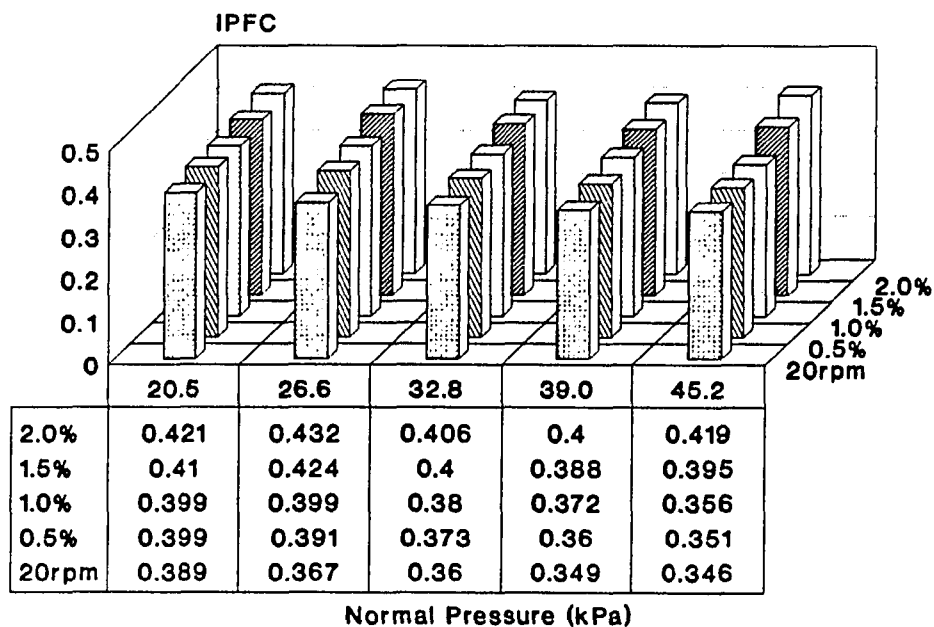


Figure 7.74 IPFC for Pellets Manufactured Using Die A241 with Mica Clay at Extruder Screw Speed 20rpm as a Function of Normal Pressure for PA 6.

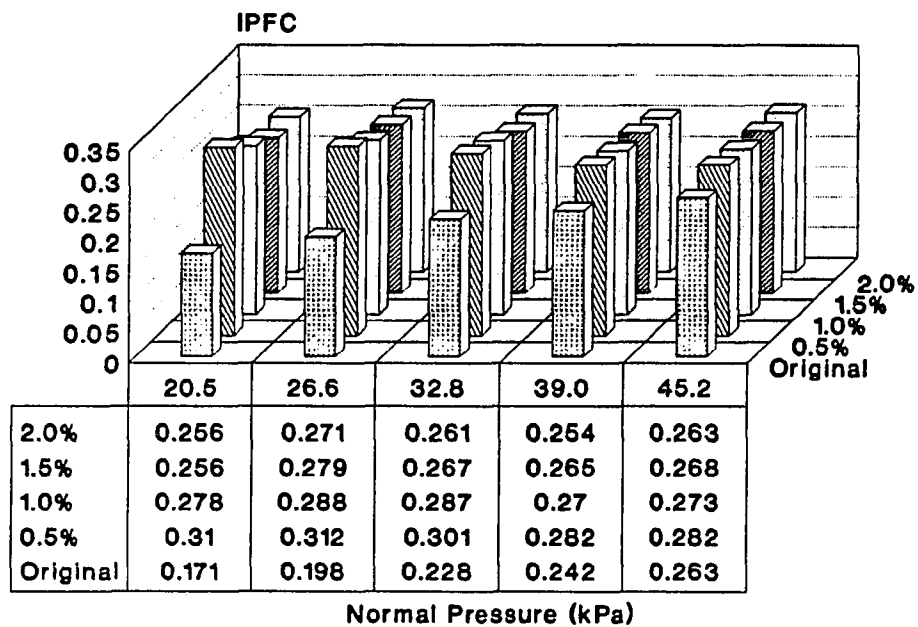


Figure 7.75 IPFC for Pellets with Circular Cross-Section with PBT Powder as a Function of Normal Pressure for POM3.

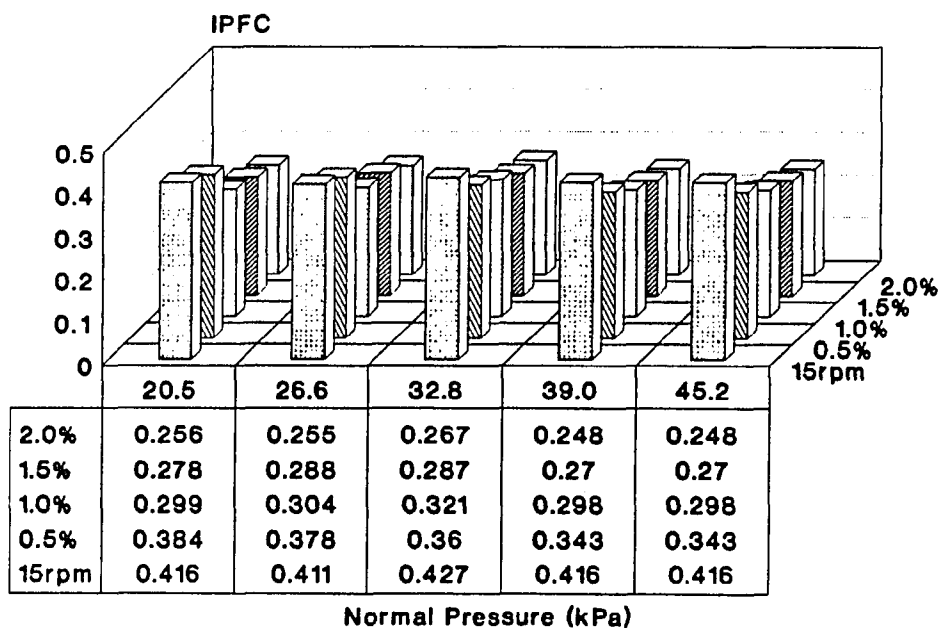


Figure 7.76 IPFC for Pellets Manufactured Using Die A212 with PBT Powder at Extruder Screw Speed 15rpm as a Function of Normal Pressure for POM3.

CHAPTER 8

DISCUSSION - THE INTERPARTICULATE FRICTION COEFFICIENT

8.1 Comparison of the IFPC for Pellets with Circular and Bilobal Cross-Sections

The results presented in Figure 7.1 indicate that the high molecular weight material, U10-01 (POM1), has a markedly greater interparticulate friction coefficient compared to the remaining materials. The medium molecular weight material, M90 (POM3), exhibits a somewhat greater coefficient than the remaining three materials. Thus, there is no real trend which can be isolated with regard to molecular weight. In addition, although the coefficient varies as a function of normal load, there is no single, discernible trend.

The results presented in Figure 7.2 indicate that the material, PE, has a markedly greater interparticulate friction coefficient compared to the remaining materials. The material, PS exhibits a somewhat greater coefficient than the remaining three materials. In addition, although the coefficient varies as a function of normal load, there is no single, discernible trend.

The results presented in Figure 7.3 to Figure 7.51 present the IPFC for the pellets with bilobal cross-section for all test materials for all different dies. The comparison of IPFC between the circular cross-section pellet and bilobal cross-section pellet for all test material with different dies are plotted in Figures 8.1 to 8.40.

In addition to the variation of the normal force and the molecular weight that was measured with the pellets of circular cross-section for acetal copolymer, the multi-lobal pellets also exhibit a variation with extruder screw speed and the die

used. These two variables combine to create variations in the size and shape of the pellets.

In Figure 8.1 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for acetal copolymer grade U10-01. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 52%-75% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 8%-41% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.2 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for acetal copolymer grade U10-01. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 32%-87% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 18%-62% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.3 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for acetal copolymer grade U10-01. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 45%-75% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A212 is 20%-55% compared to

cylindrical pellets. The pellets manufactured with die A212 have the lowest % increase among the bilobal pellets.

In Figure 8.4 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for acetal copolymer grade U10-01. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 35%-87% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 22%-62% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.5 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for acetal copolymer grade M25. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 88%-167% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 70%-111% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.6 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for acetal copolymer grade M25. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 165%-185% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 35%-65% compared to

cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.7 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for acetal copolymer grade M25. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 165%-186% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 23%-46% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.8 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for acetal copolymer grade M25. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 142%-176% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 41%-71% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.9 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for acetal copolymer grade M90. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 48%-106% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 10%-44% compared to

cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.10 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for acetal copolymer grade M90. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 66%-150% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 17%-62% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.11 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for acetal copolymer grade M90. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 85%-144% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 17%-62% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.12 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for acetal copolymer grade M90. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 77%-144% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 25%-87% compared to

cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.13 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for acetal copolymer grade M270. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 99%-141% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 4%-10% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.14 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for acetal copolymer grade M270. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 146%-158% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 11%-51% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.15 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for acetal copolymer grade M270. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 135%-173% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 24%-51% compared

to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.16 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for acetal copolymer grade M270. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 135%-152% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 29%-51% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.17 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for acetal copolymer grade M450. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 106%-143% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 6%-32% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.18 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for acetal copolymer grade M450. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 147%-159% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 5%-16% compared

to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.19 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for acetal copolymer grade M450. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 143%-173% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 19%-48% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.20 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for acetal copolymer grade M450. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A211 is 137%-166% compared to cylindrical pellets. The pellets manufactured with die A211 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 25%-54% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.21 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for PE. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 20%-42% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A211 is 3%-16% compared to cylindrical pellets. The

pellets manufactured with die A211 have the lowest % increase among the bilobal pellets.

In Figure 8.22 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for PE. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 32%-45% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A212 is 12%-23% compared to cylindrical pellets. The pellets manufactured with die A212 have the lowest % increase among the bilobal pellets.

In Figure 8.23 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for PE. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 36%-52% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A211 is 16%-29% compared to cylindrical pellets. The pellets manufactured with die A211 have the lowest % increase among the bilobal pellets.

In Figure 8.24 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for PE. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 40%-55% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A211 is 19%-36% compared to cylindrical pellets. The

pellets manufactured with die A211 have the lowest % increase among the bilobal pellets.

In Figure 8.25 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for PP. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 22%-30% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A212 is 8%-20% compared to cylindrical pellets. The pellets manufactured with die A212 have the lowest % increase among the bilobal pellets.

In Figure 8.26 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for PP. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 25%-34% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A212 is 11%-22% compared to cylindrical pellets. The pellets manufactured with die A212 have the lowest % increase among the bilobal pellets.

In Figure 8.27 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for PP. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 32%-44% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A212 is 14%-24% compared to cylindrical pellets. The

pellets manufactured with die A212 have the lowest % increase among the bilobal pellets.

In Figure 8.28 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for PP. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 34%-49% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A212 is 17%-26% compared to cylindrical pellets. The pellets manufactured with die A212 have the lowest % increase among the bilobal pellets.

In Figure 8.29 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for PS. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 52%-68% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 4%-23% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.30 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for PS. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 49%-73% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 8%-32% compared to cylindrical pellets. The

pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.31 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for PS. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 52%-81% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 12%-46% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.32 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for PS. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A221 is 52%-82% compared to cylindrical pellets. The pellets manufactured with die A221 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 14%-50% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.33 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for Nylon 6. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 20%-27% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 5%-7% compared to cylindrical pellets. The

pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.34 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for Nylon 6. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 21%-35% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 11%-15% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.35 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for Nylon 6. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 25%-39% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A212 is 12%-23% compared to cylindrical pellets. The pellets manufactured with die A212 have the lowest % increase among the bilobal pellets.

In Figure 8.36 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for Nylon 6. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A241 is 26%-44% compared to cylindrical pellets. The pellets manufactured with die A241 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A212 is 14%-24% compared to cylindrical pellets. The

pellets manufactured with die A212 have the lowest % increase among the bilobal pellets.

In Figure 8.37 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 5 rpm is compared to those with a circular cross-section for ABS. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A211 is 32%-74% compared to cylindrical pellets. The pellets manufactured with die A211 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 9%-24% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.38 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 10 rpm is compared to those with a circular cross-section for ABS. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A211 is 40%-81% compared to cylindrical pellets. The pellets manufactured with die A211 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 13%-27% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.39 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 15 rpm is compared to those with a circular cross-section for ABS. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A211 is 49%-87% compared to cylindrical pellets. The pellets manufactured with die A211 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 22%-33% compared to cylindrical pellets. The

pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

In Figure 8.40 the IPFC % increase for all bilobal pellet cross-sections at an extruder screw speed of 20 rpm is compared to those with a circular cross-section for ABS. The % increase is dependent on the profile die used in their manufacture. The % increase in IPFC for bilobal pellets manufactured with die A211 is 56%-94% compared to cylindrical pellets. The pellets manufactured with die A211 have the largest % increase among the bilobal pellets. On the other hand, the % increase for pellets manufactured with die A231 is 28%-53% compared to cylindrical pellets. The pellets manufactured with die A231 have the lowest % increase among the bilobal pellets.

However, it must be noted that the interparticulate friction coefficient of the pellets with bilobal cross-sections was always greater those for the pellets with circular cross-section. This fact is clearly illustrated in above figures.

8.2 Comparison of the IPFC for Pellets with Circular and Trilobal Cross-Sections

The pellets with trilobal cross-sections were all manufactured using the same die, A301-01 (A311) as described in Table 3.1. The effects of molecular weight, normal pressure, and extruder screw speed were determined as shown in Figures 8.41-49. From these graphical results it is difficult to discern any trends. Analysis using Box, Hunter and Hunter techniques [7] produces contradictory conclusions, depending upon the level of the factorial analysis. Enough results were not available to calculate the combined averages data, as was performed with the pellets of bilobal cross-sections. However, it is clear that the interparticulate friction coefficients for pellets with trilobal cross-sections exceeds those for pellets with circular cross-sections as presented in Figures 8.41-49, but are less than those for pellets with bilobal cross-sections.

In Figure 8.41 the IPFC % increase for trilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade U10-01. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is 40%-67% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 5 rpm is 10%-38% compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.42 the IPFC % increase for trilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade M25. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is 44%-62% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 5 rpm is 18%-30% compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.43 the IPFC % increase for trilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade M90. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is 20%-68% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets

manufactured with a screw speed of 10 rpm is 3%-31% compared to cylindrical pellets. The pellets manufactured with a screw speed of 10 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.44 the IPFC % increase for trilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade M270. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 15 rpm is 27%-51% compared to cylindrical pellets. The pellets manufactured with a screw speed of 15 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 10 rpm is 12%-28% compared to cylindrical pellets. The pellets manufactured with a screw speed of 10 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.45 the IPFC % increase for trilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade M450. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 10 rpm is 50%-68% compared to cylindrical pellets. The pellets manufactured with a screw speed of 10 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 15 rpm is 7%-19% compared to cylindrical pellets. The pellets manufactured with a screw speed of 15 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.46 the IPFC % increase for trilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for PE. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is 28%-

36% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 5 rpm is 11%-19% compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.47 the IPFC % increase for trilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for PP. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is 24%-28% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 5 rpm is 14%-24% compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.48 the IPFC % increase for trilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for PS. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is (5%-5%) compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 5 rpm is (5%-5%) compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.49 the IPFC % increase for trilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for PA 6. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is

24%-39% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 10 rpm is 17%-27% compared to cylindrical pellets. The pellets manufactured with a screw speed of 10 rpm have the lowest % increase among the four different screw speeds.

8.3 Comparison of the IPFC for Pellets with Circular and Quadrilobal Cross-Sections

The pellets with quadrilobal cross-sections were all manufactured using the same die, A401-01 (A411) as described in Table 3.1. The effects of molecular weight, normal pressure, and extruder screw speed were determined as shown in Figures 8.50-56. From these graphical results it is difficult to discern any trends. Analysis using Box, Hunter and Hunter techniques [7] produces contradictory conclusions, depending upon the level of the factorial analysis. Sufficient results were not available to calculate the combined averages data, as was performed with the pellets of bilobal cross-section. However, it is clear that the interparticulate friction coefficients for pellets with quadrilobal cross-sections exceeds those for pellets with circular cross-section as presented in Figures 8.50-56, but are less than those for pellets with bilobal cross-sections.

In Figure 8.50 the IPFC % increase for quadrilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade U10-01. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 15 rpm is 19%-42% compared to cylindrical pellets. The pellets manufactured with a screw speed of 15 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase

for pellets manufactured with a screw speed of 5 rpm is 14%-34% compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.51 the IPFC % increase for quadrilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade M25. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is 22%-37% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 5 rpm is 12%-24% compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.52 the IPFC % increase for quadrilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade M90. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is 15%-56% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 5 rpm is 10%-50% compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.53 the IPFC % increase for quadrilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade M270. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured

with a screw speed of 20 rpm is 41%-63% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 5 rpm is 14%-50% compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.54 the IPFC % increase for quadrilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for acetal copolymer grade M450. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is 25%-42% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 15 rpm is 18%-32% compared to cylindrical pellets. The pellets manufactured with a screw speed of 15 rpm have the lowest % increase among the four different screw speeds.

In Figure 8.56 the IPFC % increase for quadrilobal pellet cross-sections at four different extruder screw speeds is compared to those with a circular cross-section for PP. The % increase is dependent on the screw speed used in their manufacture. The % increase in IPFC for pellets manufactured with a screw speed of 20 rpm is 45%-54% compared to cylindrical pellets. The pellets manufactured with a screw speed of 20 rpm have the highest % increase among the four different screw speeds. On the other hand, the % increase for pellets manufactured with a screw speed of 5 rpm is 32%-41% compared to cylindrical pellets. The pellets manufactured with a screw speed of 5 rpm have the lowest % increase among the four different screw speeds.

8.4 Pellets with Bilobal, Trilobal and Quadrilobal Cross-Sections

8.4.1 Effect of Normal Pressure

The normal pressure was found to have only a weak influence on the interparticulate friction coefficient. As seen in Figures 7.1-7.67, the effect is somewhat random. The two level and three level factorial results produced conflicting conclusions which confirms the randomness of the results. So, the results were averaged at fixed values of the normal pressure to dampen the scatter. The averages for acetal copolymer are presented in Table 8.1. The averages for PE, PP, PS, PA 6, and ABS are presented in Table 8.2. As the normal pressure increases, the average IPFC decreases for the pellets with bilobal, trilobal and quadrilobal cross-sections. However, the decrease is only gradual.

8.4.2 Effect of Extruder Screw Speed

The extruder screw speed used in the manufacture of the pellets also has a weak influence the interparticulate friction coefficient. As seen in Figures 8.1 - 8.56 the effect is somewhat random. In addition, the two level and three level factorial results produced conflicting conclusions which confirms the randomness of the results. So again, the results were averaged to dampen the scatter, but this time with respect to the extruder screw speed. The averages IPFC for acetal copolymer are presented in Table 8.3. The averages IPFC for PE, PP, PS, PA 6, and ABS are presented in Table 8.4. As the extruder screw speed increases, the average IPFC increases for the pellets with bilobal, trilobal, quadrilobal cross-sections. However the increase is slight.

8.4.3 Effect of Molecular Weight

The molecular weight, as represented by the melt index, was found to have a weak influence on the interparticulate friction coefficient. This can be seen from Figures 8.1-8.56. The conflicting conclusions from the two level and three level factorials, and the randomness of the averages for the IPFC of acetal copolymer are presented in Table 8.5 for the pellets with bilobal, trilobal and quadrilobal cross-sections support this statement.

8.4.4 Effect of Extrusion Die Geometry

The extrusion die geometry has a distinct effect on the interparticulate friction coefficient. The average IPFC values for acetal copolymer using each die are presented in Table 8.6. The averages for PE, PP, PS, PA 6, and ABS using each die are presented in Table 8.7. It is apparent that die A202-01 produces pellets with superior interparticulate friction coefficients for acetal copolymer, due to the shape of the pellet that it produces.

8.4.5 Effect of Agitation of the Particulate Bed

The interparticulate friction coefficient was found to increase for all non-circular pellet geometries after agitation. The increases are clearly seen in Figures 8.57 - 8.121.

Figures 8.57-8.61 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 211 for all five samples of acetal copolymer with agitation. Figure 8.57 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade U10-01. The value of the IPFC is 0.434 to 0.51. Figure 8.58 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M25. The value of the IPFC is 0.393 to 0.54. Figure 8.59 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M90. The value of the IPFC is 0.408 to

0.534. Figure 8.60 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M270. The value of the IPFC is 0.398 to 0.502. Figure 8.61 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer M450. The value of the IPFC is 0.382 to 0.536.

Figures 8.62-8.66 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 212 for all five samples of acetal copolymer with agitation. Figure 8.62 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade U10-01. The value of the IPFC is 0.438 to 0.642. Figure 8.63 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M25. The value of the IPFC is 0.46 to 0.568. Figure 8.64 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M90. The value of the IPFC is 0.416 to 0.517. Figure 8.65 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M270. The value of the IPFC is 0.54 to 0.6. Figure 8.66 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M450. The value of the IPFC is 0.48 to 0.588.

Figures 8.67-8.71 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 212 for all five samples of acetal copolymer with agitation. Figure 8.67 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade U10-01. The value of the IPFC is 0.474 to 0.562. Figure 8.68 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M25. The value of the IPFC is 0.384 to 0.459. Figure 8.69 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M90. The value of the IPFC is 0.445 to 0.517. Figure 8.70 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M270. The value of the IPFC is 0.428 to

0.512. Figure 8.71 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M450. The value of the IPFC is 0.476 to 0.588.

Figures 8.72-8.77 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 231 for all five samples of acetal copolymer with agitation. Figure 8.72 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade U10-01. The value of the IPFC is 0.408 to 0.546. Figure 8.73 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M25. The value of the IPFC is 0.298 to 0.434. Figure 8.74 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M90. The value of the IPFC is 0.309 to 0.386. Figure 8.75 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M270. The value of the IPFC is 0.224 to 0.332. Figure 8.76 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer M450. The value of the IPFC is 0.274 to 0.362.

Figures 8.77-8.81 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 241 for all five samples of acetal copolymer with agitation. Figure 8.77 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade U10-01. The value of the IPFC is 0.534 to 0.616. Figure 8.78 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M25. The value of the IPFC is 0.445 to 0.565. Figure 8.79 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M90. The value of the IPFC is 0.408 to 0.501. Figure 8.80 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M270. The value of the IPFC is 0.386 to 0.514. Figure 8.81 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer M450. The value of the IPFC is 0.438 to 0.598.

Figures 8.82-8.86 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 211 for all five samples of polyethylene, polypropylene, polystyrene, nylon 6, ABS with agitation. The value of the IPFC is presented as described here. Figure 8.82 shows the IPFC as a function of pressure for bilobal pellets manufactured from PE. The value of the IPFC is 0.398 to 0.493. Figure 8.83 shows the IPFC as a function of pressure for bilobal pellets manufactured from PP. The value of the IPFC is 0.28 to 0.37. Figure 8.84 shows the IPFC as a function of pressure for bilobal pellets manufactured from PS. The value of the IPFC is 0.352 to 0.448. Figure 8.85 shows the IPFC as a function of pressure for bilobal pellets manufactured from PA 6. The value of the IPFC is 0.322 to 0.442. Figure 8.86 shows the IPFC as a function of pressure for bilobal pellets manufactured from ABS. The value of the IPFC is 0.306 to 0.392.

Figures 8.87-8.90 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 212 for all five samples of polyethylene, polypropylene, polystyrene, and nylon 6 with agitation. The value of the IPFC is presented as described here. Figure 8.87 shows the IPFC as a function of pressure for bilobal pellets manufactured from PE. The value of the IPFC is 0.388 to 0.472. Figure 8.88 shows the IPFC as a function of pressure for bilobal pellets manufactured from PP. The value of the IPFC is 0.28 to 0.36. Figure 8.89 shows the IPFC as a function of pressure for bilobal pellets manufactured from PS. The value of the IPFC is 0.344 to 0.406. Figure 8.90 shows the IPFC as a function of pressure for bilobal pellets manufactured from PA 6. The value of the IPFC is 0.313 to 0.41.

Figures 8.91-8.95 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 221 for all five samples of polyethylene, polypropylene, polystyrene, nylon 6, ABS with agitation. The value of the IPFC is presented as described here. Figure 8.91 shows the IPFC as a function of pressure for bilobal pellets manufactured from PE. The value of the IPFC is 0.408 to 0.492. Figure 8.92

shows the IPFC as a function of pressure for bilobal pellets manufactured from PP. The value of the IPFC is 0.324 to 0.412. Figure 8.93 shows the IPFC as a function of pressure for bilobal pellets manufactured from PS. The value of the IPFC is 0.479 to 0.565. Figure 8.94 shows the IPFC as a function of pressure for bilobal pellets manufactured from PA 6. The value of the IPFC is 0.35 to 0.483. Figure 8.95 shows the IPFC as a function of pressure for bilobal pellets manufactured from ABS. The value of the IPFC is 0.258 to 0.372.

Figures 8.96-8.100 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 231 for all five samples of polyethylene, polypropylene, polystyrene, nylon 6, and ABS with agitation. The value of the IPFC is presented as described here. Figure 8.96 shows the IPFC as a function of pressure for bilobal pellets manufactured from PE. The value of the IPFC is 0.4 to 0.45. Figure 8.97 shows the IPFC as a function of pressure for bilobal pellets manufactured from PP. The value of the IPFC is 0.319 to 0.438. Figure 8.98 shows the IPFC as a function of pressure for bilobal pellets manufactured from PS. The value of the IPFC is 0.344 to 0.448. Figure 8.99 shows the IPFC as a function of pressure for bilobal pellets manufactured from PA 6. The value of the IPFC is 0.336 to 0.452. Figure 8.100 shows the IPFC as a function of pressure for bilobal pellets manufactured from ABS. The value of the IPFC is 0.234 to 0.329.

Figures 8.101-8.105 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 241 for all five samples of polyethylene, polypropylene, polystyrene, nylon 6, and ABS with agitation. The value of the IPFC is presented as described here. Figure 8.101 shows the IPFC as a function of pressure for bilobal pellets manufactured from PE. The value of the IPFC is 0.394 to 0.492. Figure 8.102 shows the IPFC as a function of pressure for bilobal pellets manufactured from PP. The value of the IPFC is 0.324 to 0.391. Figure 8.103 shows the IPFC as a function of pressure for bilobal pellets manufactured from PS. The

value of the IPFC is 0.350 to 0.62. Figure 8.104 shows the IPFC as a function of pressure for bilobal pellets manufactured from PA 6. The value of the IPFC is 0.35 to 0.474. Figure 8.105 shows the IPFC as a function of pressure for bilobal pellets manufactured from ABS. The value of the IPFC is 0.242 to 0.414.

Figures 8.106-8.110 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 311 for all five samples of acetal copolymer with agitation. The value of the IPFC is presented as described here. Figure 8.106 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grades U10-01. The value of the IPFC is 0.35 to 0.48. Figure 8.107 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grades M25. The value of the IPFC is 0.242 to 0.309. Figure 8.108 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grades M90. The value of the IPFC is 0.238 to 0.31. Figure 8.109 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grades M270.. The value of the IPFC is 0.24 to 0.309. Figure 8.110 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grades M450. The value of the IPFC is 0.195 to 0.288.

Figures 8.111-8.115 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 411 for all five samples of acetal copolymer with agitation. The value of the IPFC is presented as described here. Figure 8.111 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade U10-01. The value of the IPFC is 0.383 to 0.556. Figure 8.112 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M25. The value of the IPFC is 0.245 to 0.332. Figure 8.113 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer grade M90. The value of the IPFC is 0.31 to 0.385. Figure 8.114 shows the IPFC as a function of pressure for bilobal pellets manufactured from PA 6.

The value of the IPFC is 0.28 to 0.363. Figure 8.115 shows the IPFC as a function of pressure for bilobal pellets manufactured from acetal copolymer. The value of the IPFC is 0.255 to 0.286.

Figures 116-119 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 311 for polyethylene, polypropylene, polystyrene, nylon 6, and ABS with agitation. The value of the IPFC is presented as described here. Figure 8.116 shows the IPFC as a function of pressure for pellets manufactured from PE. The value of the IPFC is 0.375 to 0.462. Figure 8.117 shows the IPFC as a function of pressure for pellets manufactured from PP. The value of the IPFC is 0.298 to 0.36. Figure 8.118 shows the IPFC as a function of pressure for pellets manufactured from PS. The value of the IPFC is 0.348 to 0.422. Figure 8.119 shows the IPFC as a function of pressure for pellets manufactured from PA 6. The value of the IPFC is 0.375 to 0.465.

Figures 120-121 show the IPFC as a function of pressure for the bilobal pellets manufactured using die 411 for polyethylene, polypropylene, polystyrene, nylon 6, and ABS with agitation. The value of the IPFC is presented as described here. Figure 8.120 shows the IPFC as a function of pressure for pellets manufactured from PE. The value of the IPFC is 0.4 to 0.472. Figure 8.121 shows the IPFC as a function of pressure for pellets manufactured from PP. The value of the IPFC is 0.343 to 0.402.

8.4.6 Effect of Consolidation Pressure of the Particulate Bed

The pellets manufactured using die A211 from polyethylene were consolidated with a consolidation pressure of 126.3 kPa. In the tests, the static load is applied on the cap of the shear cell. The effect of consolidation pressure on the IPFC is illustrated in Figure 8.122. The consolidation pressure has only a weak, but positive, influence on the IPFC. while the consolidation pressure put on the particulate bed.

8.4.7 Effect of Consolidation Time of the Particulate Bed

The specimen of particulates was consolidated at a pressure 126.3 kPa for different time periods. No shear force is applied on the shear cell with a normal force of $N = A \sigma$, where A is the cross-sectional area of the cell and σ is the consolidation pressure. After the lapse of the prescribed interval of time, one at a time, the cell is placed on the shear apparatus and the IPFC is measured as described in chapter six. The effect on IPFC for bilobal pellets manufactured using die A211 from polyethylene is shown in Figure 8.123. The consolidation time has a weak, influence on the IPFC values for polyethylene.

8.4.8 Effect of Particulate Powders

The influence of additive for cylindrical pellets and bilobal pellets is measured by adding the mica clay into the material nylon 6 as additive in weight percentage from 0.5% to 2%. Both the pellets with circular cross-sections and bilobal cross-sections with adding mica clay is performed. The % increase of IPFC for the pellets with circular cross-sections with mica clay is presented in Figure 8.124. The % increase of IPFC for the pellets with bilobal cross-sections with mica clay is presented in Figure 8.125. The increase is more notable with the pellets of circular cross-sections than with the pellets of bilobal cross-sections. The fact that an increase in the value of the IPFC occurred at all was surprising. The mica clay powder was expected to destabilize the solid bed by providing rolling contacts with low friction coefficients. In fact, it appears to have acted in an adhesive manner.

In addition, the effect of additive for cylindrical pellets and bilobal pellets are also measured adding PBT powder into the acetal copolymer grade M90 (POM3) in weight percentage from 0.5% to 2%. The % increase for IPFC by adding polyester powder (PBT) into cylindrical pellet are shown in Figure 8.126. The % decrease for IPFC by adding PBT powder into bilobal pellet are shown in Figure 8.127, Here the

expected increase in IPFC value was observed with pellets of cylindrical cross-section, especially at low pressure. The addition of polymer powder to polymer pellets is known to improve solids conveying in extrusion, and this effect is expected if the IPFC increases as measured. However, the consistent decrease in the IPFC value for pellets with bilobal cross-sections was unexpected. The PBT powder appears to reverse its role as the pellet geometry changes.

8.4.9 Effect of Surface Lubricants

The influence of surface lubricants on the IPFC for cylindrical pellets and bilobal pellets is also measured by adding zinc stearate into the material M90 (POM3) in weight percentage from 0.25% to 1%. However, solid lubricants are frequently added to polymeric pellets among manufacturing. The % decrease of IPFC for the pellets with circular cross-sections by adding zinc stearate are shown in Figure 8.128. The % decrease of IPFC pellets with bilobal cross-sections with zinc stearate are presented in Figures 8.129 and 8.130 respectively for pellets manufactured with different dies and hence possessing different shapes. For all three geometries the IPFC values are significantly reduced, although the decrease with pellets of circular cross-section is significantly less. Even small amounts of zinc stearate (0.25%) reduce the IPFC over 40%. The measurements are very significant, and explain why materials with external lubricant present convey poorly and cause surging in injection molding, blow molding and extrusion operations.

8.5 Comparison of the IPFC for Pellets with Bilobal, Trilobal and Quadrilobal Cross-Sections

Of course the initial hypothesis in this work was those bilobal, trilobal, and quadrilobal pellets would increase the interparticulate friction coefficient. This was found to be the case for all comparable situations. This finding is shown in Figure 8.1 to Figure 8.57 for acetal copolymer, polyethylene, polypropylene, polystyrene, nylon

6 and ABS. These figures indicate the percentage increase in the value of the interparticulate friction coefficient as a function of normal pressure for each of the profile dies used, and all of the extruder screw speeds used. Each and every point in these figures indicates that the interparticulate friction coefficient is improved by the sole action of profiling the pellets. The average IPFC values of bilobal, trilobal, and quadrilobal for all ten samples are presented in Table 8.8.

8.6 Effect of the IPFC Increases on the Performance of Plastics Solid Conveying Equipment

The results clearly indicate that the interparticulate friction coefficient is increased with profiled pellets as compared to cylindrical pellets. The hypothesis can readily be drawn that solids beds of profiled pellets will exhibit greater integrity, and not break up readily. However, the profiled pellets must also be conveyed in mechanical systems other than plasticating screws, and in these instances the flexibility is required to be high, and the increased interparticulate friction coefficients may be disadvantageous. It will cause an increase in the coefficient, which reflects the magnitude of the cohesive forces in the solid bed, which must be exceeded if flow is to occur. This, in turn, could lead to arching and piping in bins and hoppers. The solution to these flow anomalies is known to be the use of live bottoms, or hopper stirrers, but this entails an increased cost for the processor, and may limit the use of profiled pellets.

Table 8.1 Effect of Normal Pressure on the Average IPFC for Acetal Copolymer.

Normal Pressure kPa	Average IPFC Bilobal	Average IPFC Trilobal	Average IPFC Quadrilobal
20.46	0.364	0.275	0.253
26.64	0.372	0.270	0.283
32.82	0.369	0.269	0.259
39.00	0.367	0.267	0.258
45.18	0.358	0.260	0.254

Table 8.2 Effect of Normal Pressure on the Average IPFC for PE, PP, PS, PA6 and ABS.

Normal Pressure kPa	Average IPFC Bilobal	Average IPFC Trilobal	Average IPFC Quadrilobal
20.46	0.309	0.304	0.340
26.64	0.312	0.315	0.342
32.82	0.313	0.314	0.343
39.00	0.311	0.310	0.338
45.18	0.309	0.307	0.332

Table 8.3 Effect of Extruder Screw Speed on the Average IPFC for Acetal Copolymer.

Extruder screw speed rev/min	Average IPFC Bilobal	Average IPFC Trilobal	Average IPFC Quadrilobal
5	0.339	0.247	0.259
10	0.360	0.267	0.264
15	0.367	0.271	0.262
20	0.375	0.288	0.270

Table 8.4 Effect of Extruder Screw Speed on the Average IPFC for PE, PP, PS, PA6 and ABS.

Extruder screw speed rev/min	Average IPFC Bilobal	Average IPFC Trilobal	Average IPFC Quadrilobal
5	0.289	0.299	0.330
10	0.300	0.312	0.340
15	0.313	0.313	0.344
20	0.328	0.324	0.348

Table 8.5 Effect of Molecular Weight on the Average IPFC for Acetal Copolymer.

Melt Index	Average IPFC Bilobal	Average IPFC Trilobal	Average IPFC Quadrilobal
1.0	0.409	0.411	0.346
2.5	0.371	0.234	0.235
9.0	0.366	0.254	0.272
27.0	0.342	0.226	0.242
45.0	0.341	0.225	0.211

Table 8.6 Effect of Die Geometry on the Average IPFC for Acetal Copolymer.

Profile Die No	Average IPFC
A201-01	0.381
A201-02	0.383
A202-01	0.413
A203-01	0.274
A204-01	0.397
A301-01	0.270
A401-01	0.261

Table 8.7 Effect of Die Geometry on the Average IPFC for PE, PP, PS, PA 6 and ABS.

Profile Die No	Average IPFC
A201-01	0.310
A201-02	0.304
A202-01	0.332
A203-01	0.278
A204-01	0.323
A301-01	0.310
A401-01	0.339

Table 8.8 The Average IPFC values for Pellets with Bilobal, Trilobal and Quadrilobal Cross-Section for Acetal Copolymer, PE, PP, PS, PA 6 and ABS.

Material	Average IPFC Bilobal	Average IPFC Trilobal	Average IPFC Quadrilobal
U10-01	0.409	0.411	0.346
M25	0.371	0.234	0.235
M90	0.366	0.254	0.272
M270	0.342	0.226	0.242
M450	0.341	0.225	0.211
PE	0.337	0.317	0.352
PP	0.289	0.280	0.327
PS	0.351	0.308	N/A
PA 6	0.329	0.338	N/A
ABS	0.250	N/A	N/A

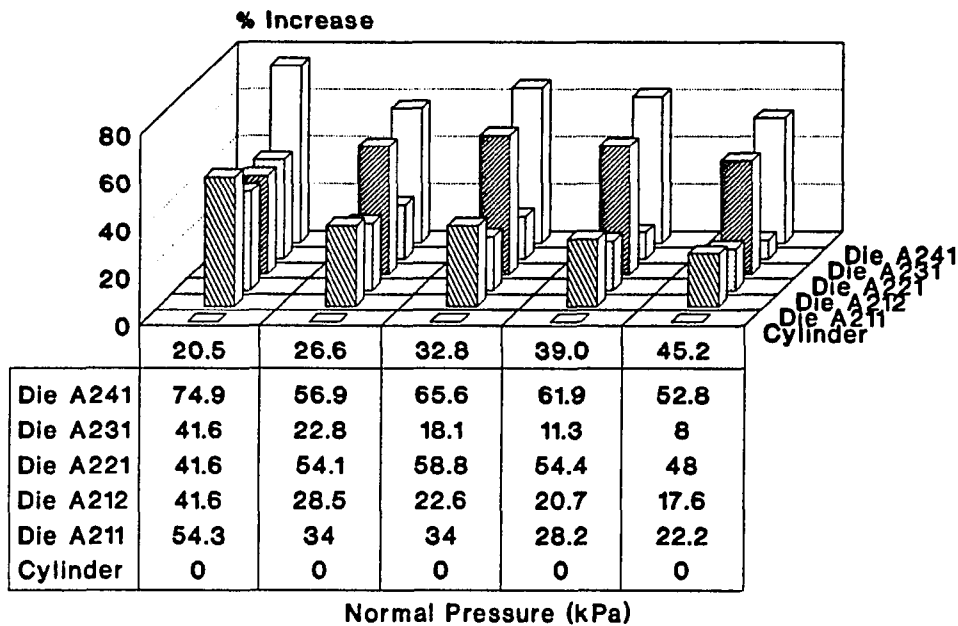


Figure 8.1 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM1.

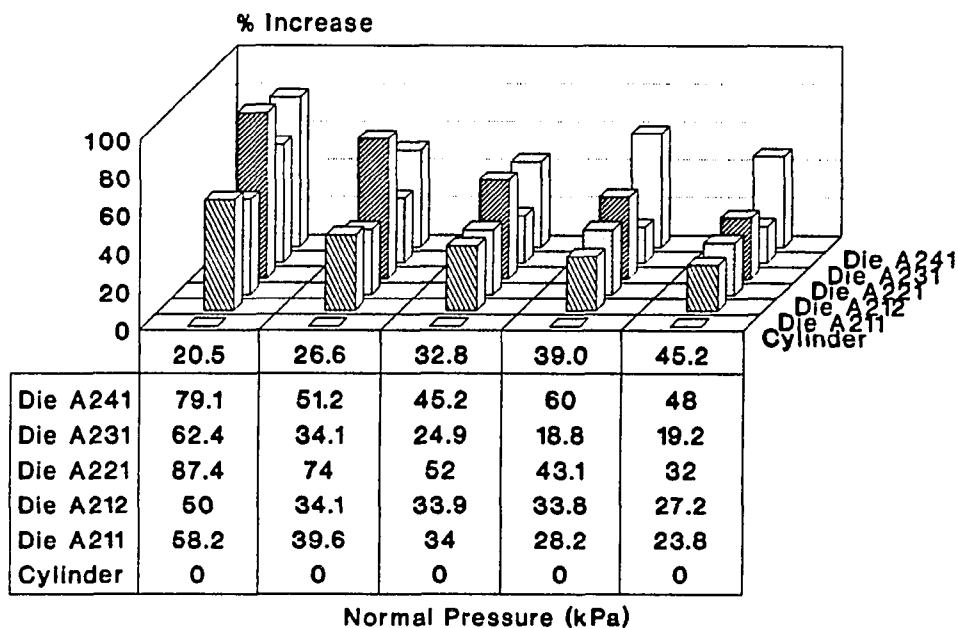


Figure 8.2 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM1.

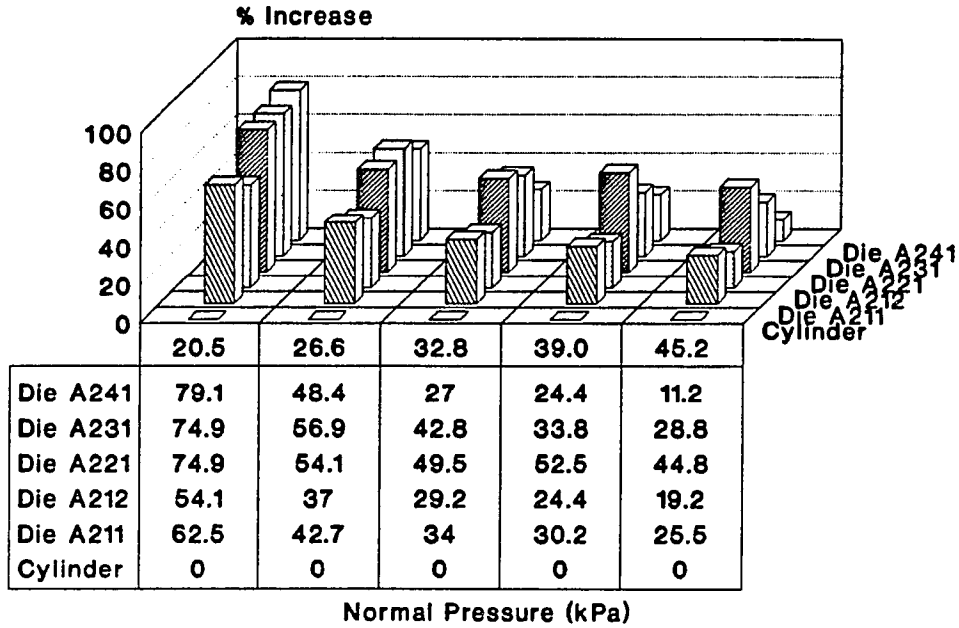


Figure 8.3 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM1.

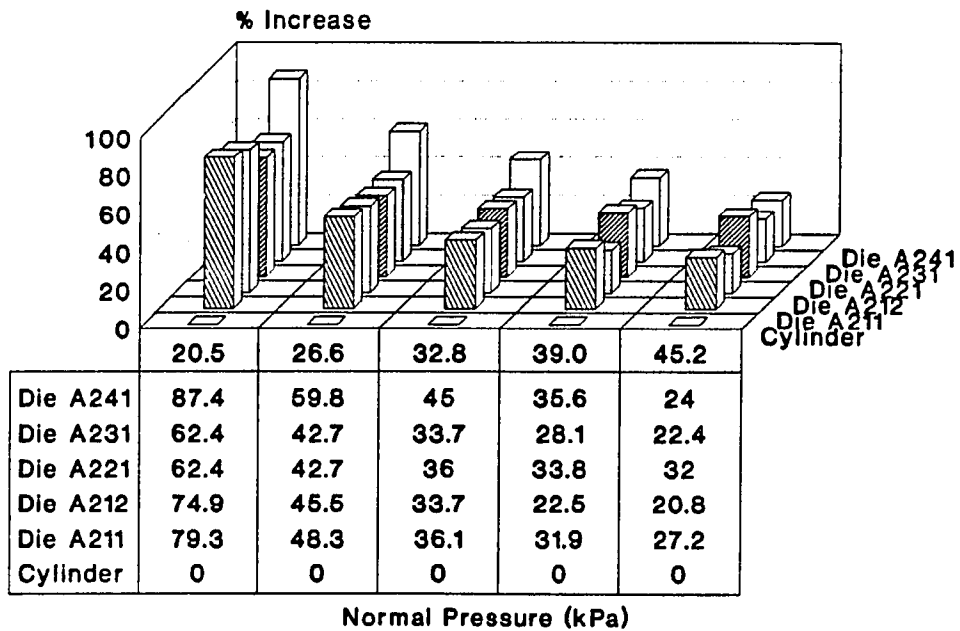


Figure 8.4 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM1.

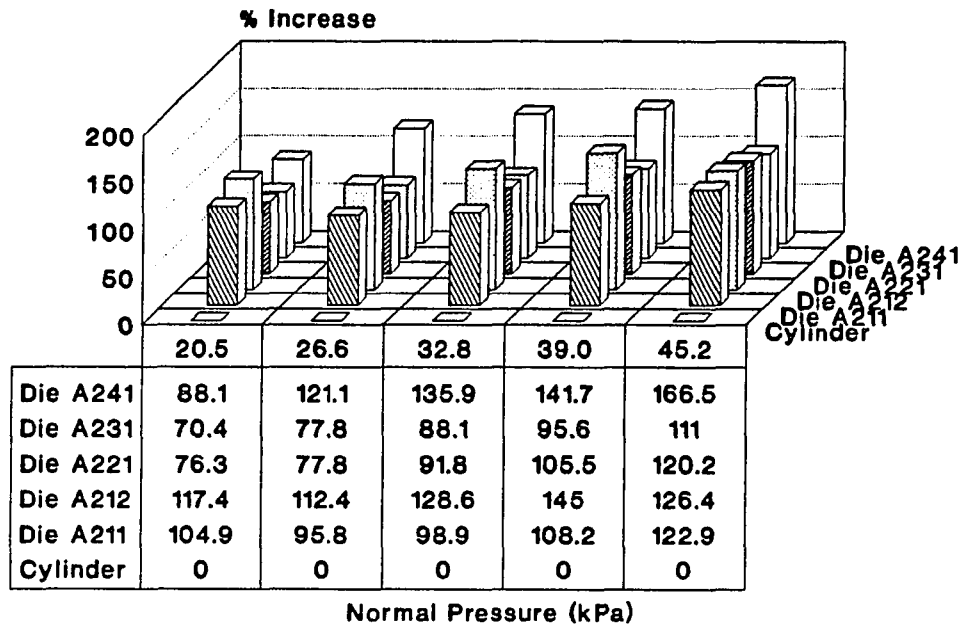


Figure 8.5 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM2.

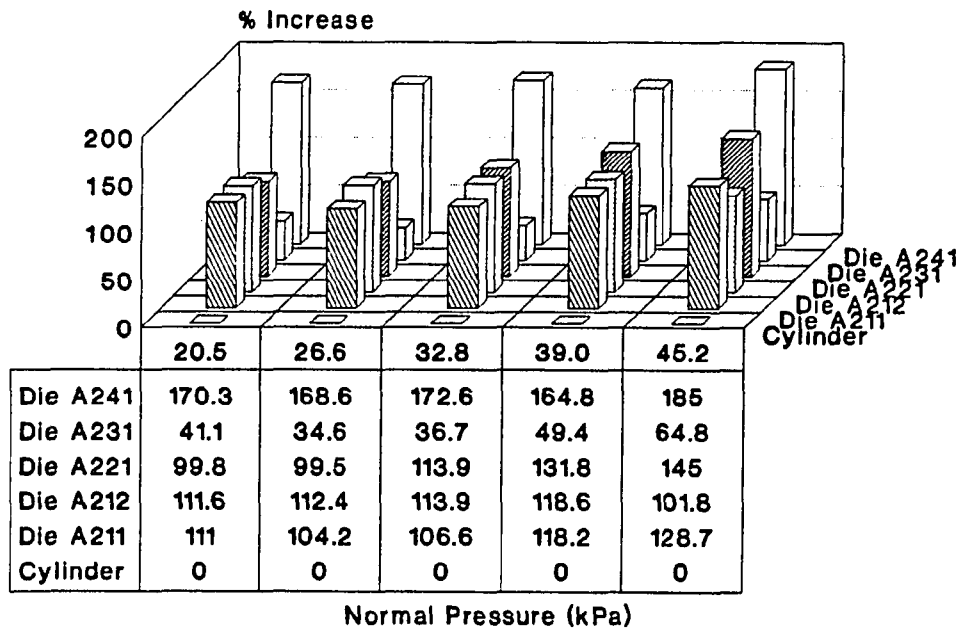


Figure 8.6 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM2.

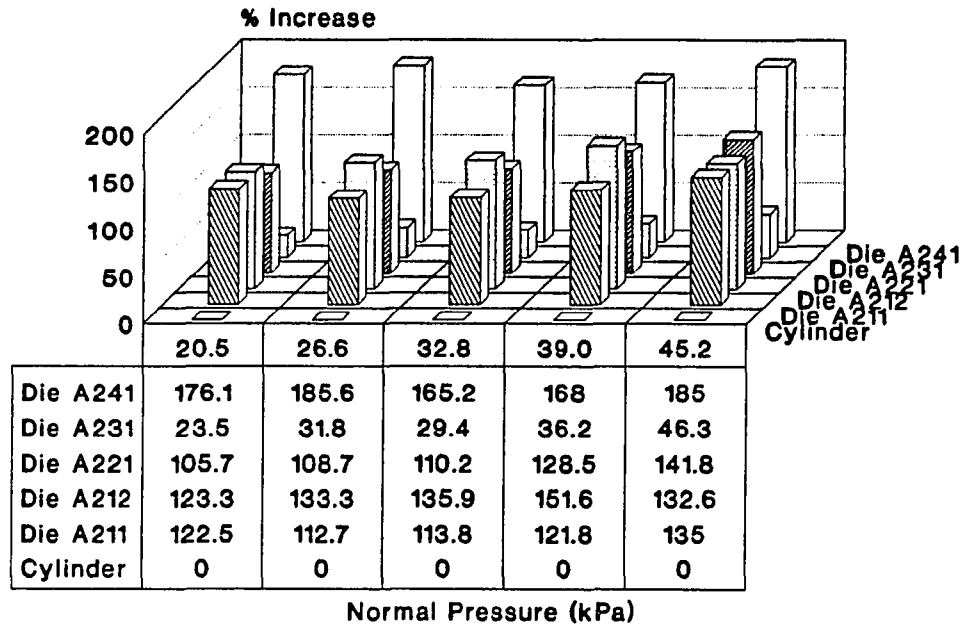


Figure 8.7 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM2.

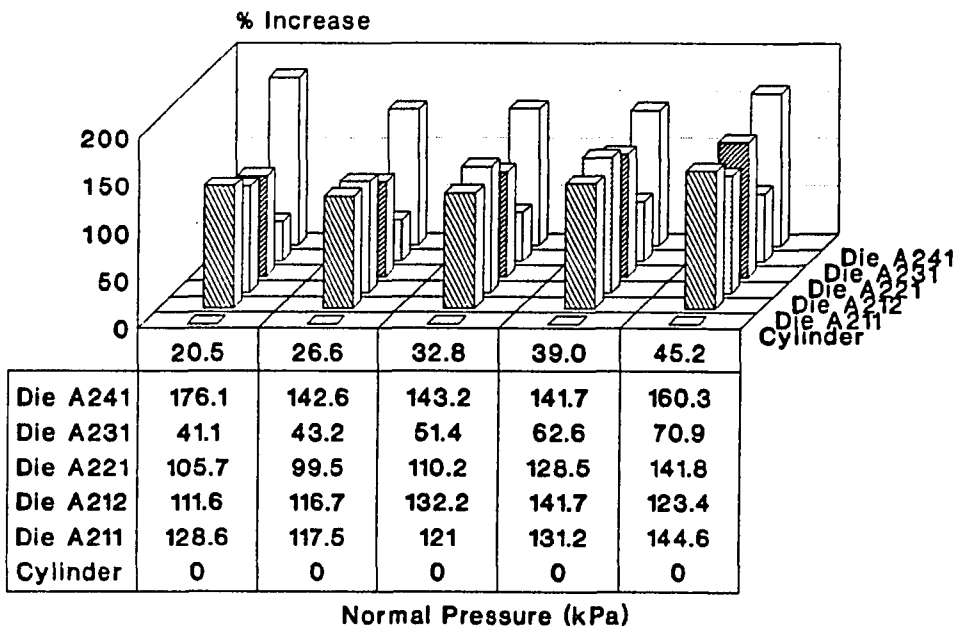


Figure 8.8 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM2.

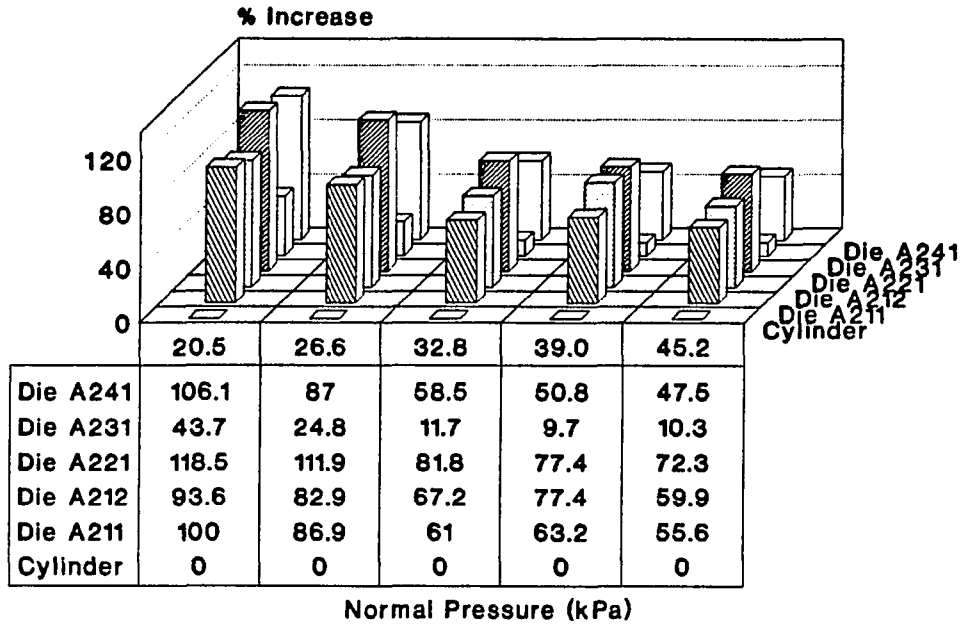


Figure 8.9 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM3.

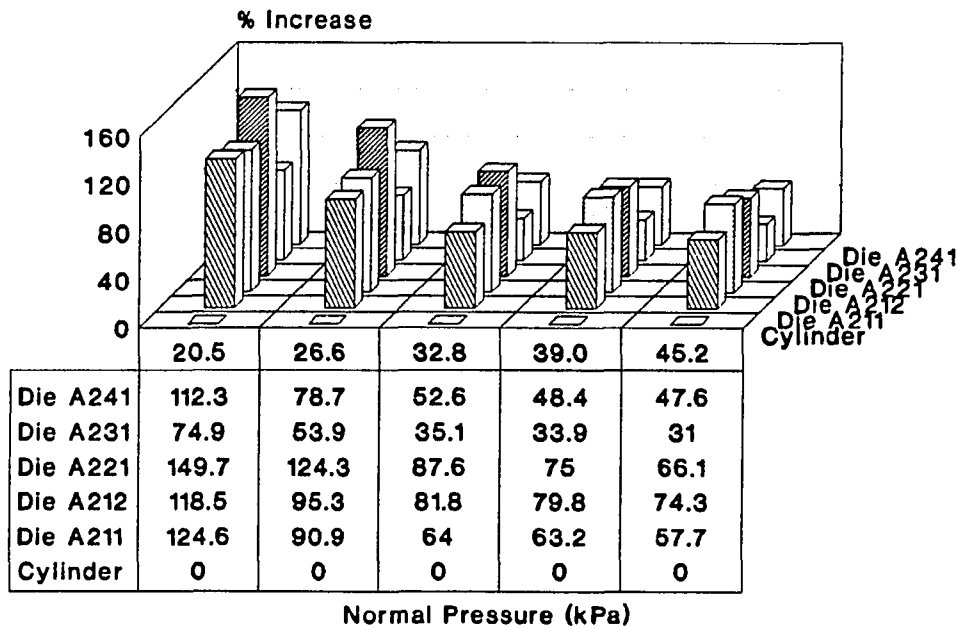


Figure 8.10 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM3.

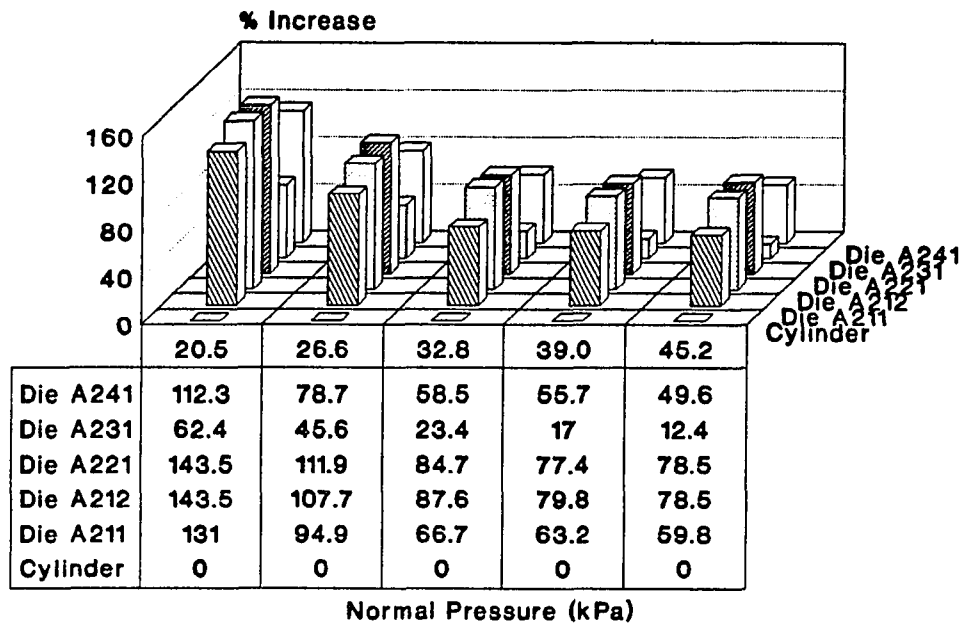


Figure 8.11 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM3.

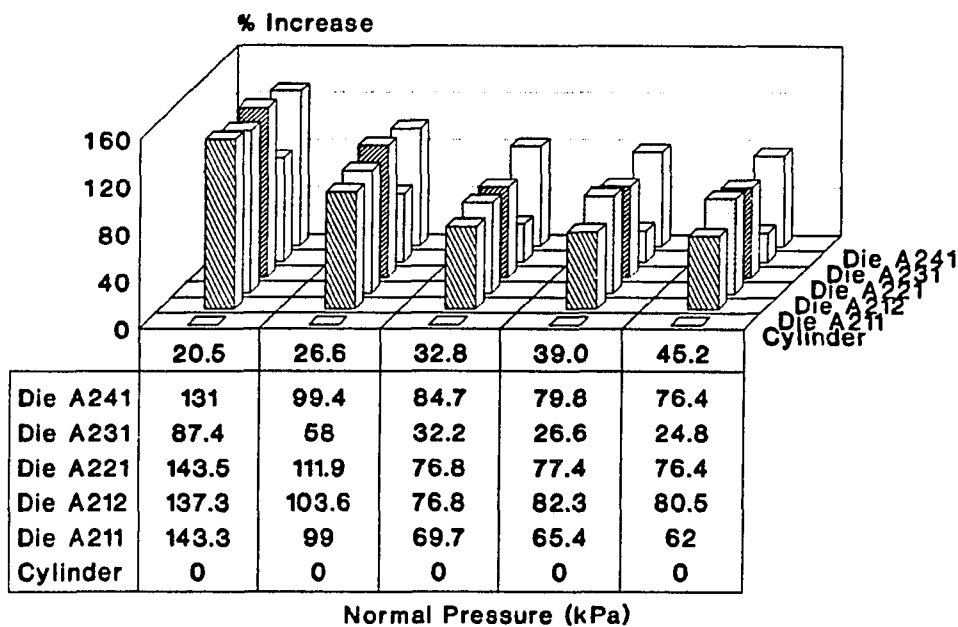


Figure 8.12 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM3.

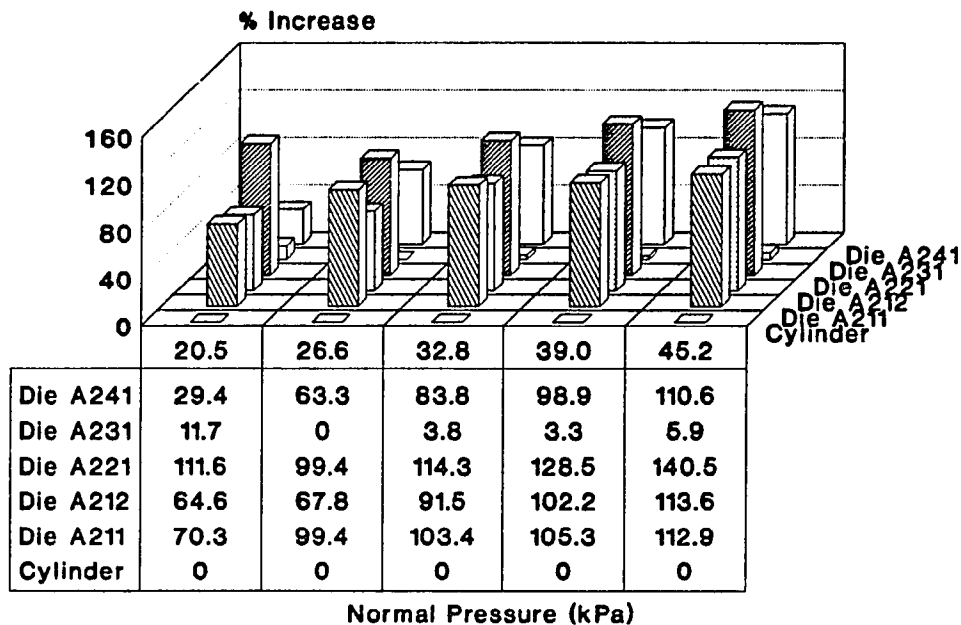


Figure 8.13 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM4.

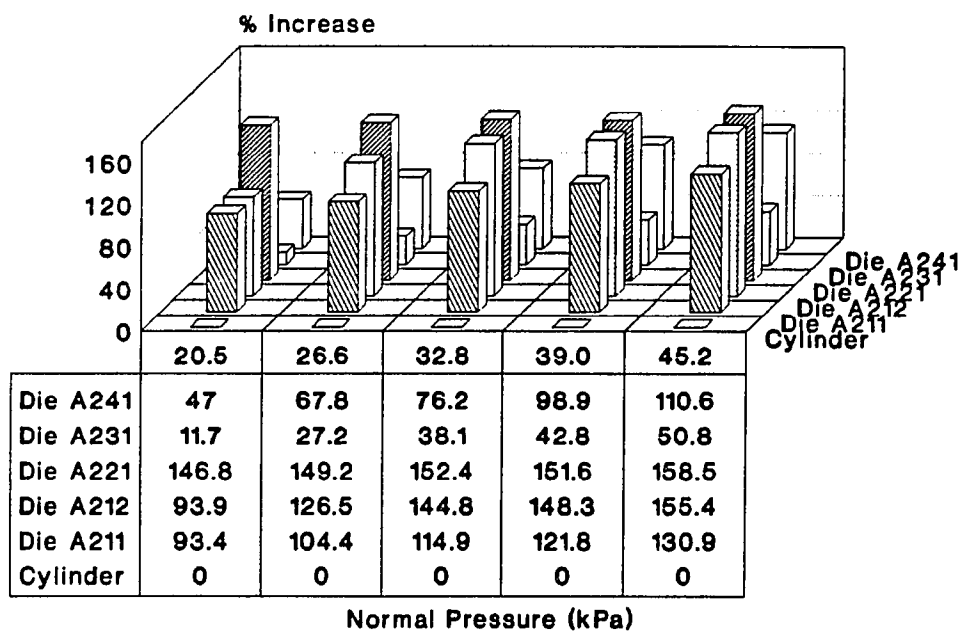


Figure 8.14 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM4.

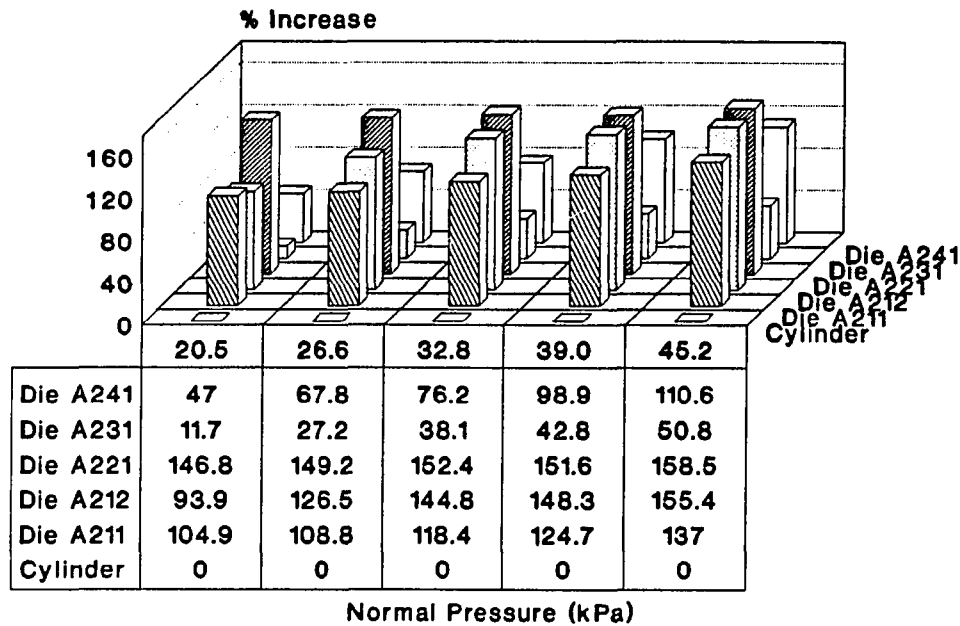


Figure 8.15 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM4.

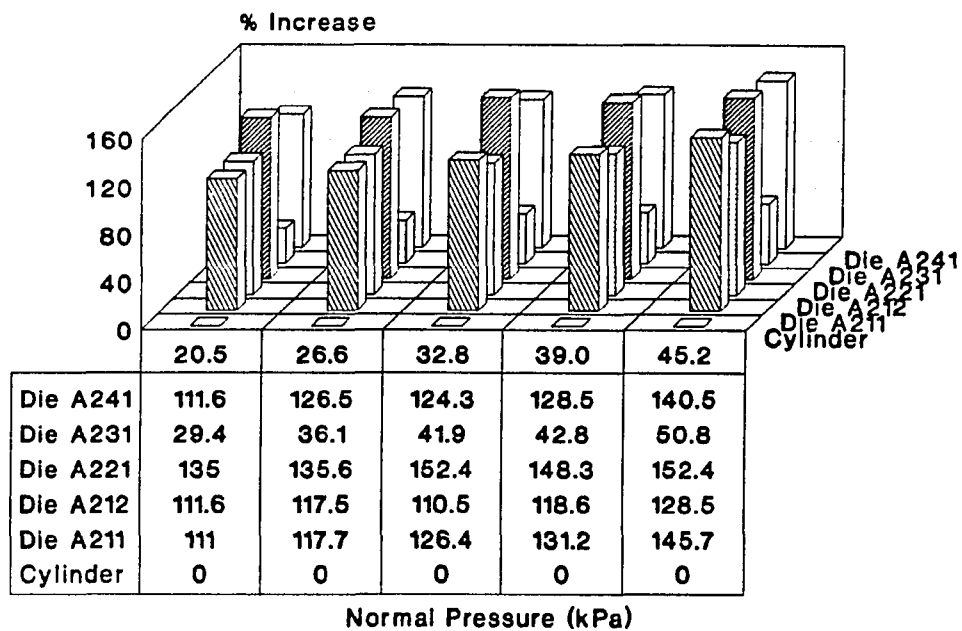


Figure 8.16 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM4.

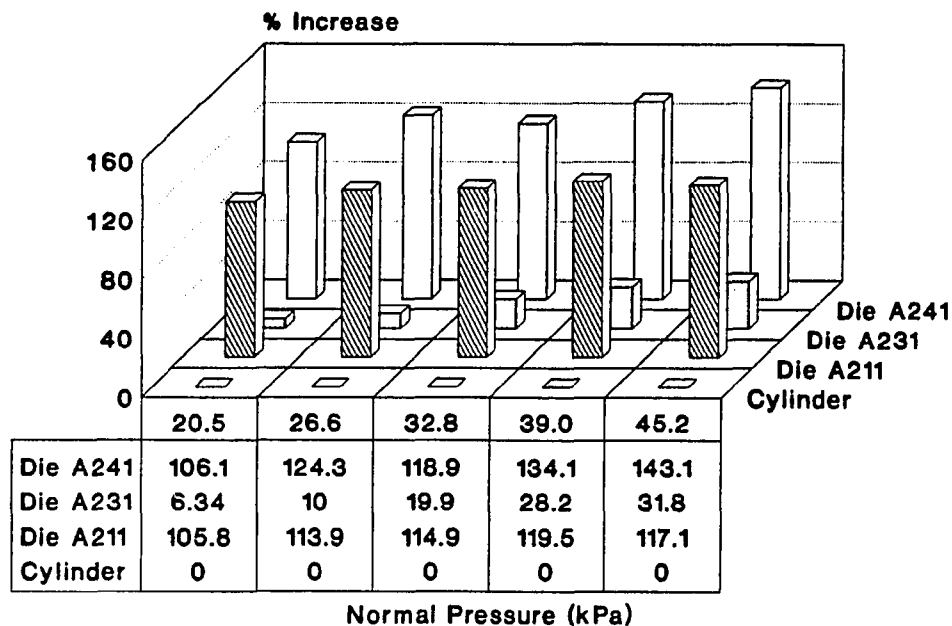


Figure 8.17 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for POM5.

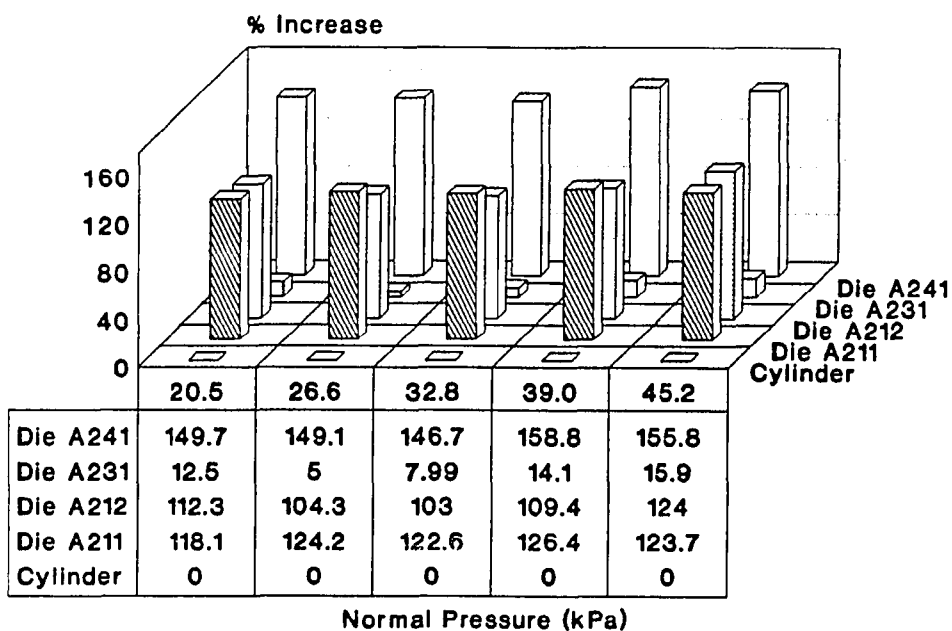


Figure 8.18 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for POM5.

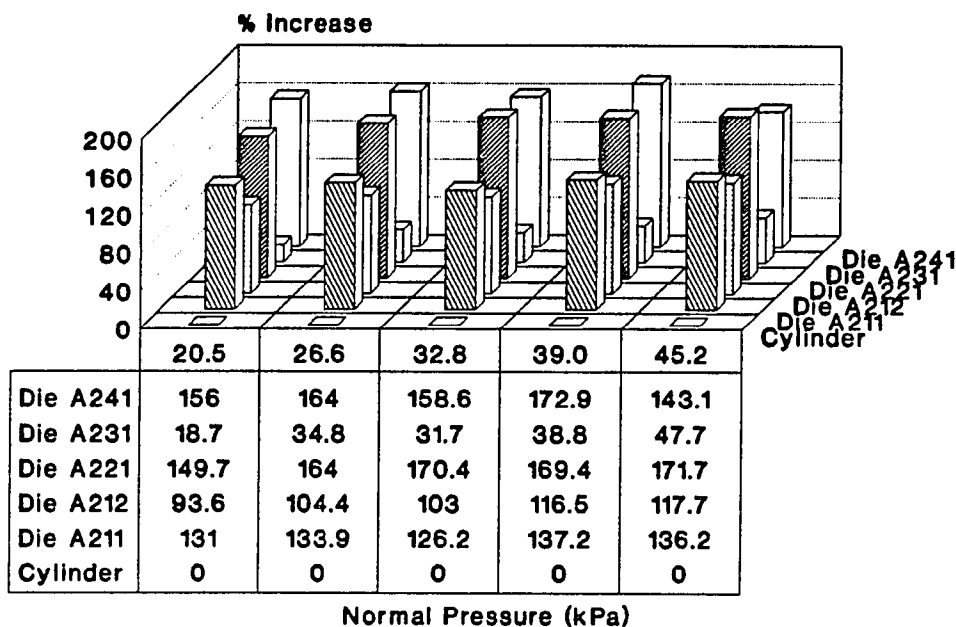


Figure 8.19 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for POM5.

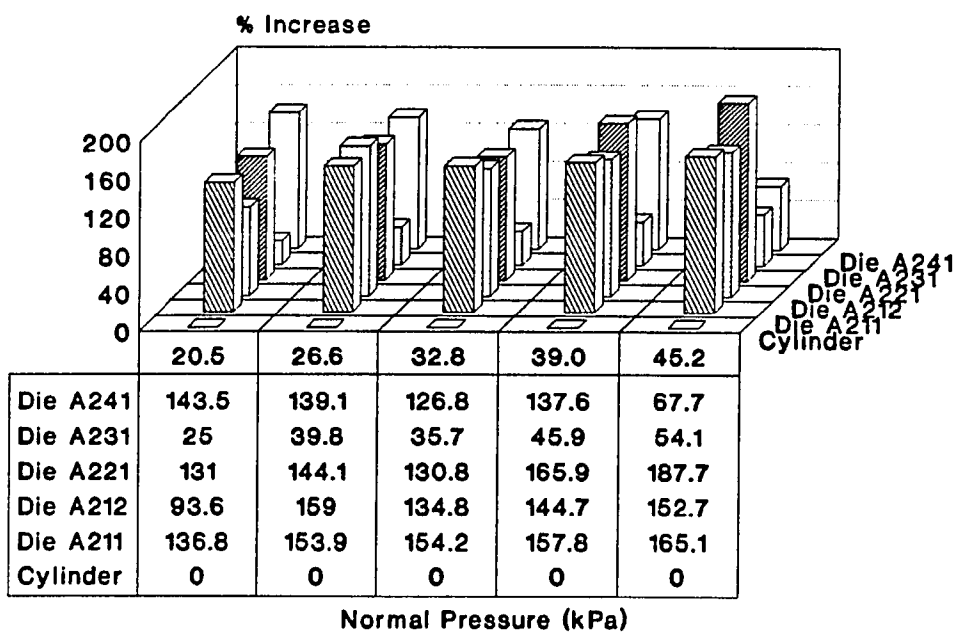


Figure 8.20 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for POM5.

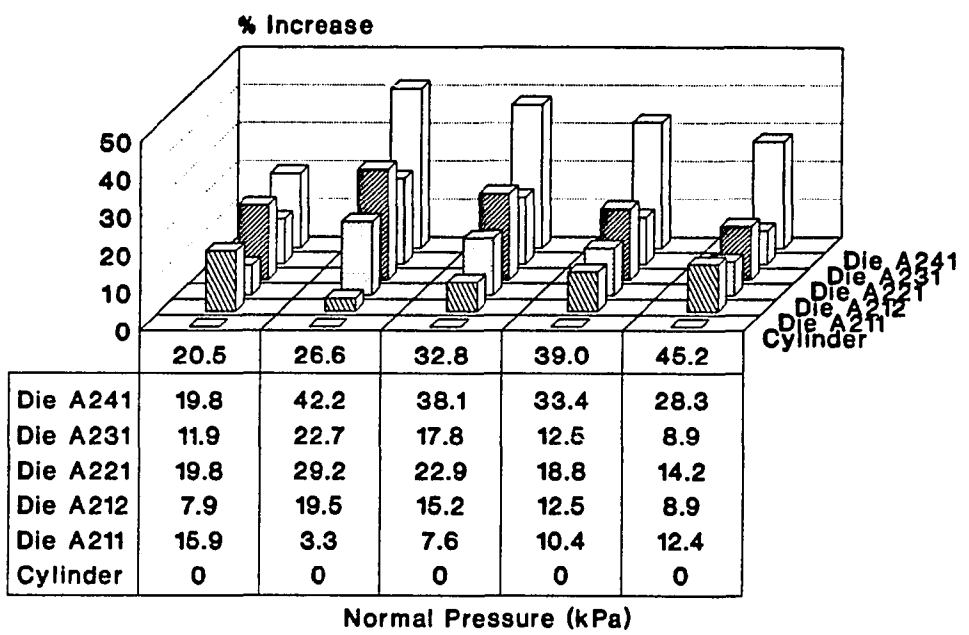


Figure 8.21 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for PE.

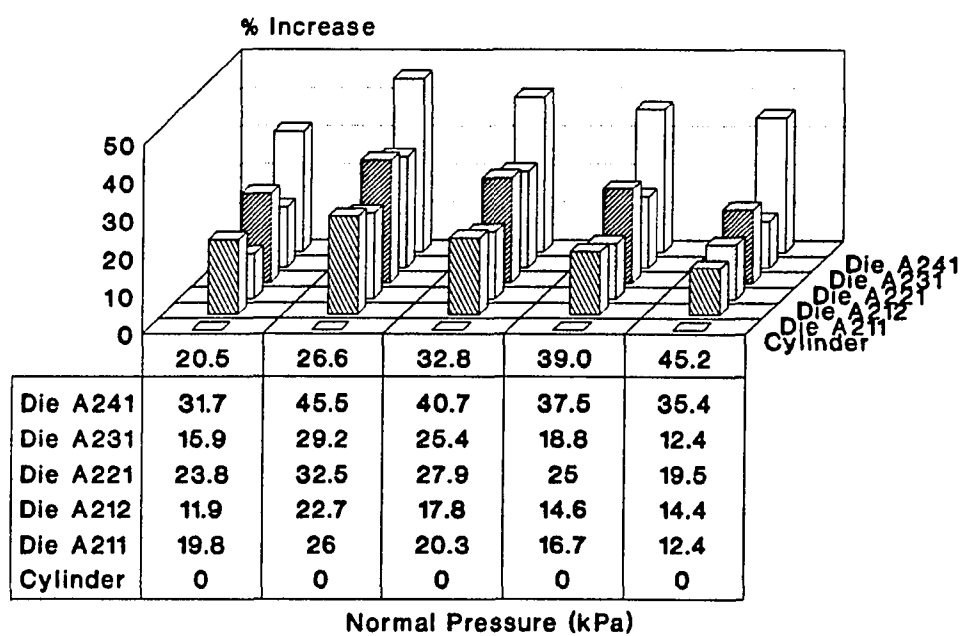


Figure 8.22 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for PE.

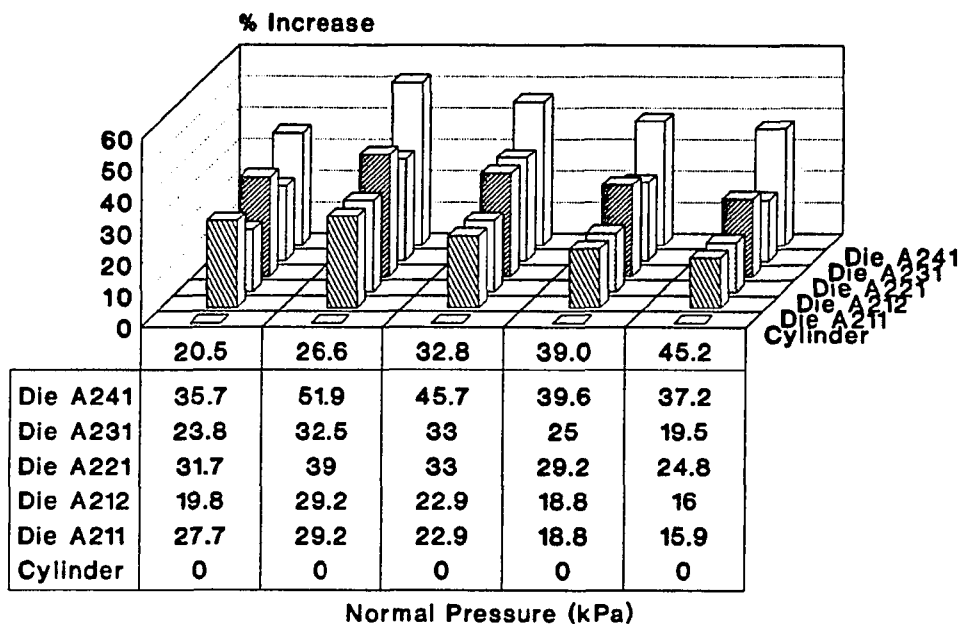


Figure 8.23 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for PE.

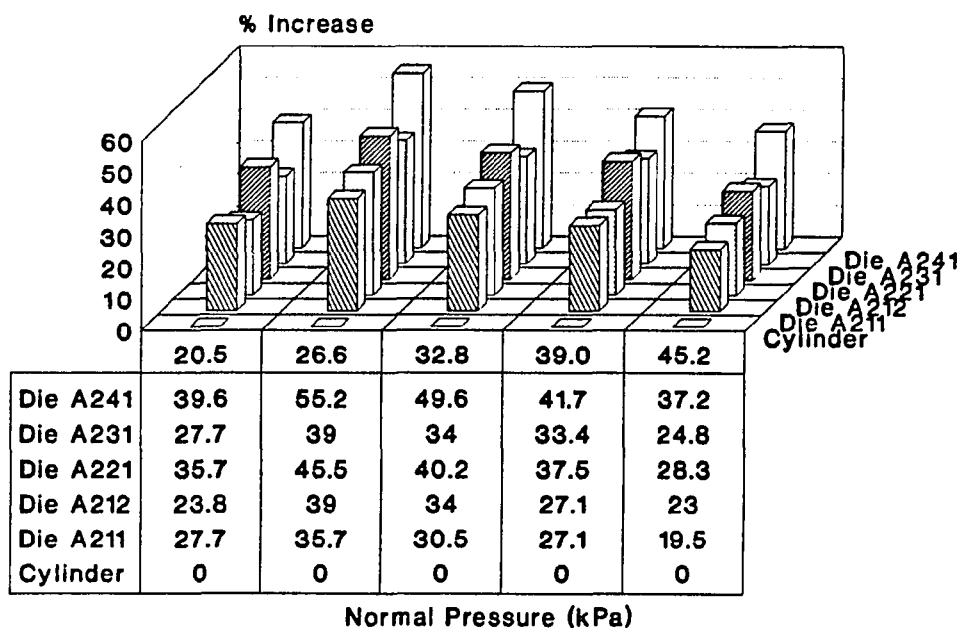


Figure 8.24 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for PE.

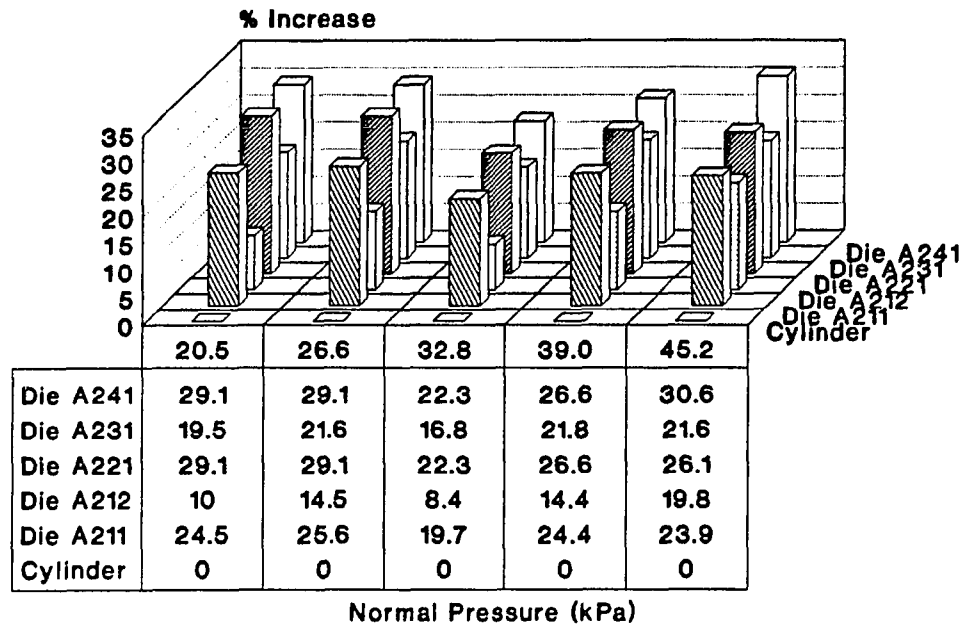


Figure 8.25 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for PP.

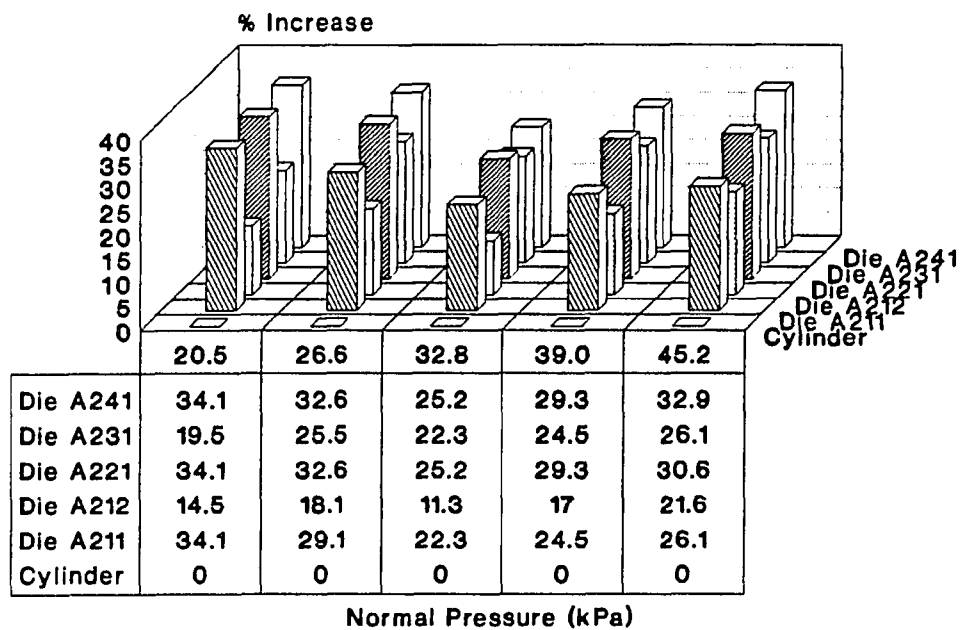


Figure 8.26 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for PP.

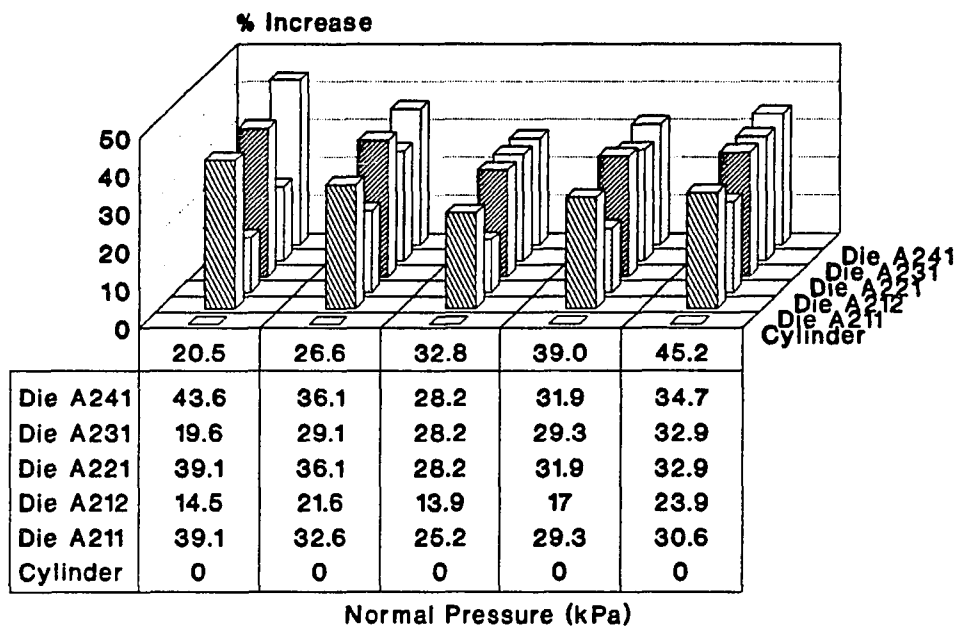


Figure 8.27 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for PP.

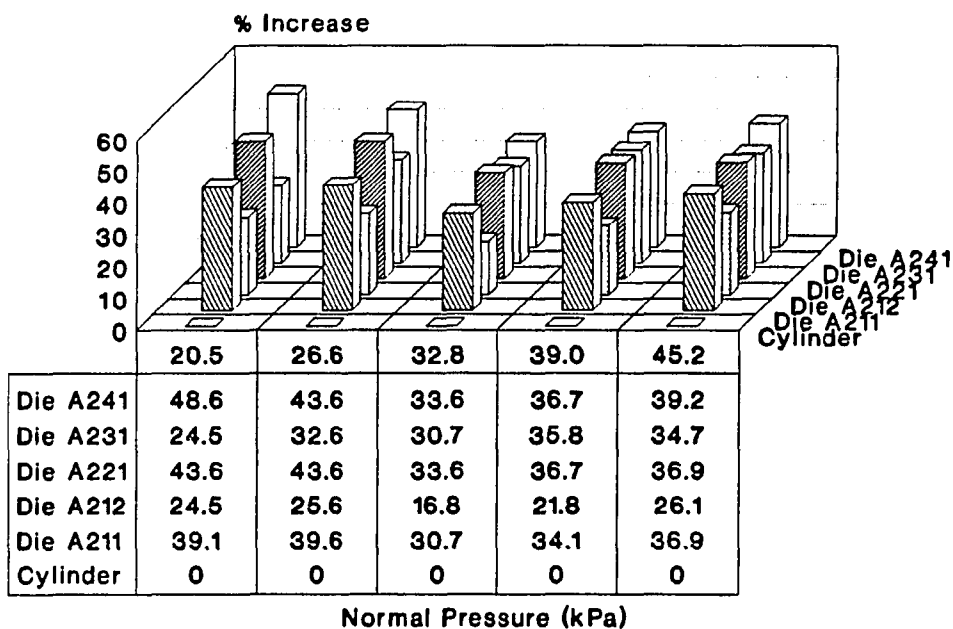


Figure 8.28 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for PP.

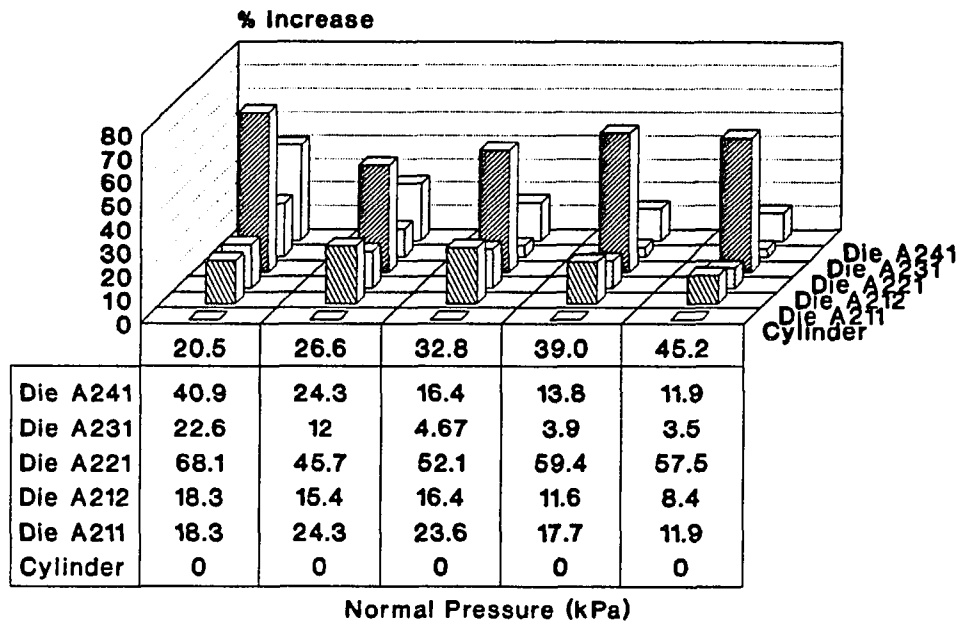


Figure 8.29 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for PS.

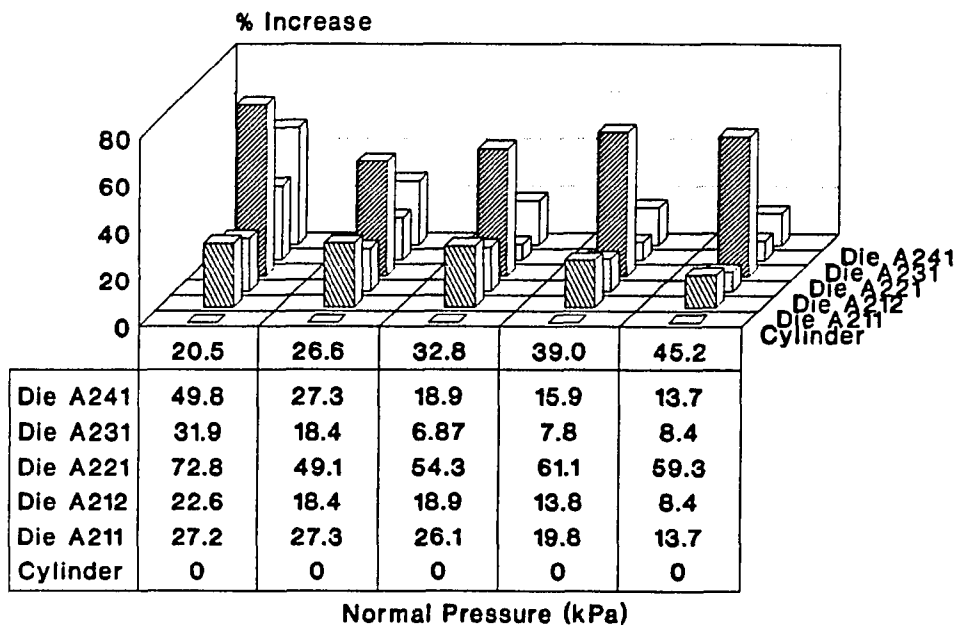


Figure 8.30 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for PS.

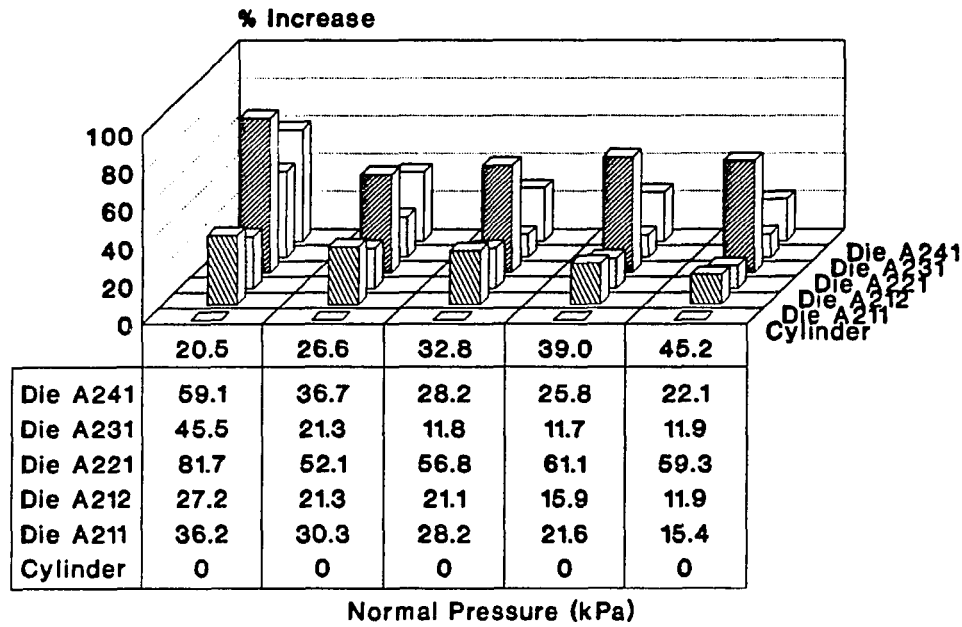


Figure 8.31 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for PS.

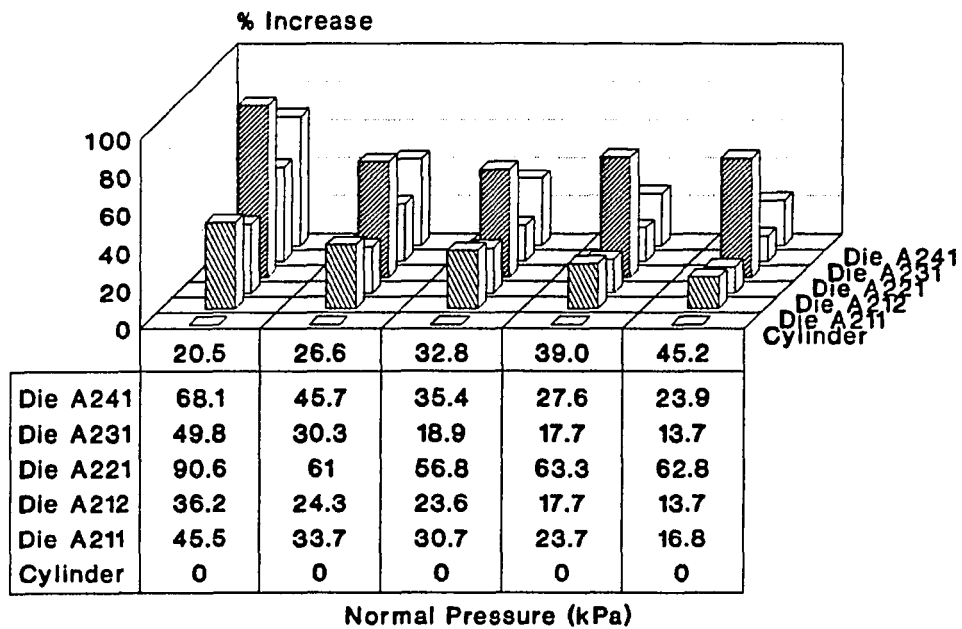


Figure 8.32 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for PS.

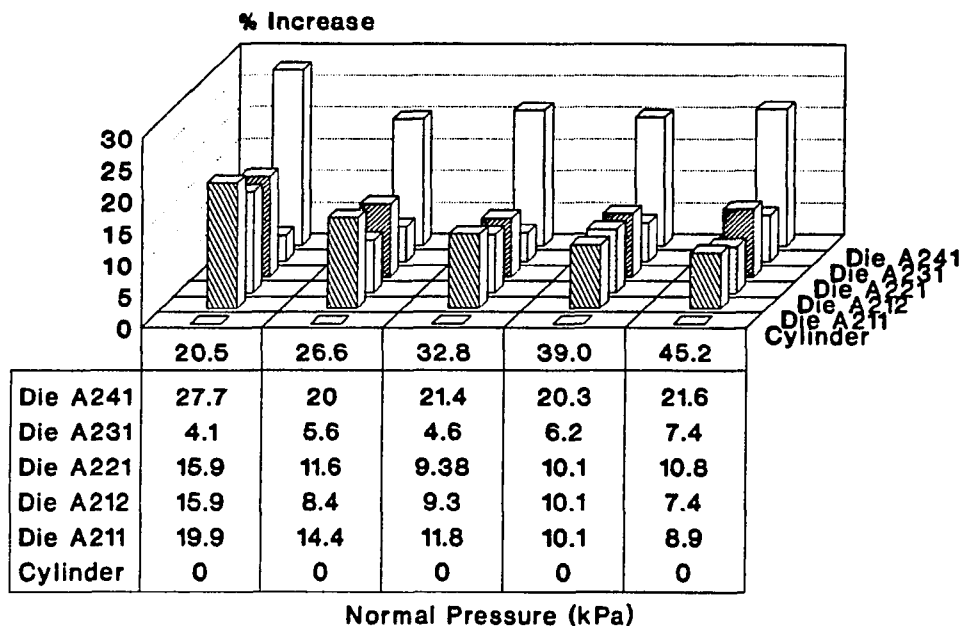


Figure 8.33 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for PA 6.

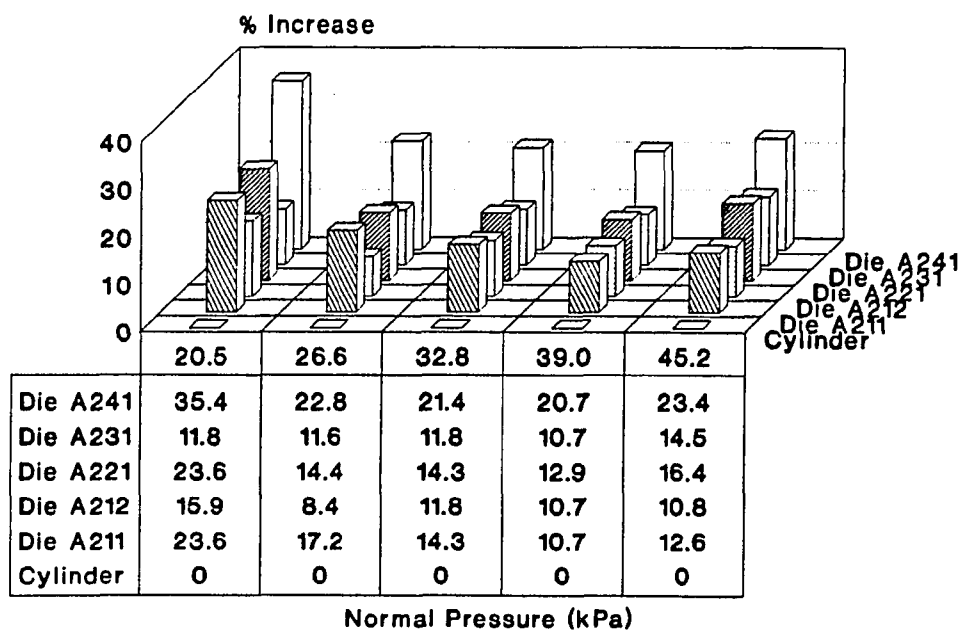


Figure 8.34 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for PA 6.

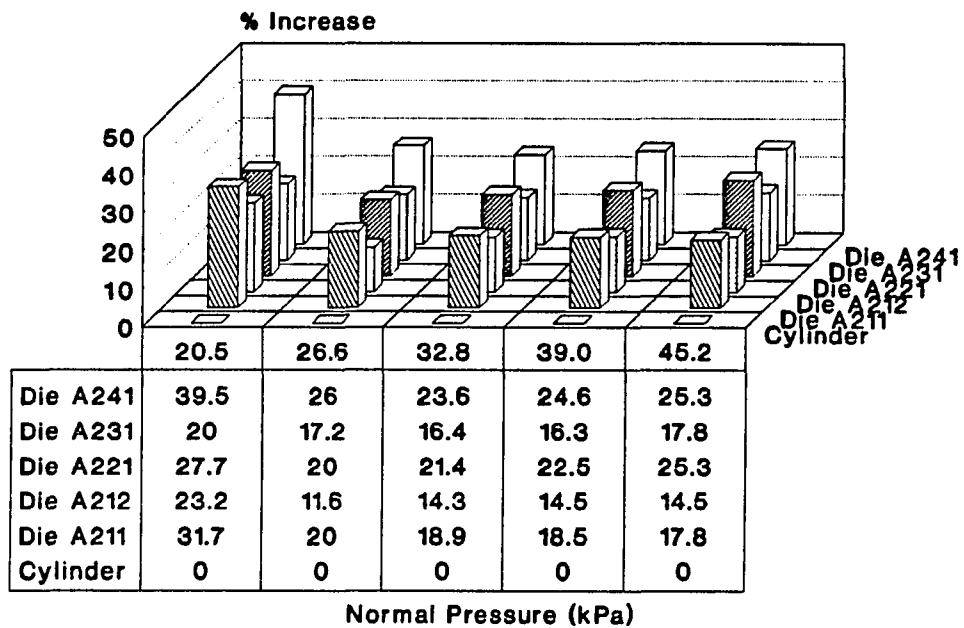


Figure 8.35 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for PA 6.

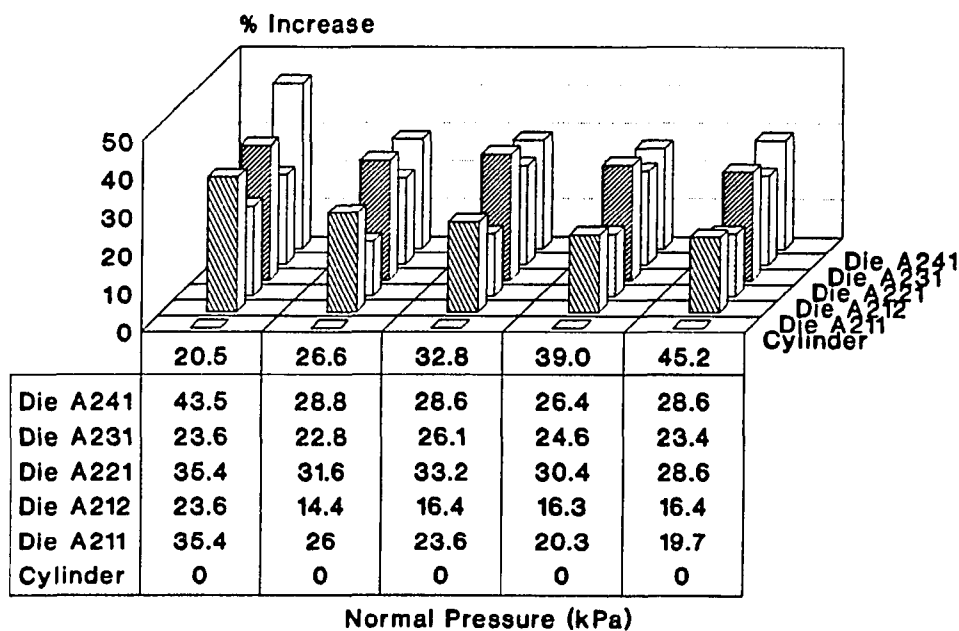


Figure 8.36 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for PA 6.

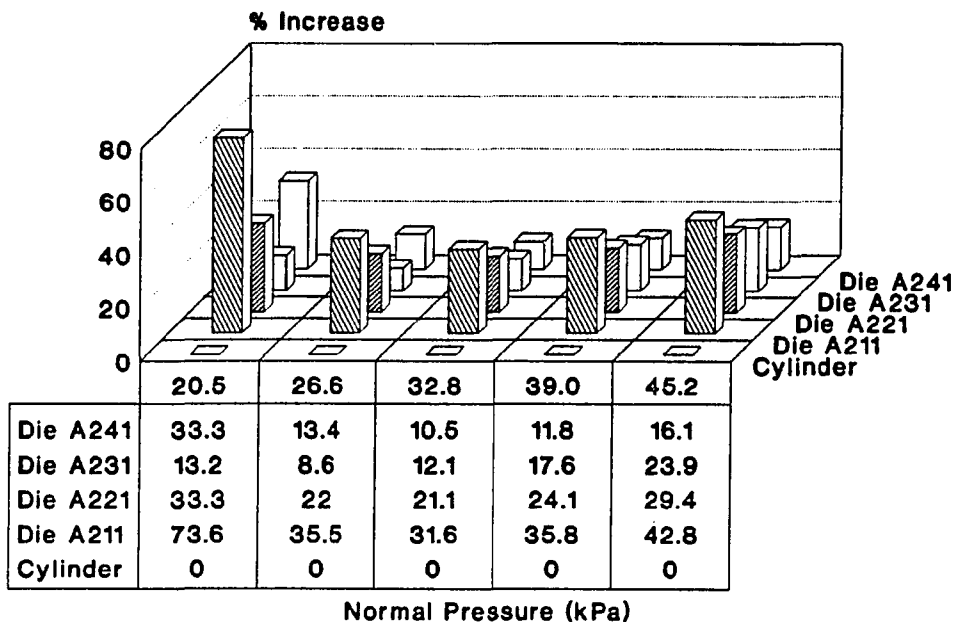


Figure 8.37 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 5rpm for ABS.

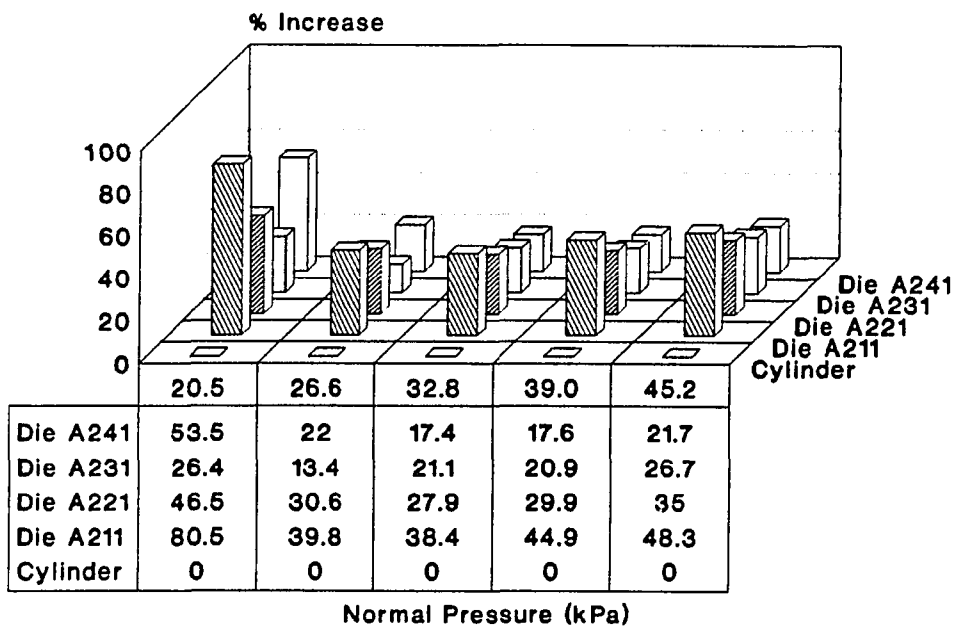


Figure 8.38 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 10rpm for ABS.

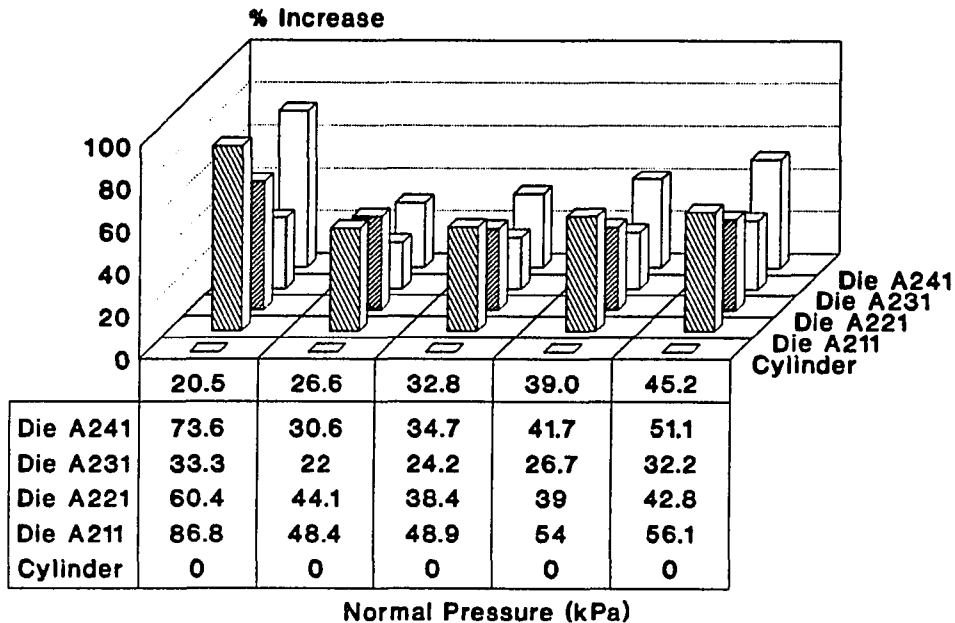


Figure 8.39 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 15rpm for ABS.

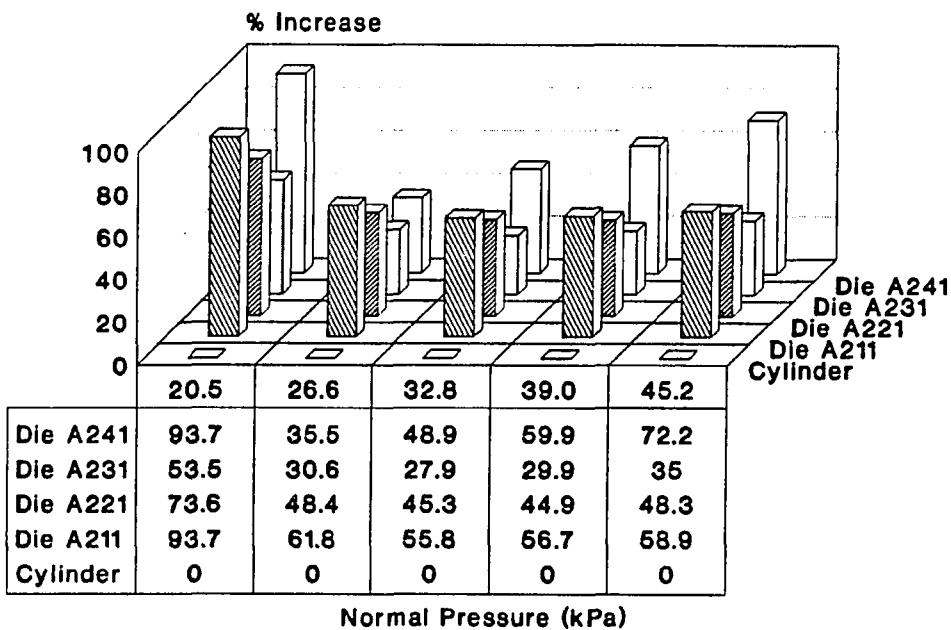


Figure 8.40 % Increase for all Bilobal Pellets Compared to Circular Pellets at an Extruder Screw Speed 20rpm for ABS.

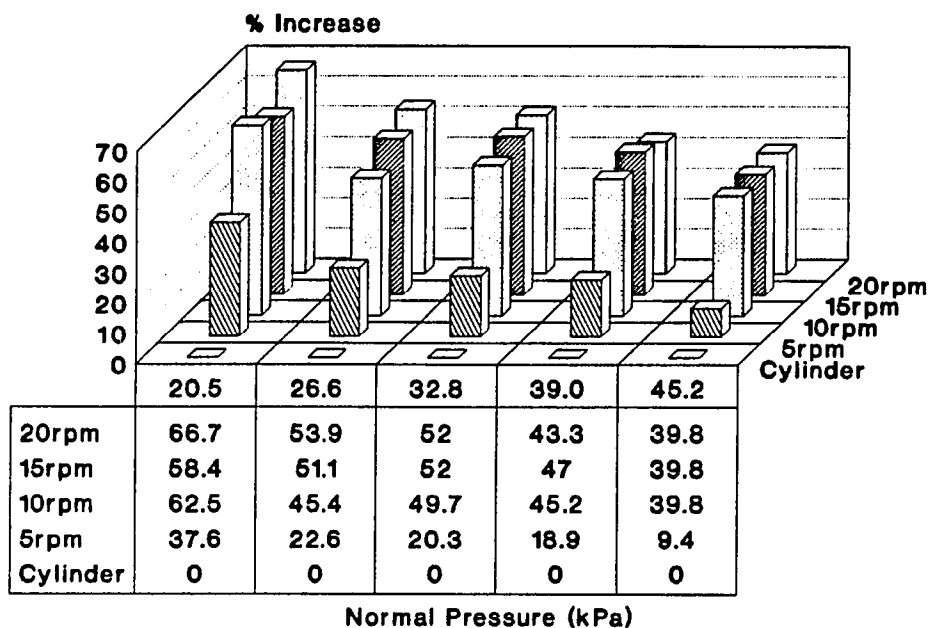


Figure 8.41 % Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM1.

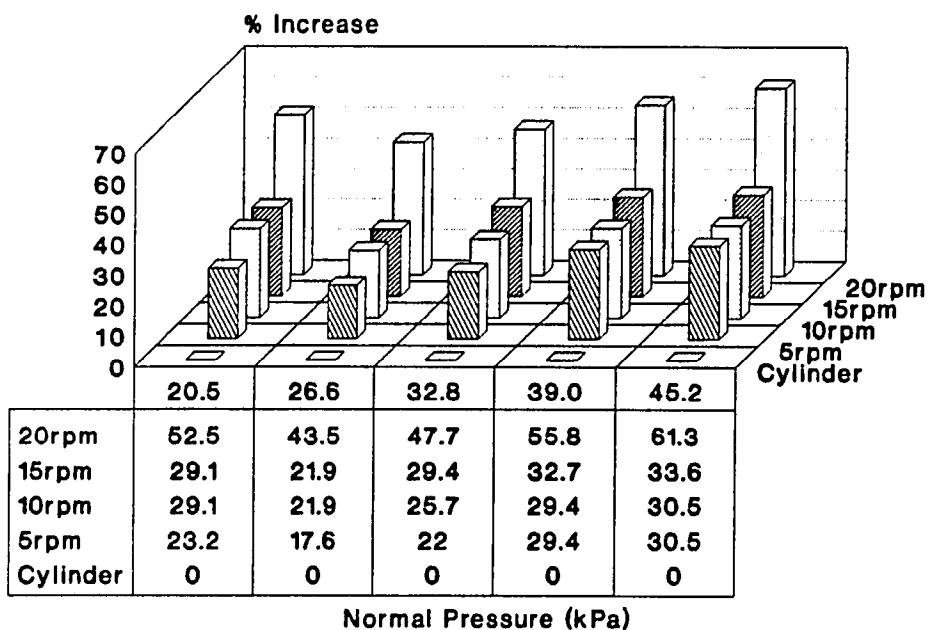


Figure 8.42 % Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM2.

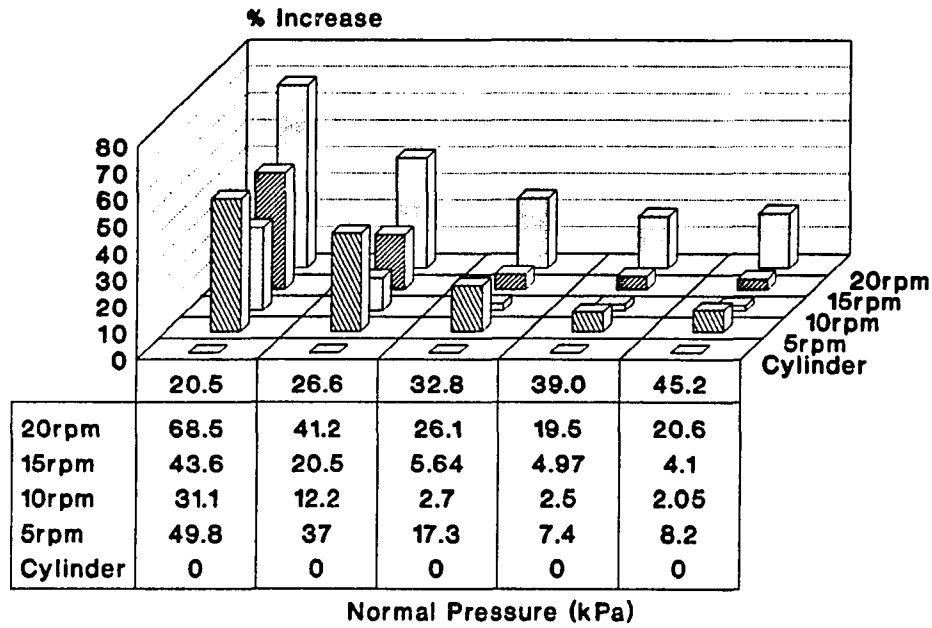


Figure 8.43 % Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM3.

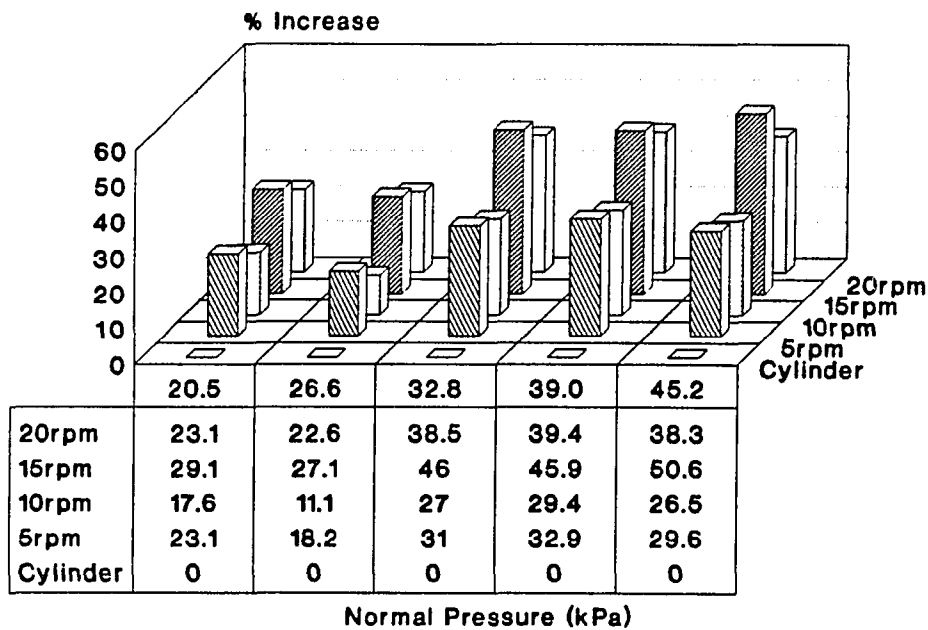


Figure 8.44 % Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM4.

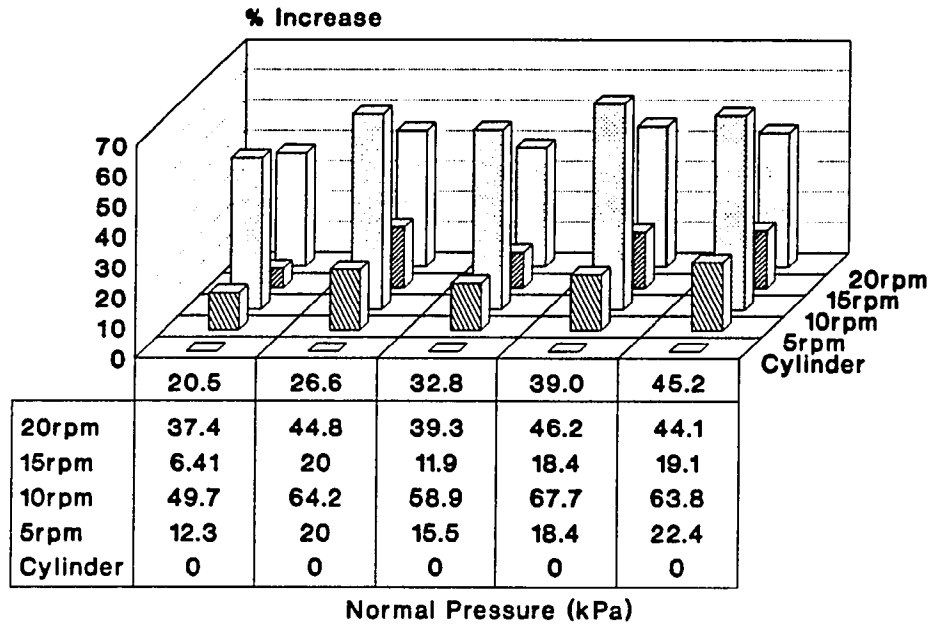


Figure 8.45 % Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM5.

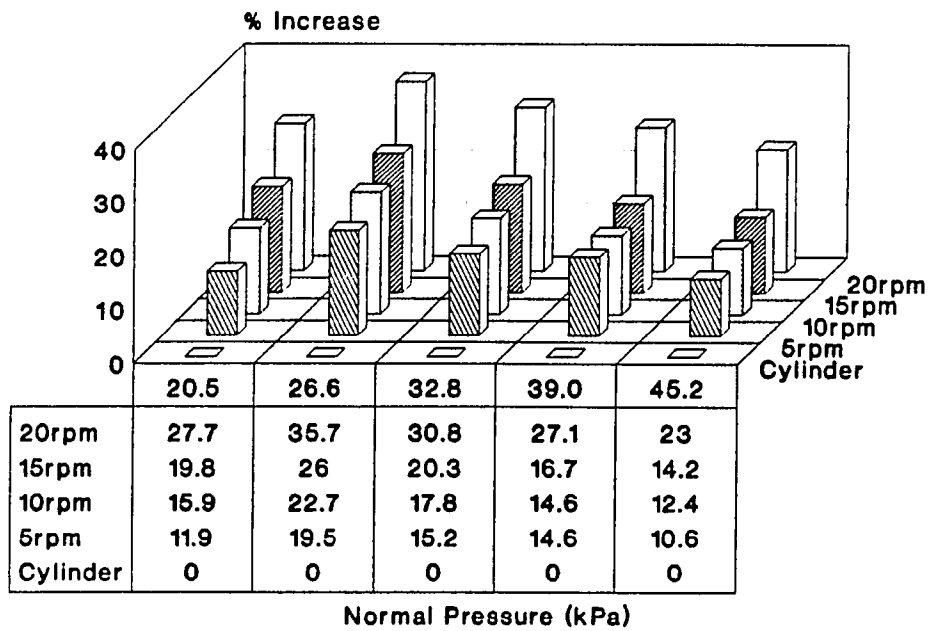


Figure 8.46 % Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PE.

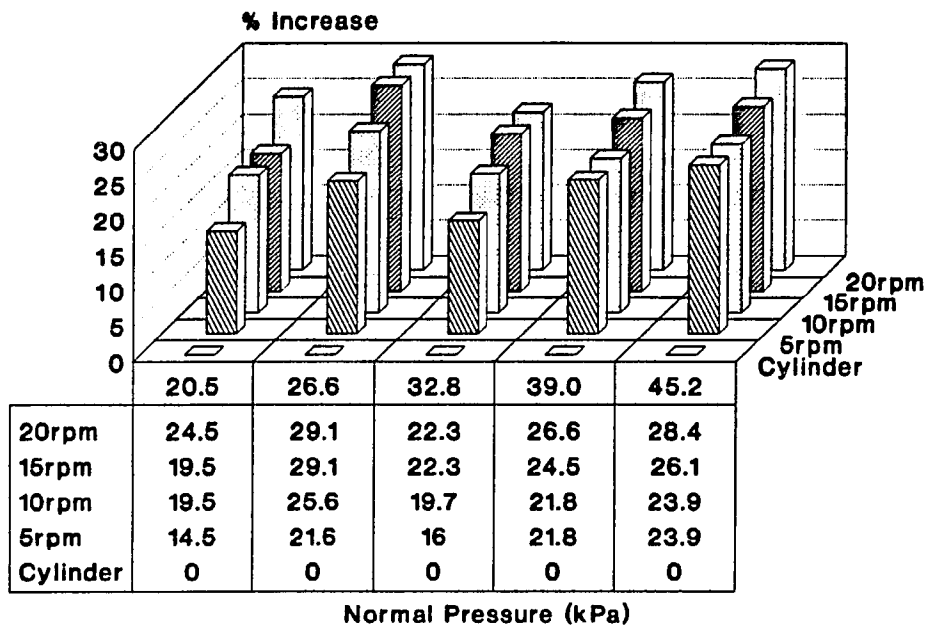


Figure 8.47 % Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PP.

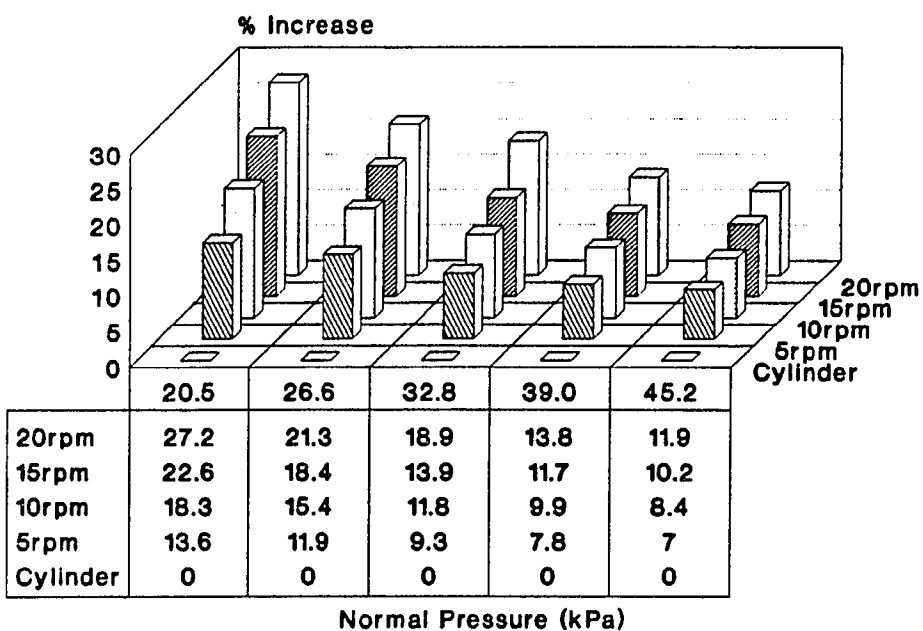


Figure 8.48 % Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PS.

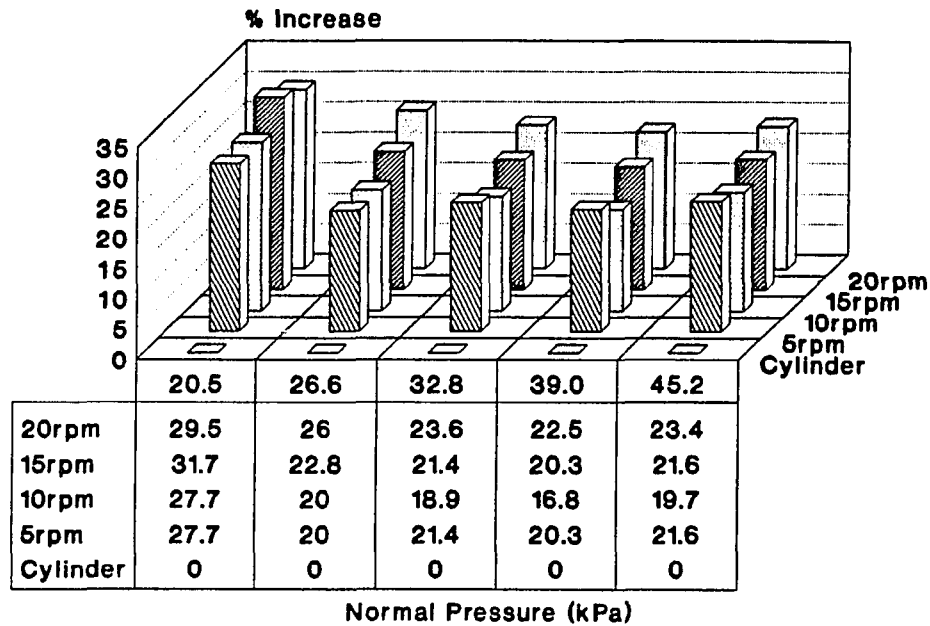


Figure 8.49 % Increase for Trilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PA 6.

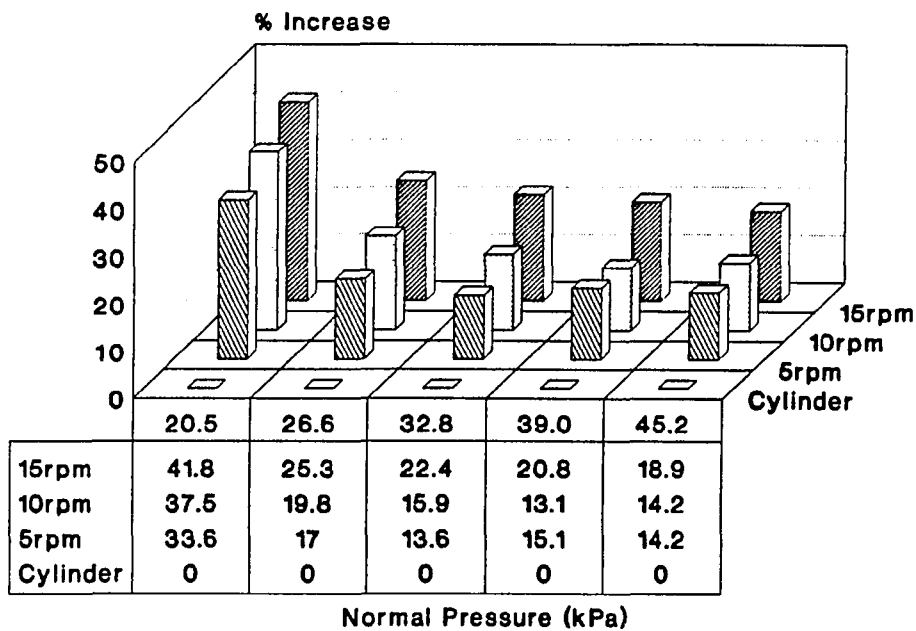


Figure 8.50 % Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM1.

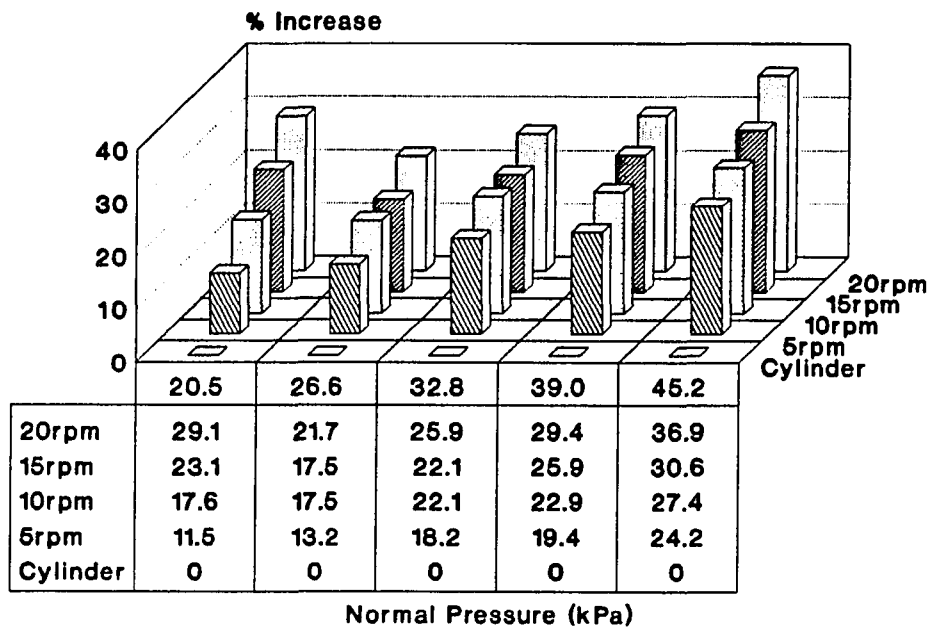


Figure 8.51 % Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM2.

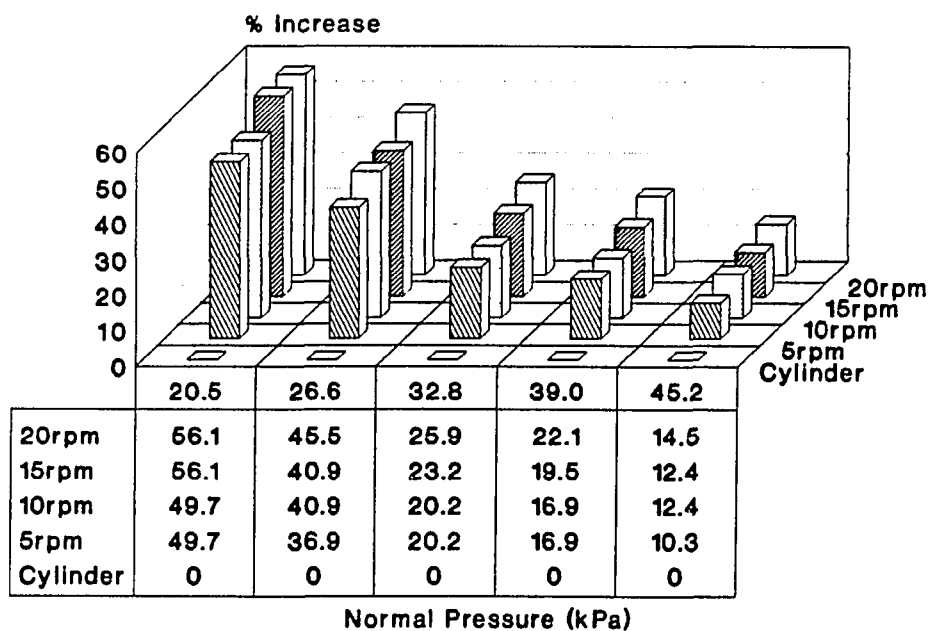


Figure 8.52 % Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM3.

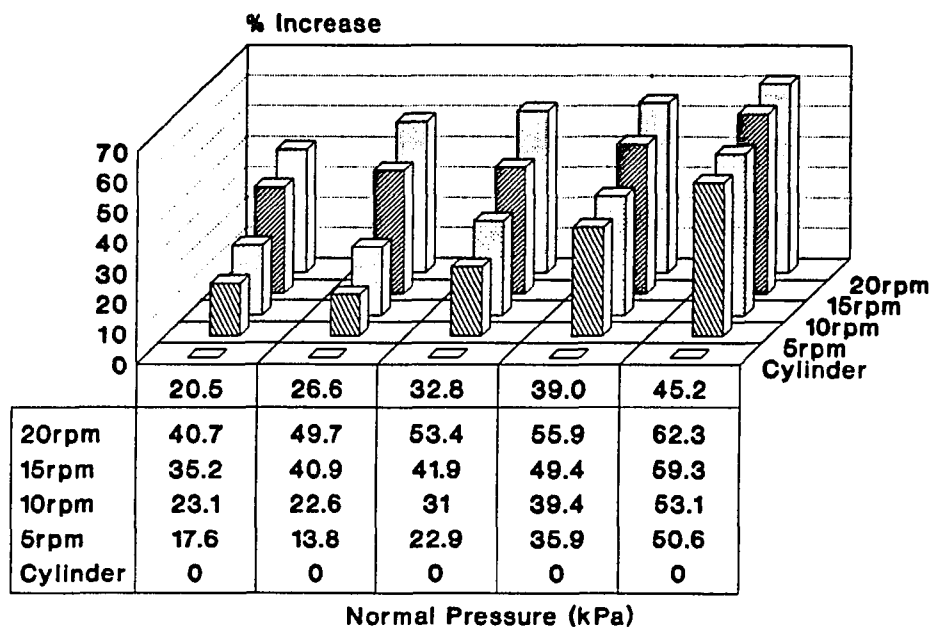


Figure 8.53 % Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM4.

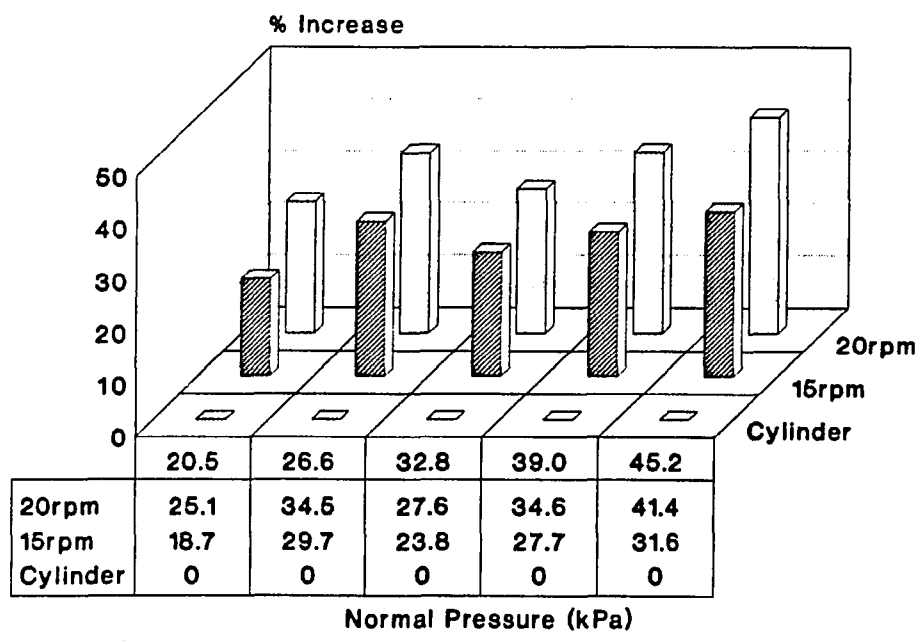


Figure 8.54 % Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for POM5.

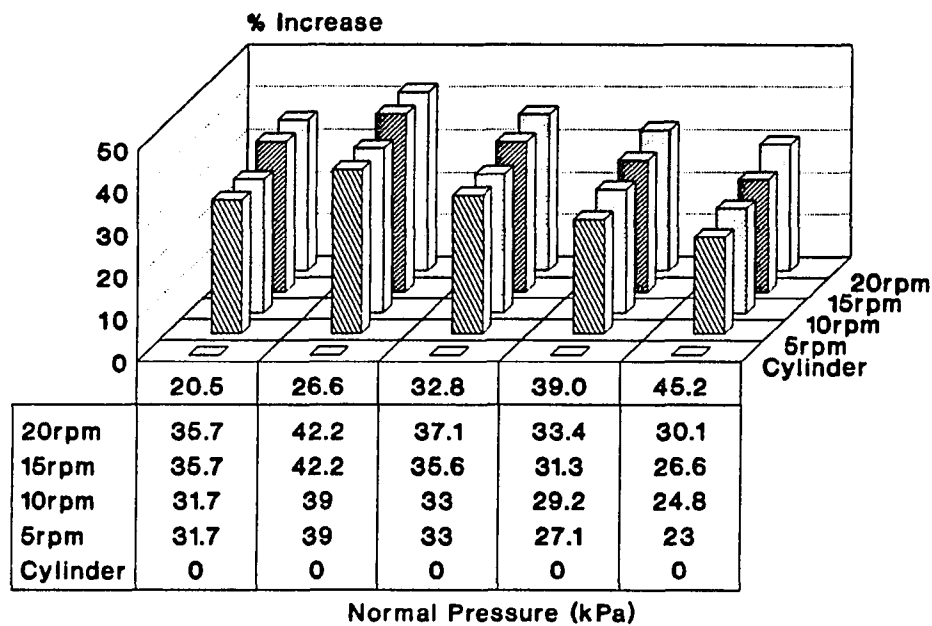


Figure 8.55 % Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PE.

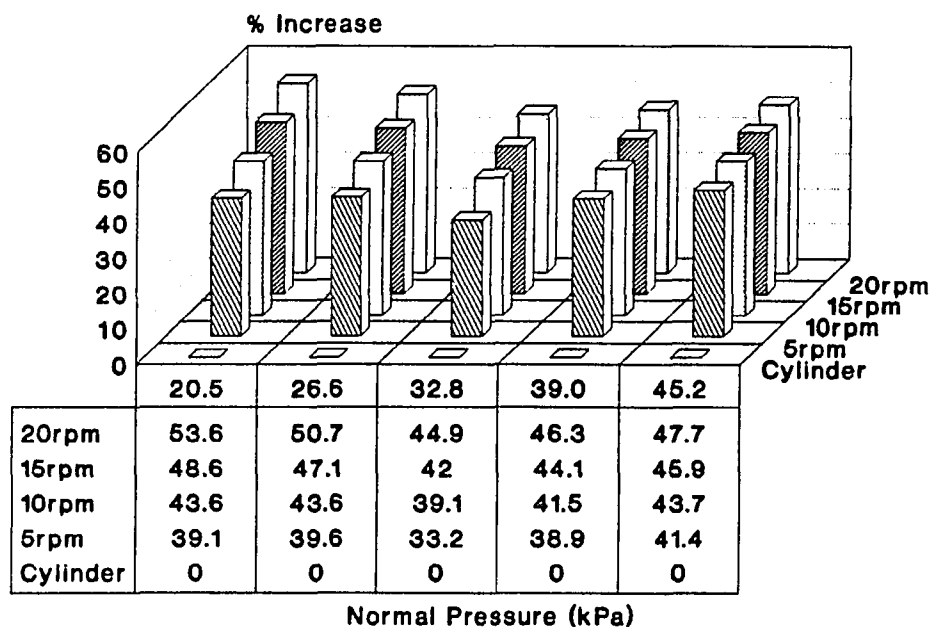


Figure 8.56 % Increase for Quadrilobal Pellets Compared to Circular Pellets at Four Different Extruder Screw Speed for PP.

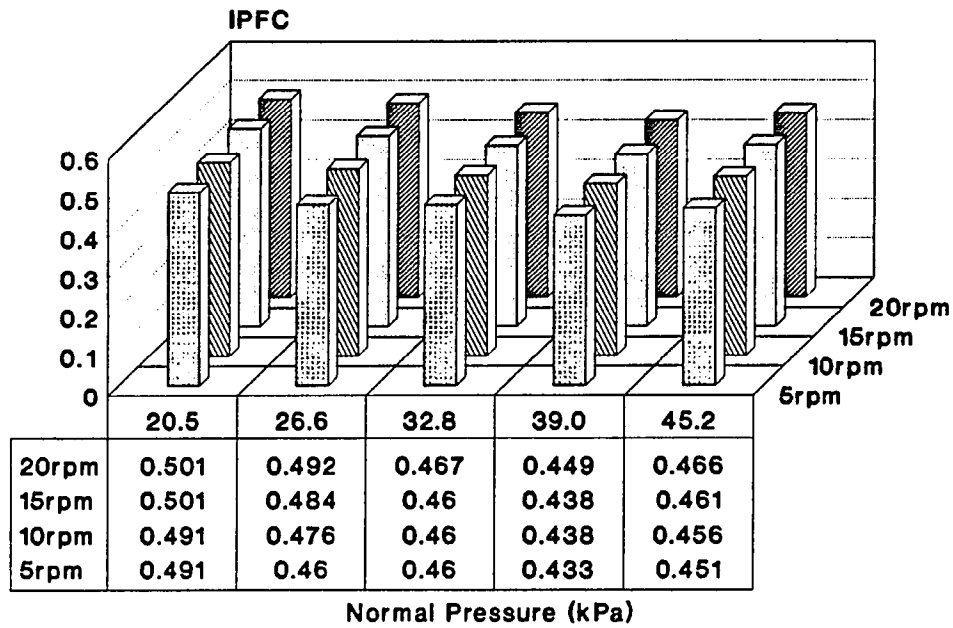


Figure 8.57 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM1 with Agitation.

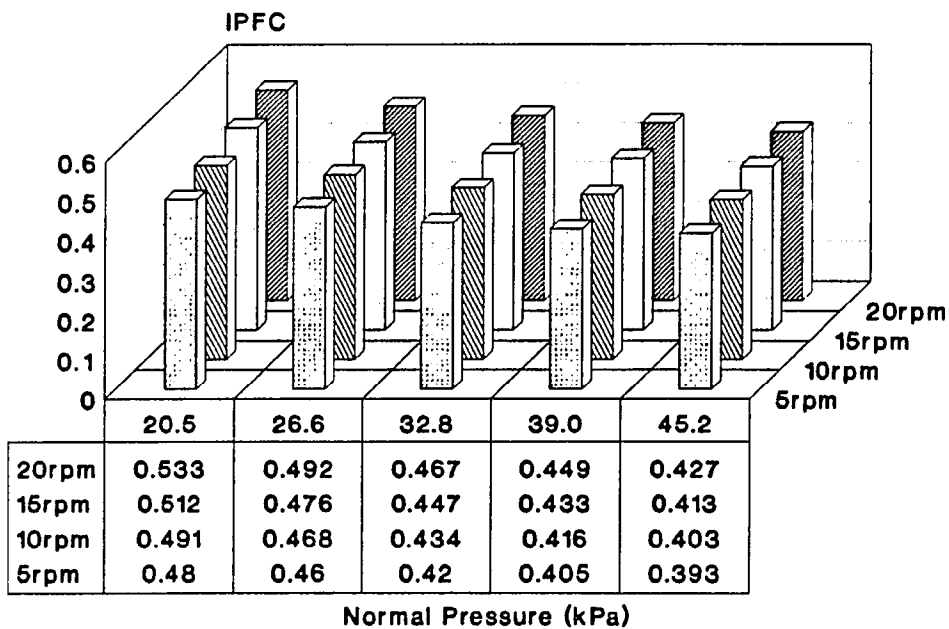


Figure 8.58 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM2 with Agitation.

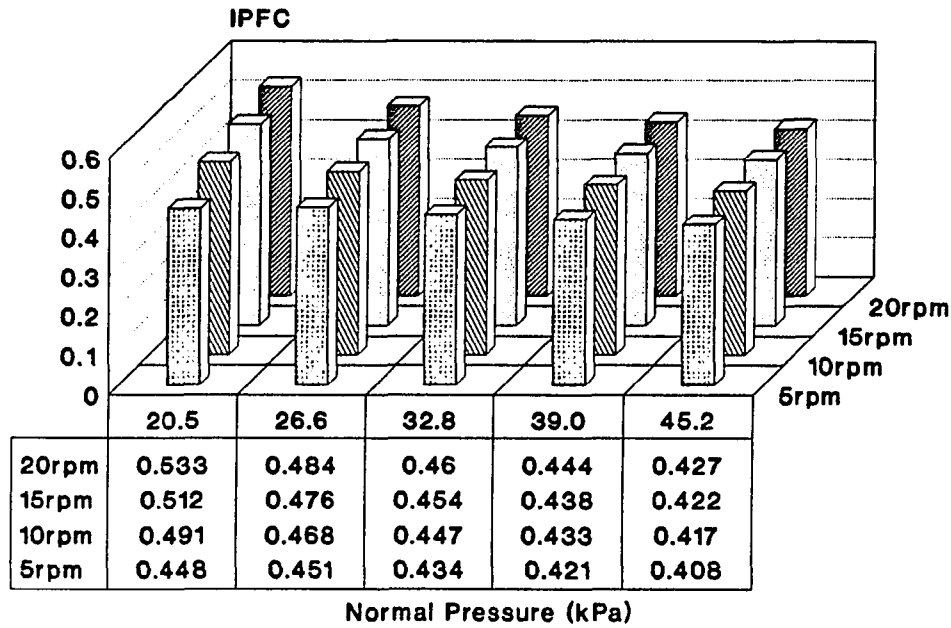


Figure 8.59 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM3 with Agitation.

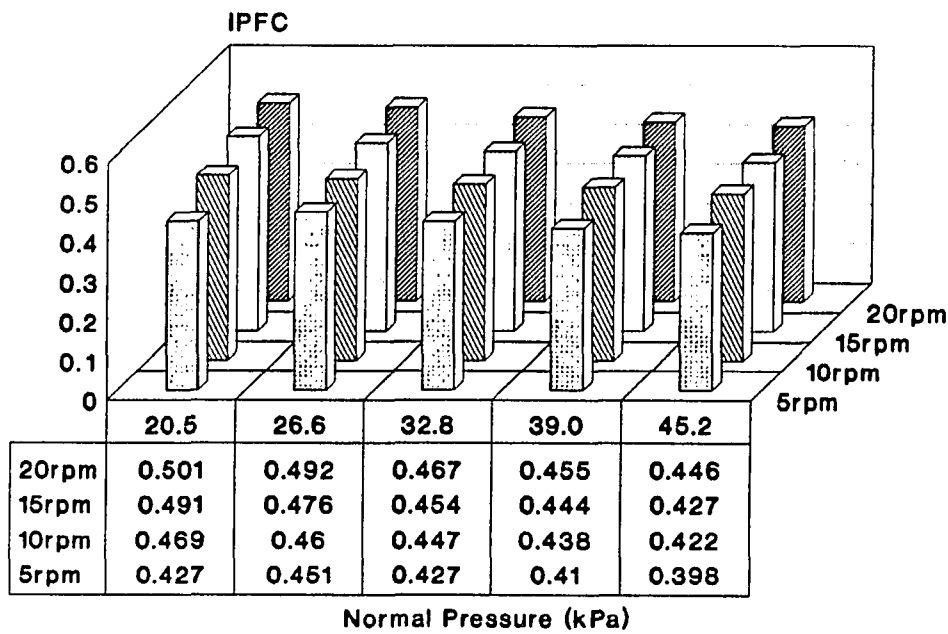


Figure 8.60 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM4 with Agitation.

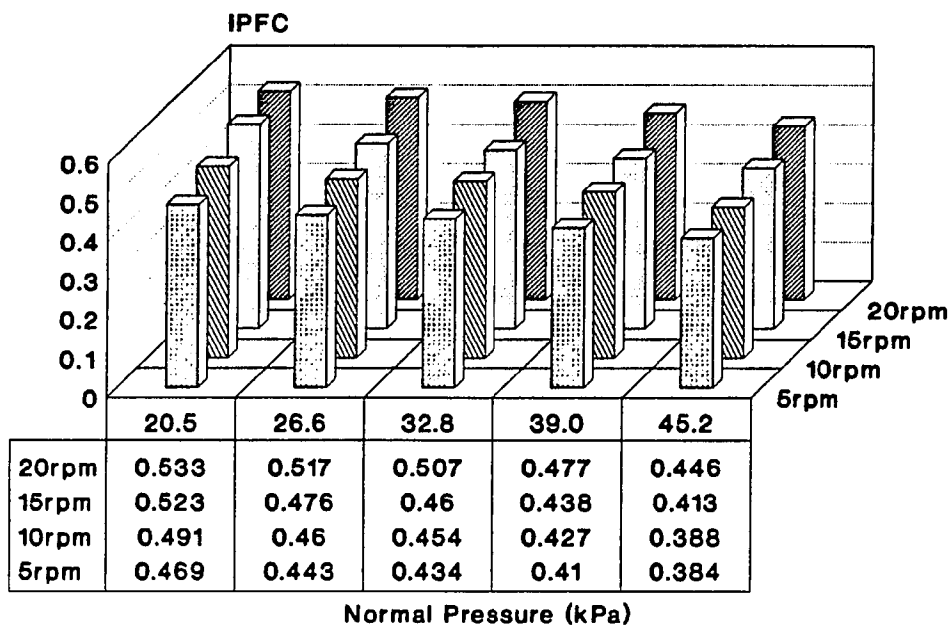


Figure 8.61 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for POM5 with Agitation.

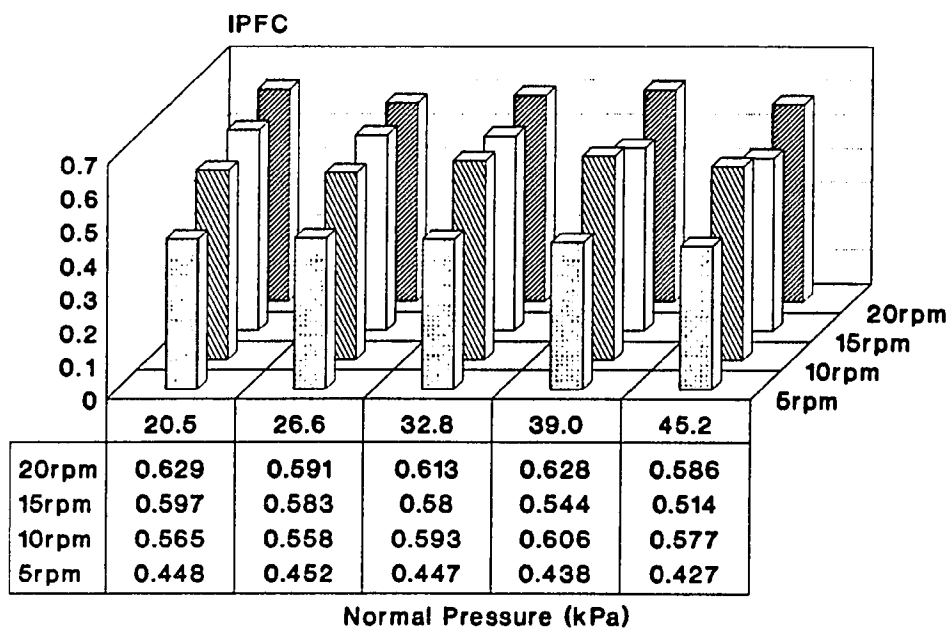


Figure 8.62 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM1 with Agitation.

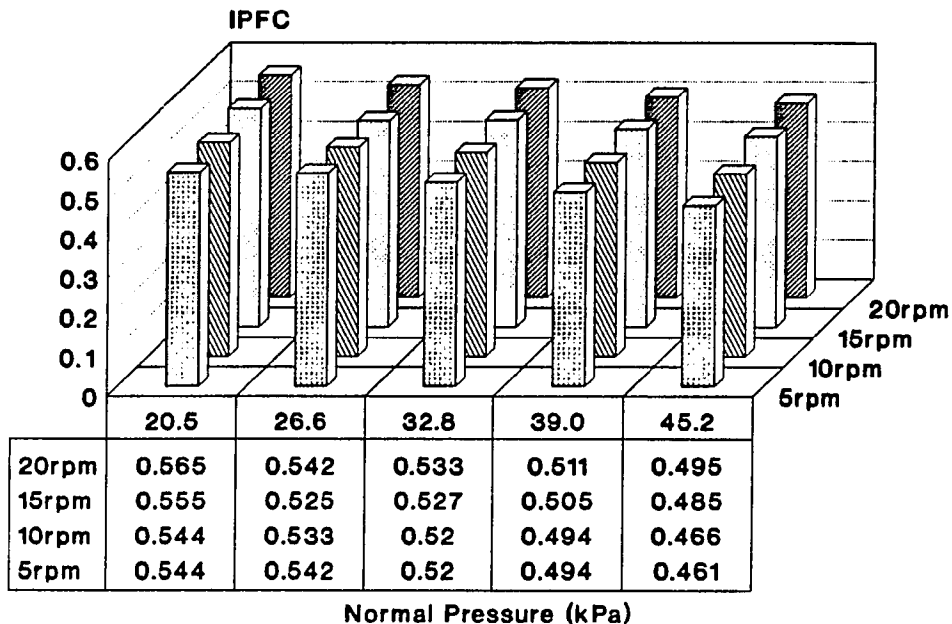


Figure 8.63 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM2 with Agitation.

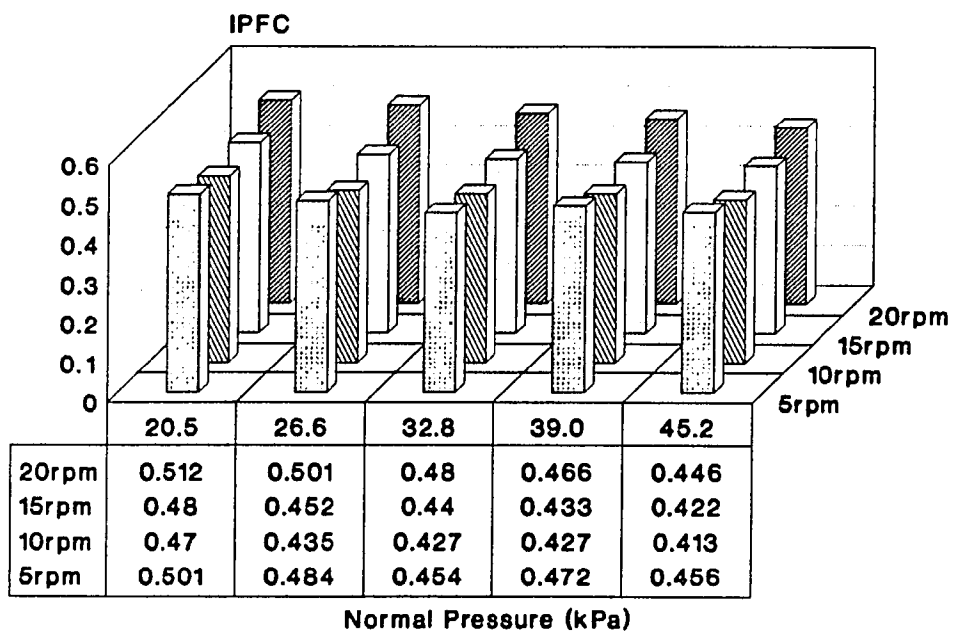


Figure 8.64 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM3 with Agitation.

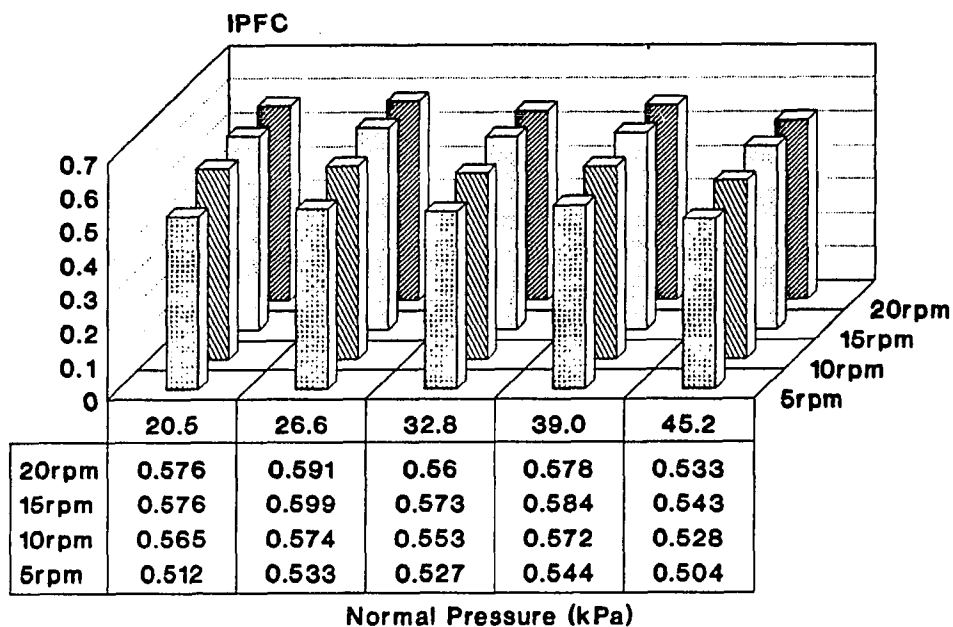


Figure 8.65 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM4 with Agitation.

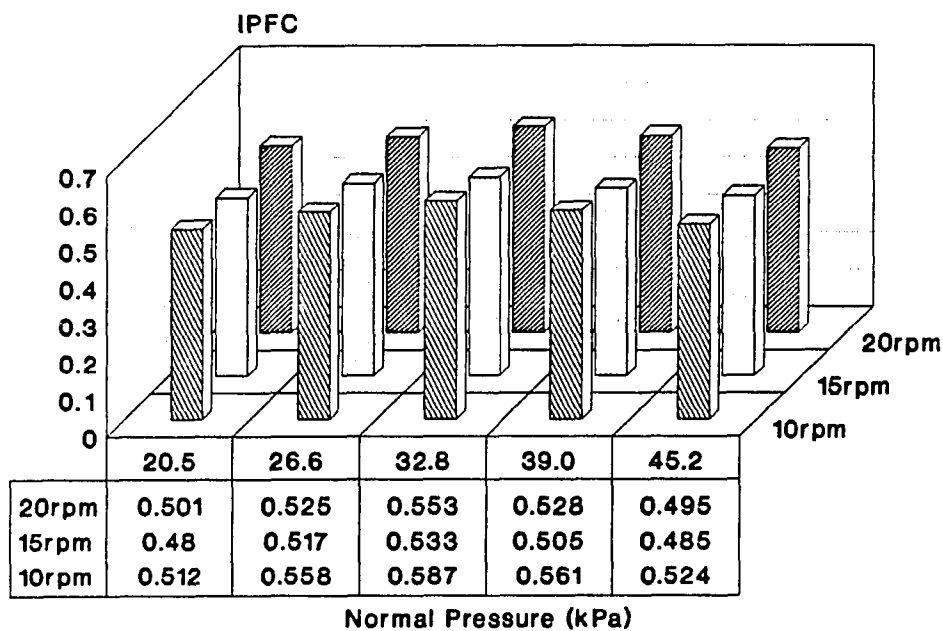


Figure 8.66 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for POM5 with Agitation.

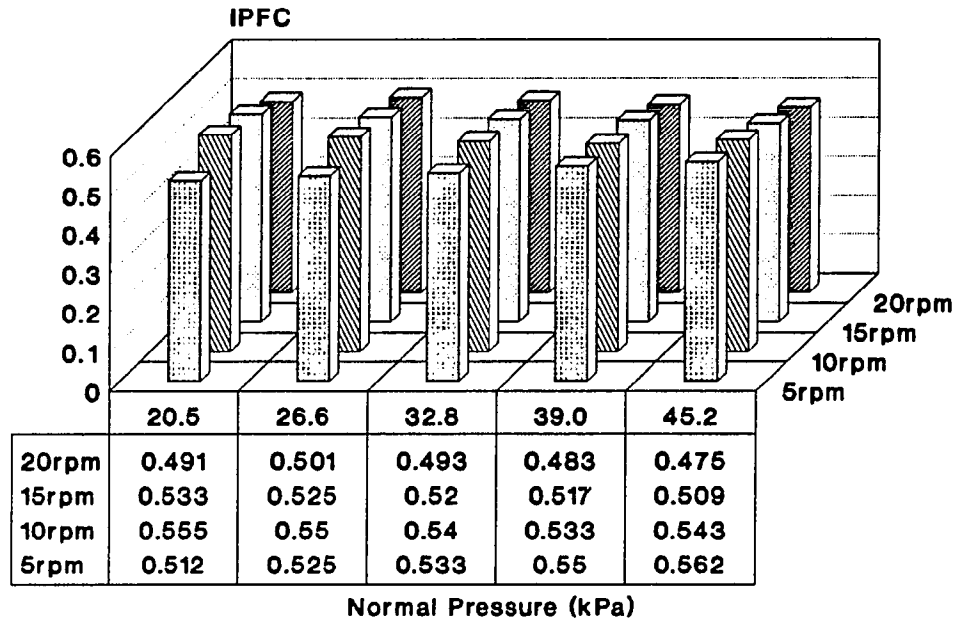


Figure 8.67 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM1 with Agitation.

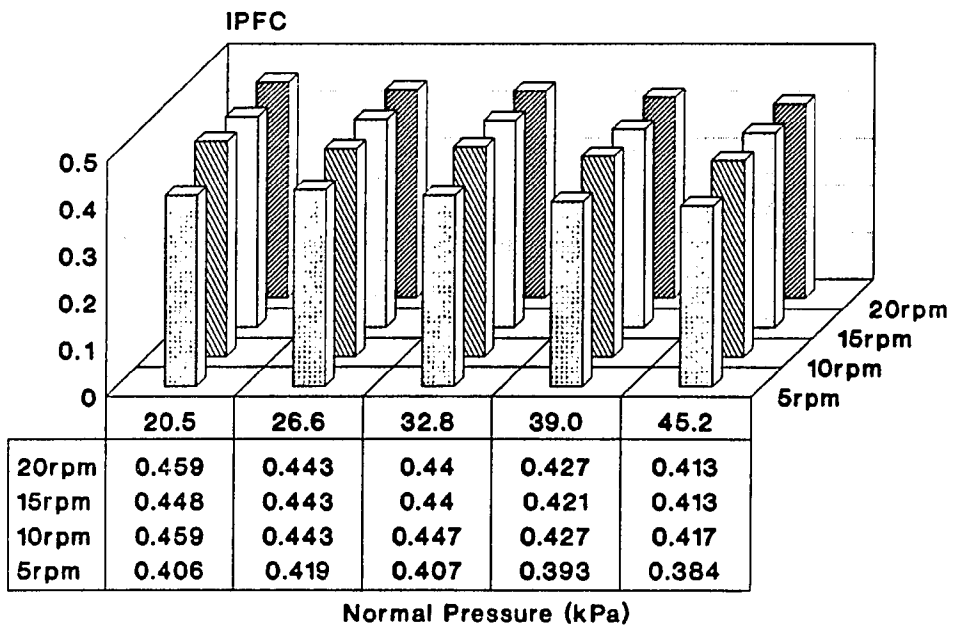


Figure 8.68 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM2 with Agitation.

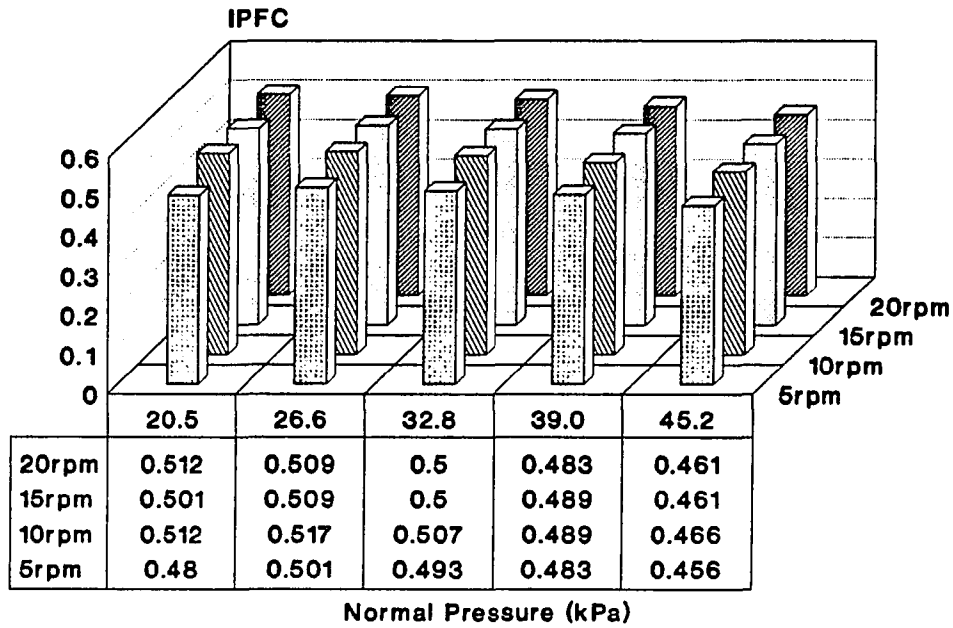


Figure 8.69 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM3 with Agitation.

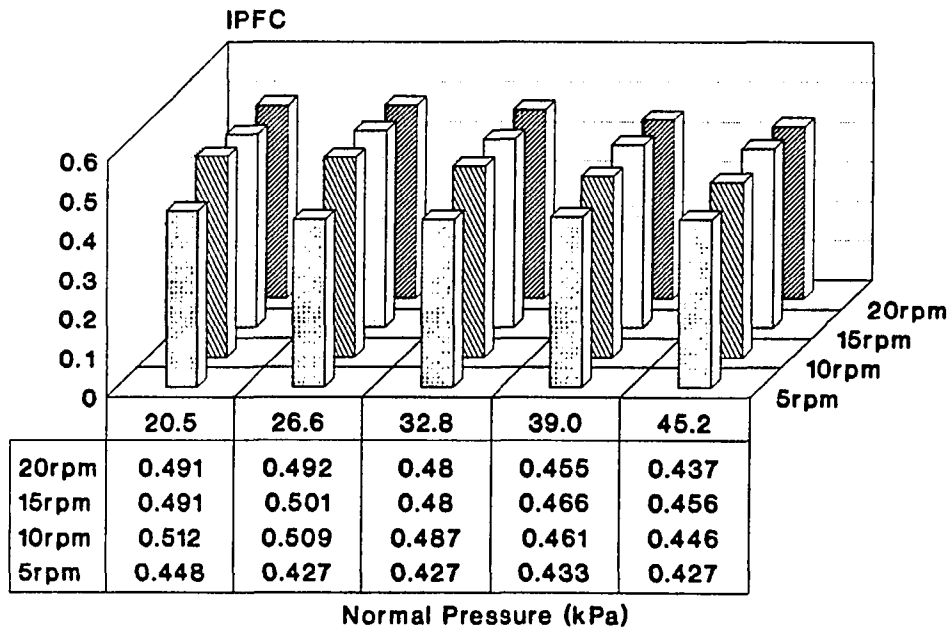


Figure 8.70 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM4 with Agitation.

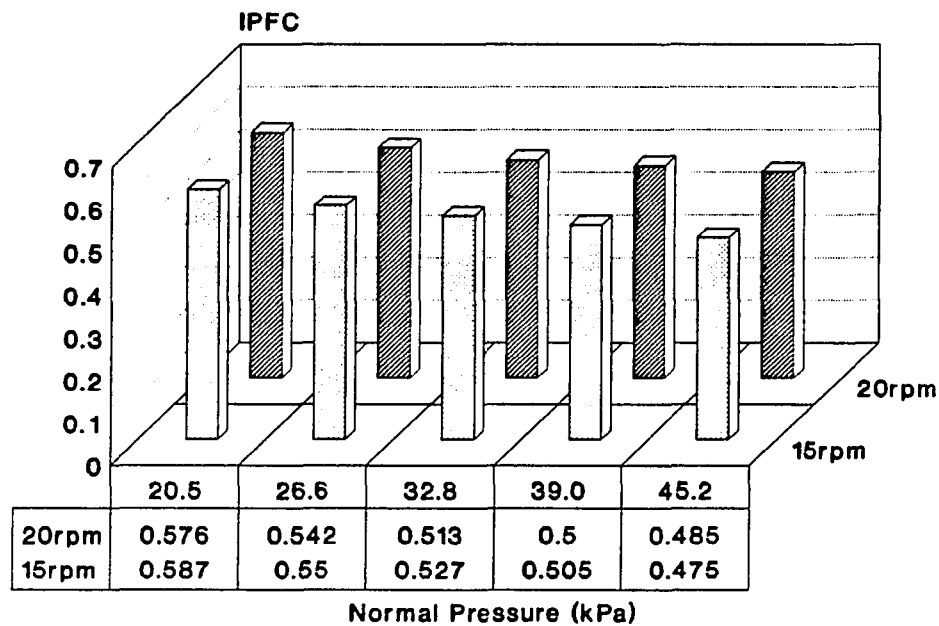


Figure 8.71 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for POM5 with Agitation.

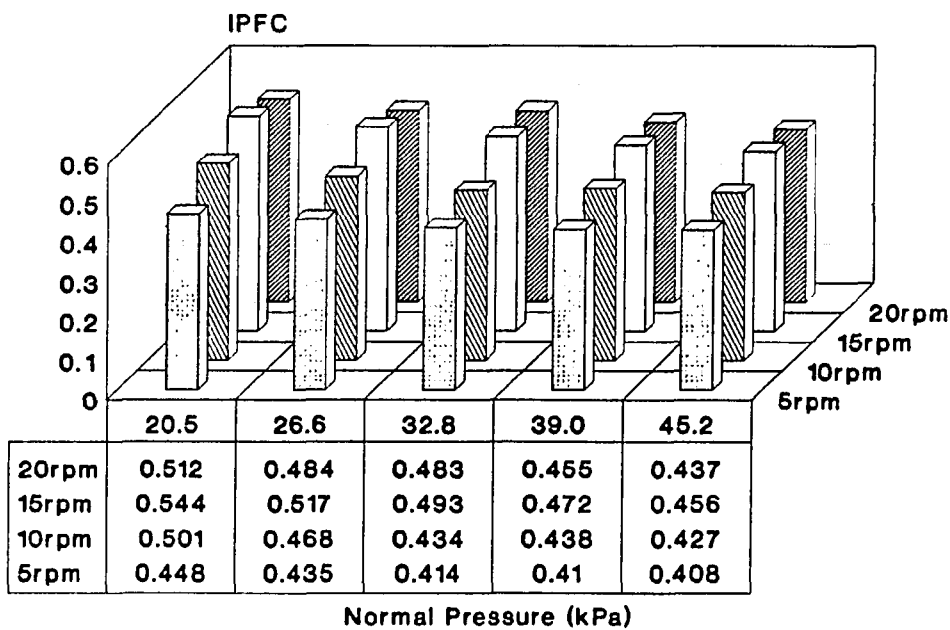


Figure 8.72 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM1 with Agitation.

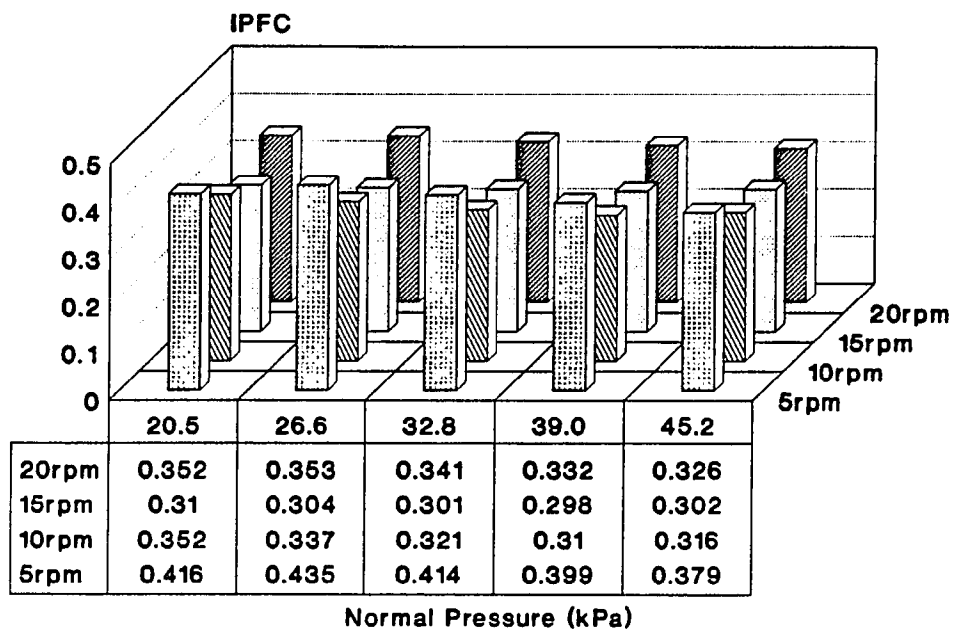


Figure 8.73 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM2 with Agitation.

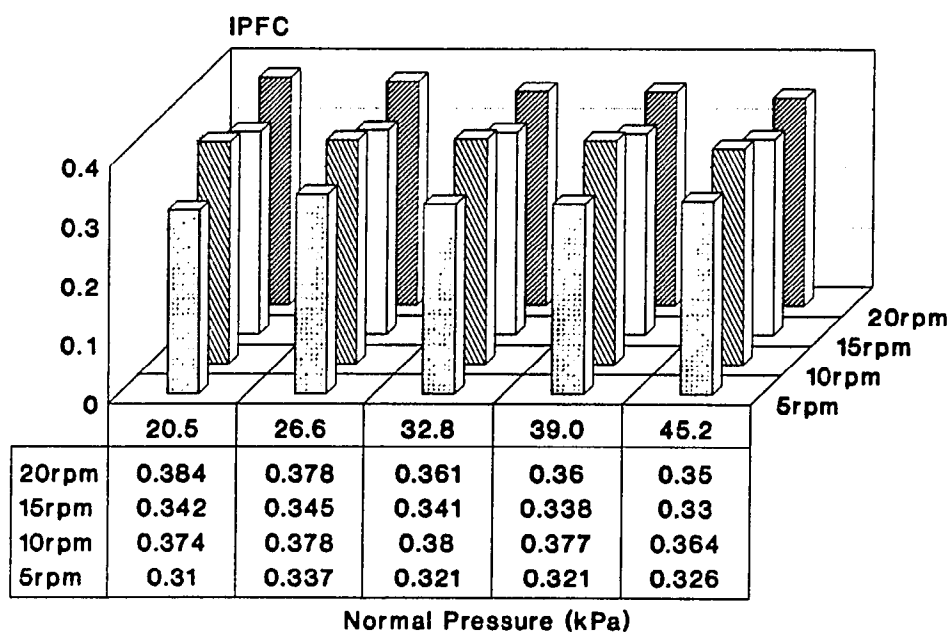


Figure 8.74 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM3 with Agitation.

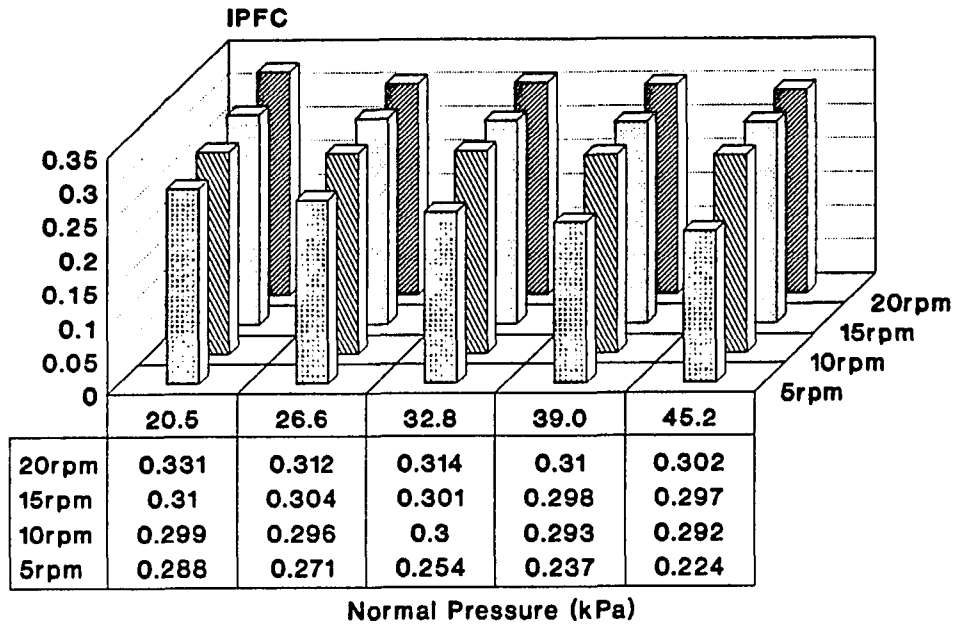


Figure 8.75 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM4 with Agitation.

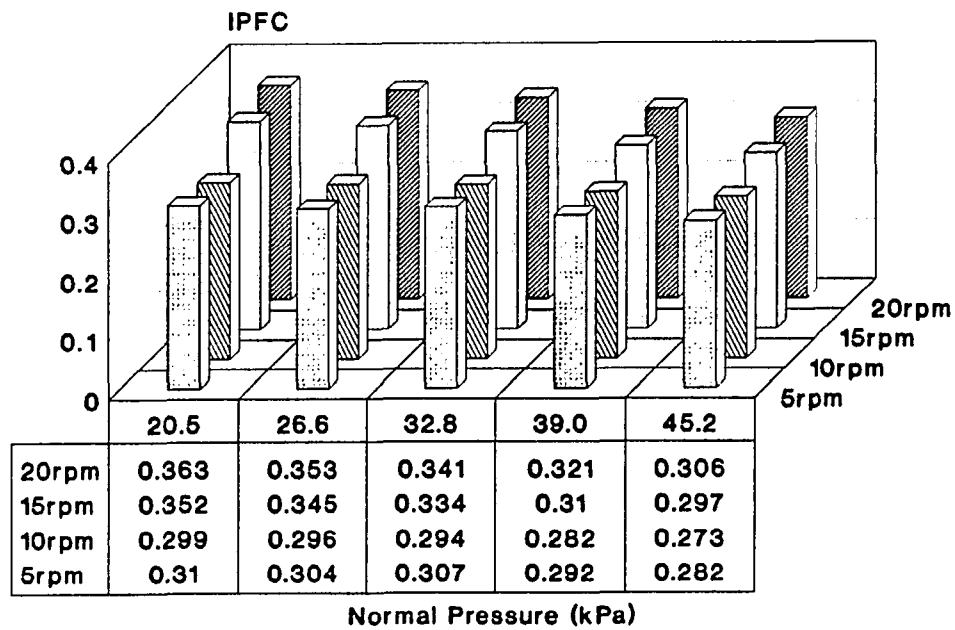


Figure 8.76 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for POM5 with Agitation.

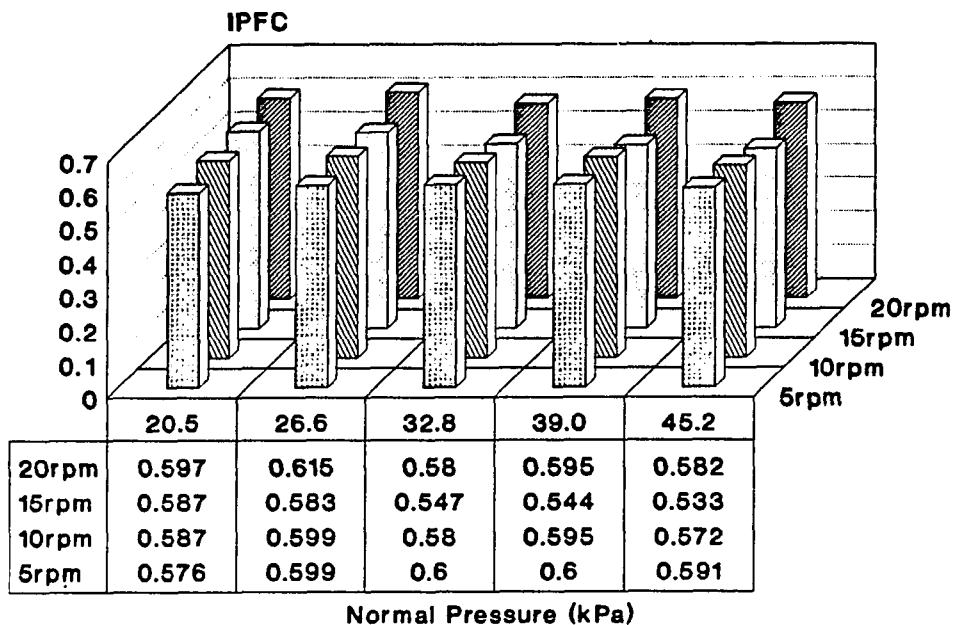


Figure 8.77 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM1 with Agitation.

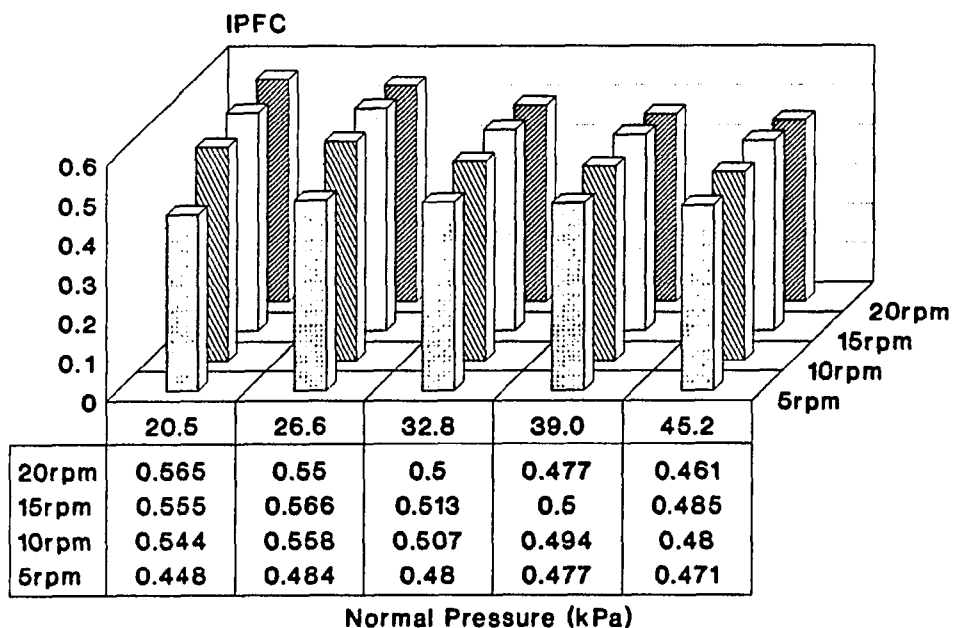


Figure 8.78 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM2 with Agitation..

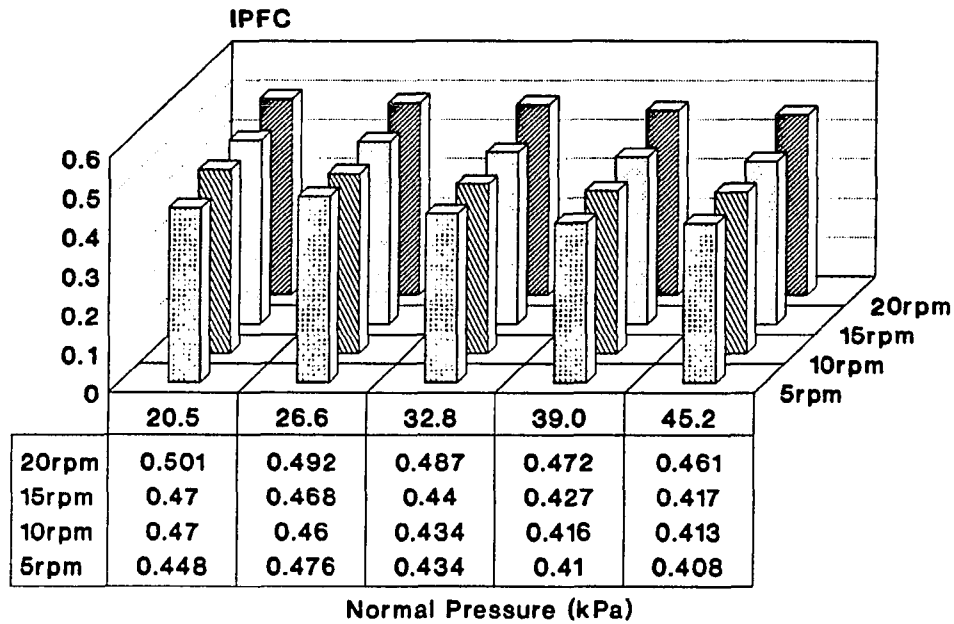


Figure 8.79 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM3 with Agitation.

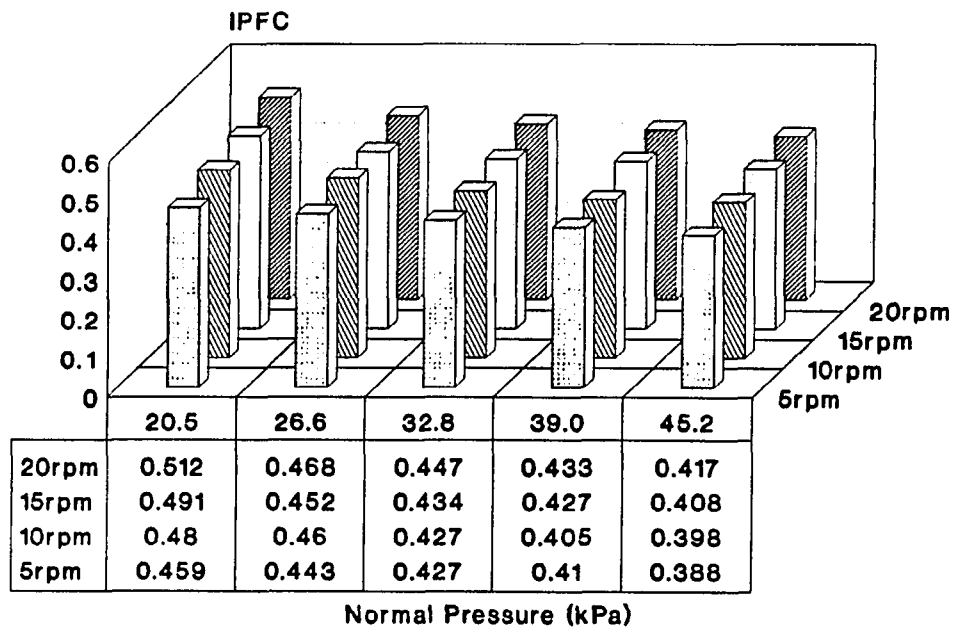


Figure 8.80 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM4 with Agitation.

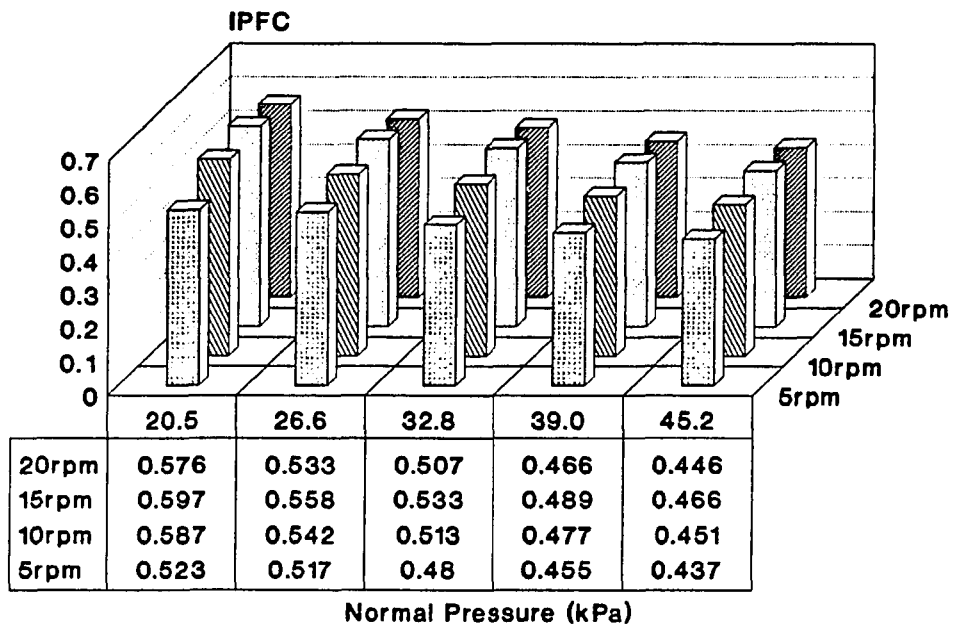


Figure 8.81 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for POM5 with Agitation.

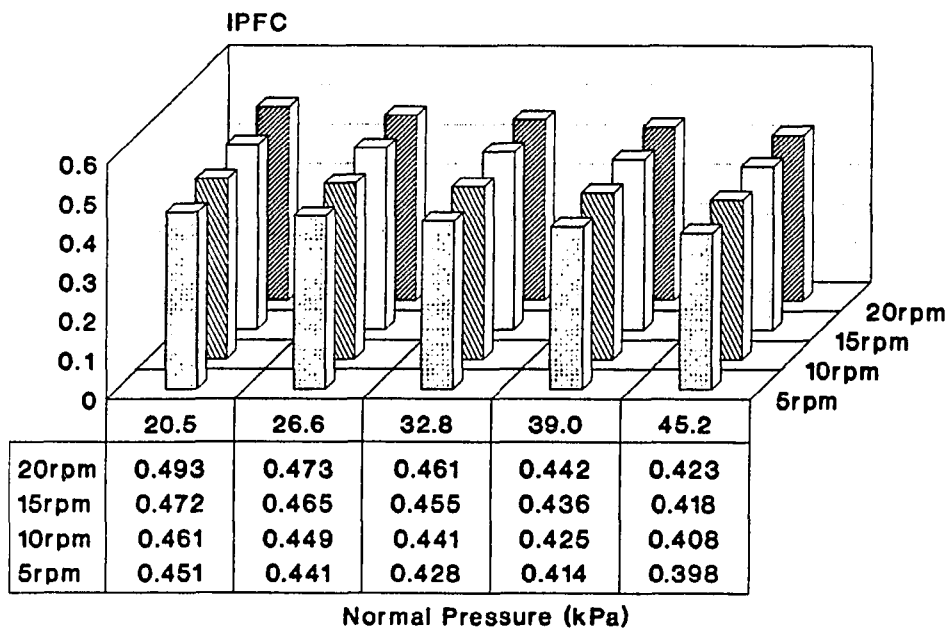


Figure 8.82 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PE with Agitation.

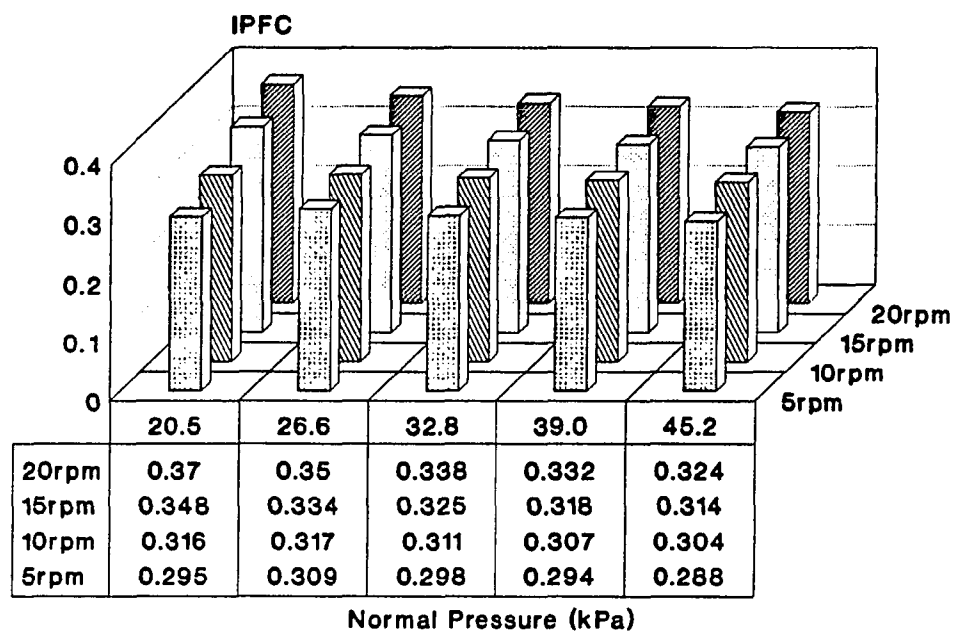


Figure 8.83 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PP with Agitation.

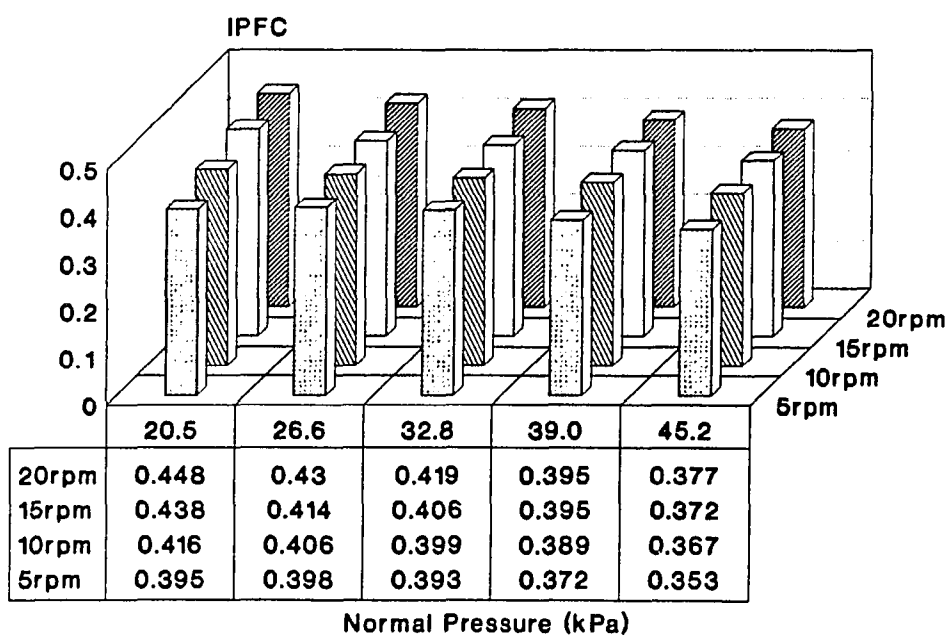


Figure 8.84 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PS with Agitation.

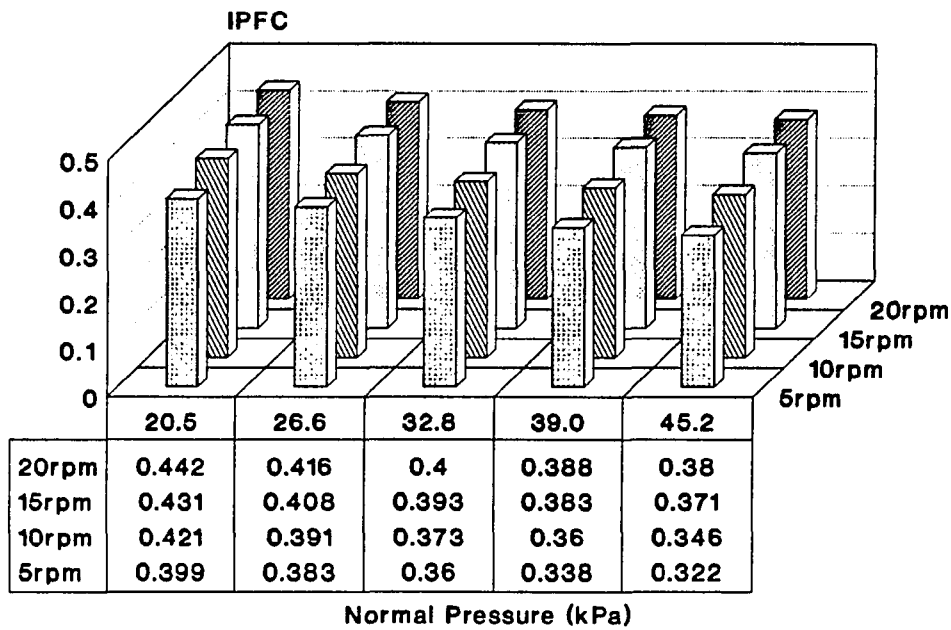


Figure 8.85 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for PA 6 with Agitation.

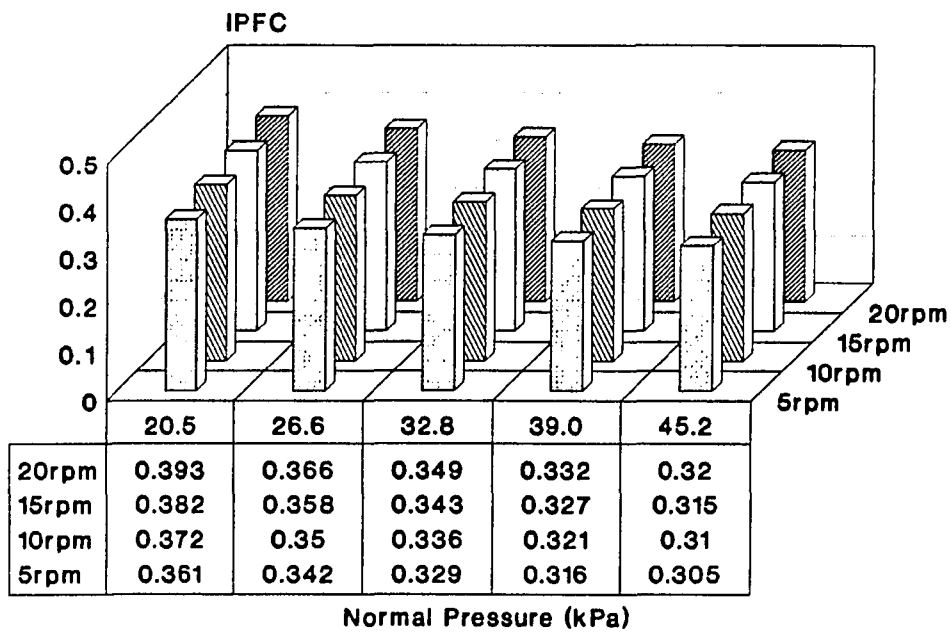


Figure 8.86 IPFC for Pellets Manufactured Using Die A211 as a Function of Normal Pressure for ABS with Agitation.

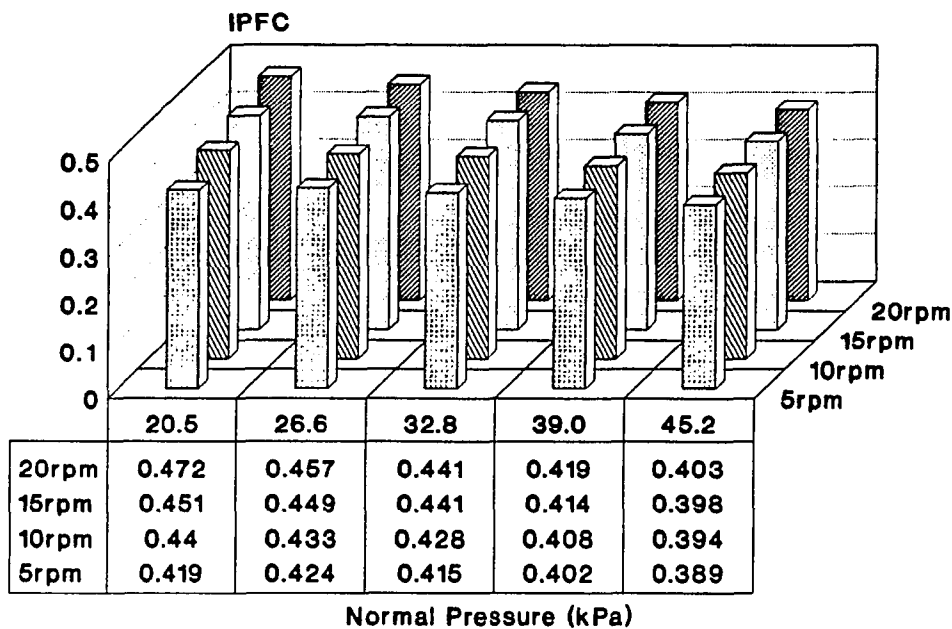


Figure 8.87 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PE with Agitation.

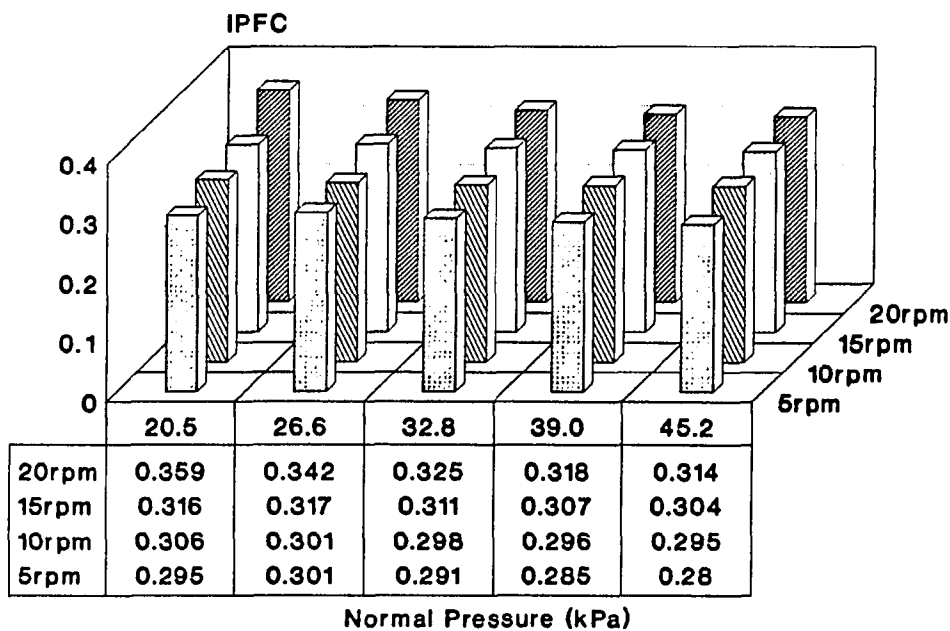


Figure 8.88 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PP with Agitation.

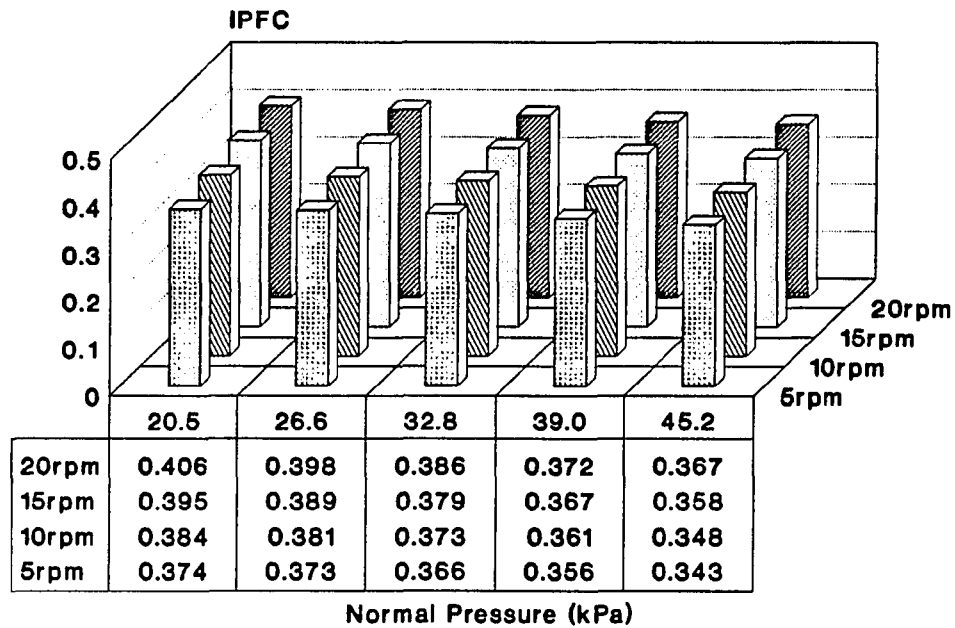


Figure 8.89 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PS with Agitation.

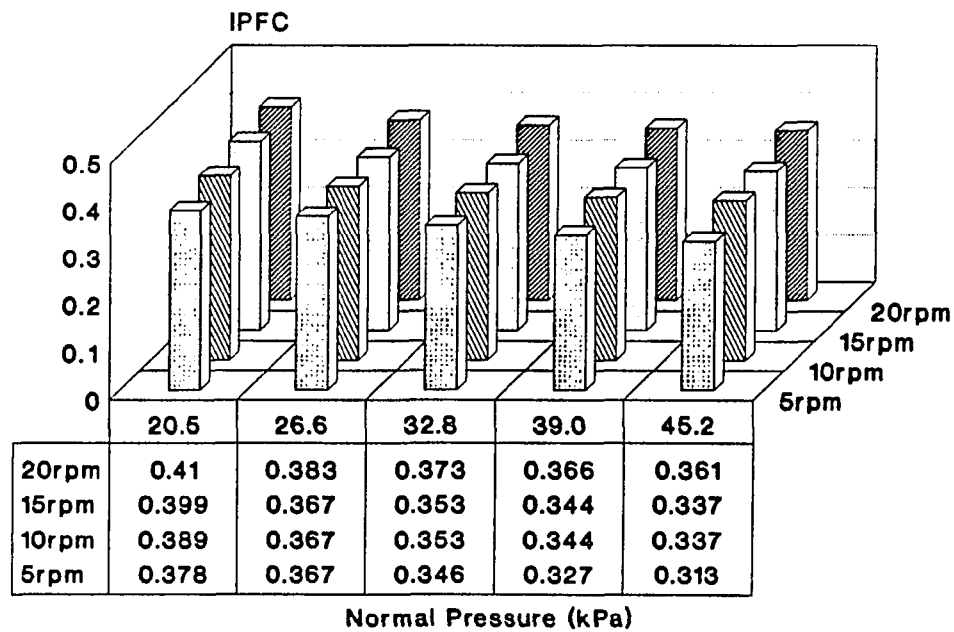


Figure 8.90 IPFC for Pellets Manufactured Using Die A212 as a Function of Normal Pressure for PA 6 with Agitation.

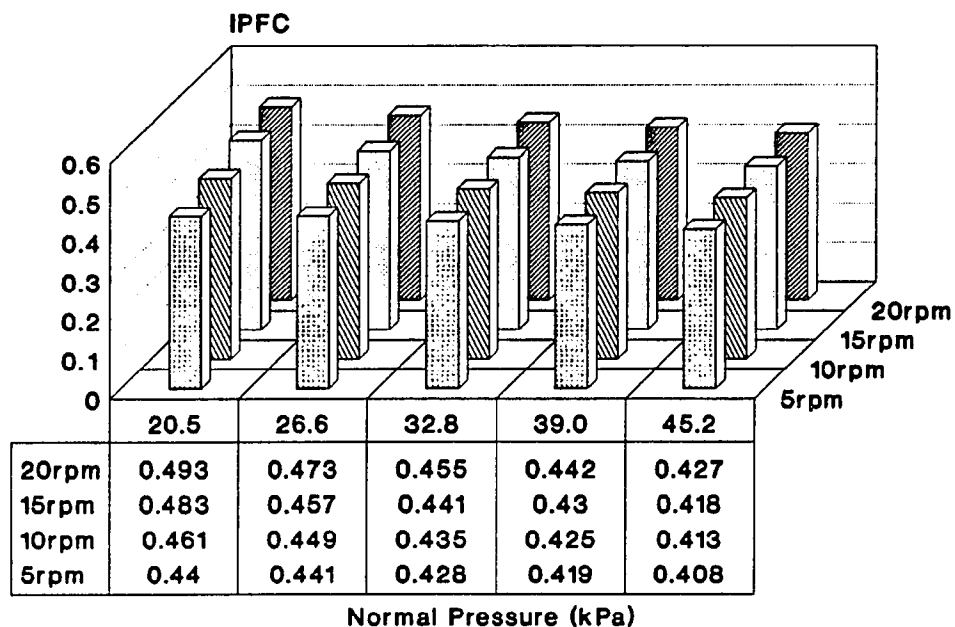


Figure 8.91 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PE with Agitation.

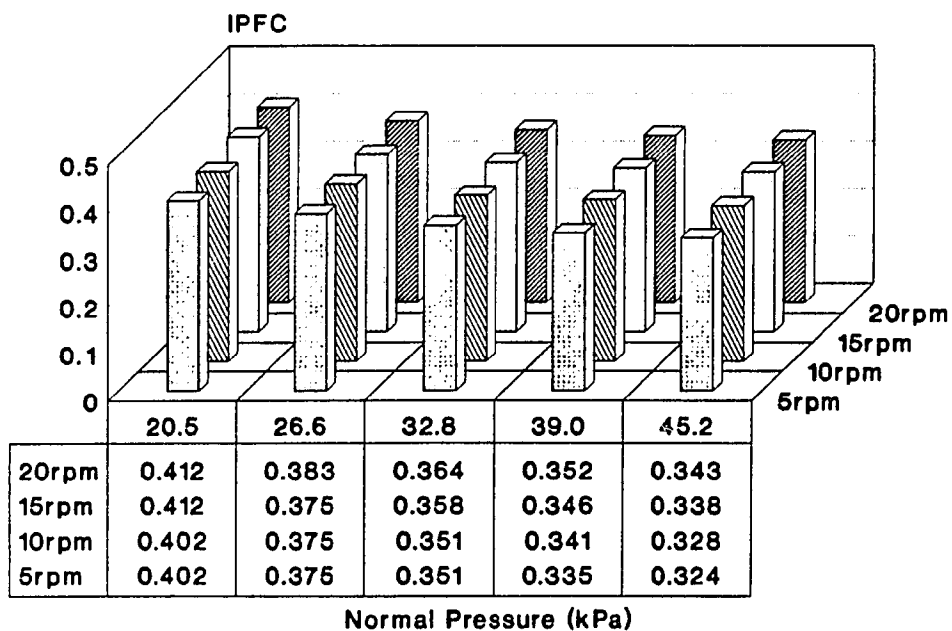


Figure 8.92 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PP with Agitation.

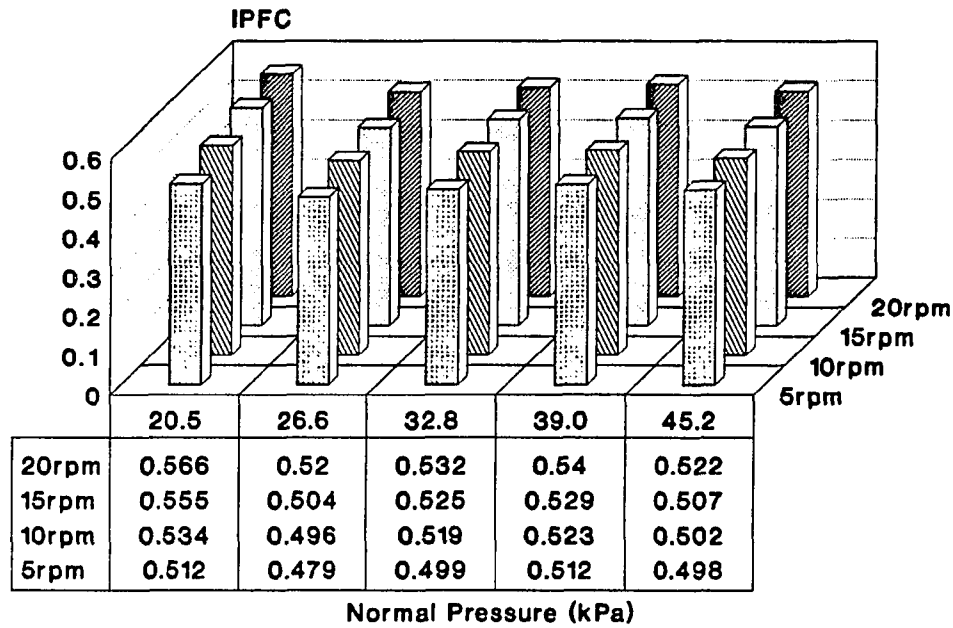


Figure 8.93 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PS with Agitation.

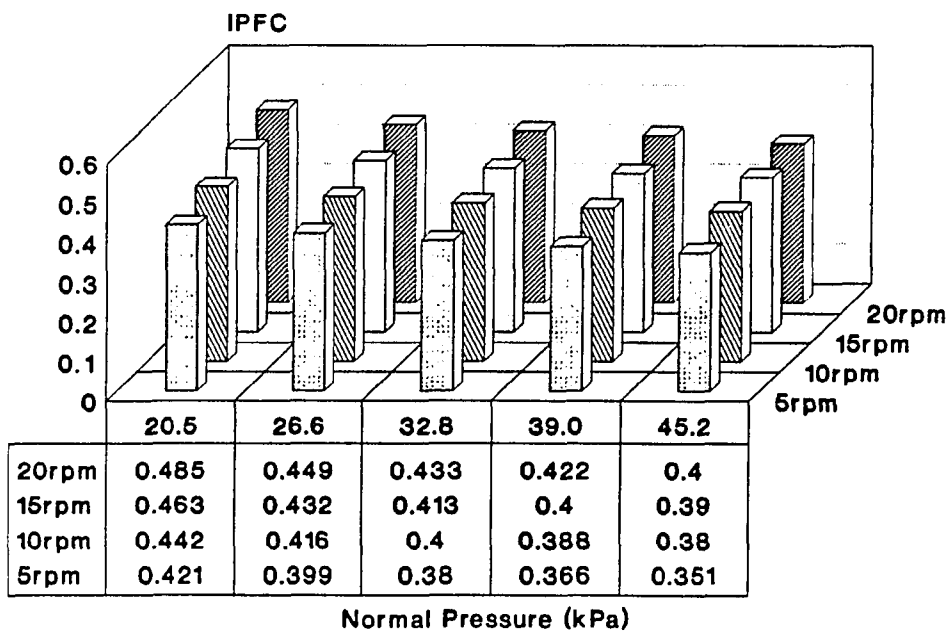


Figure 8.94 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for PA 6 with Agitation.

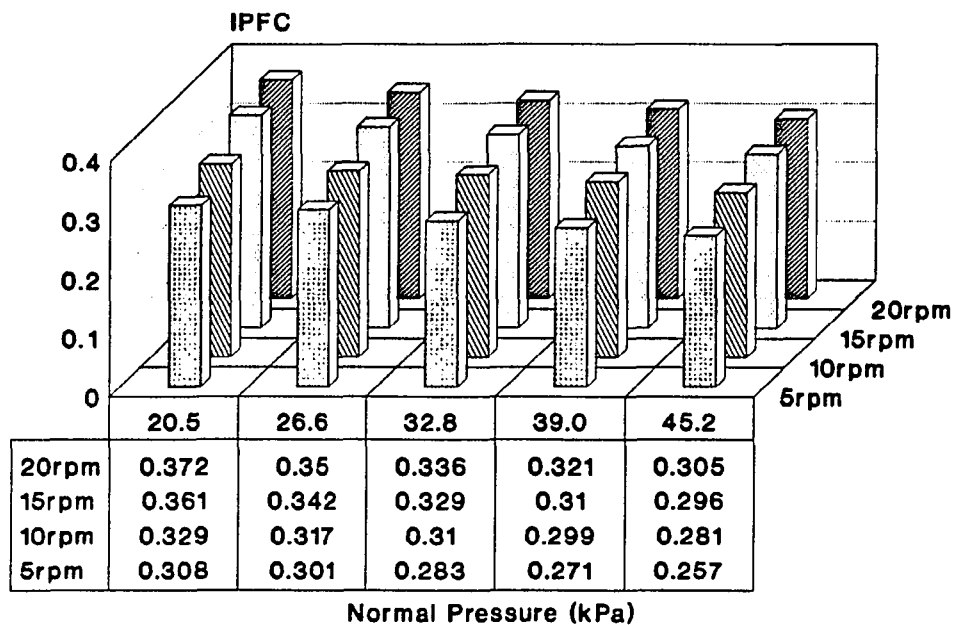


Figure 8.95 IPFC for Pellets Manufactured Using Die A221 as a Function of Normal Pressure for ABS with Agitation.

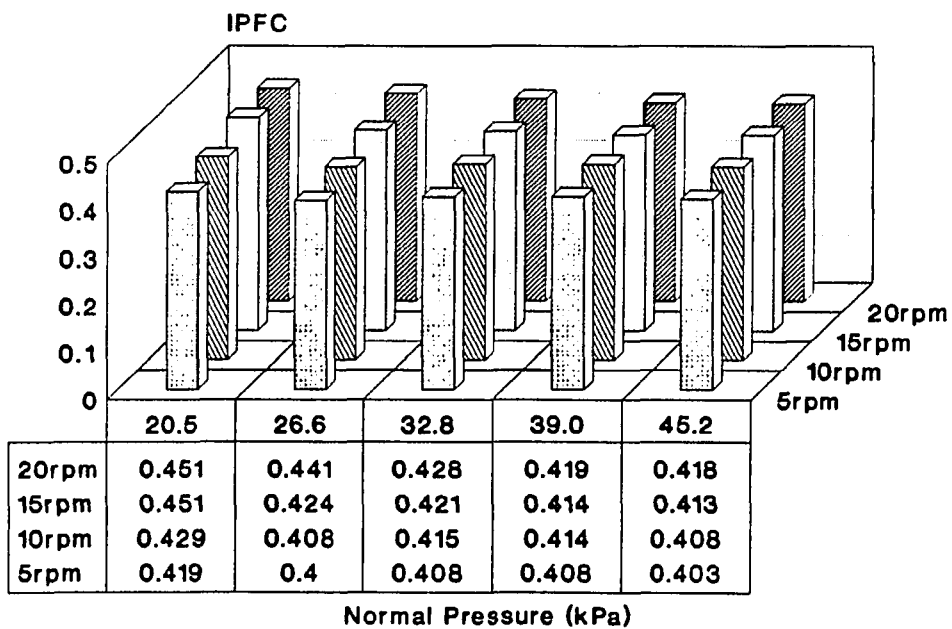


Figure 8.96 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PE with Agitation.

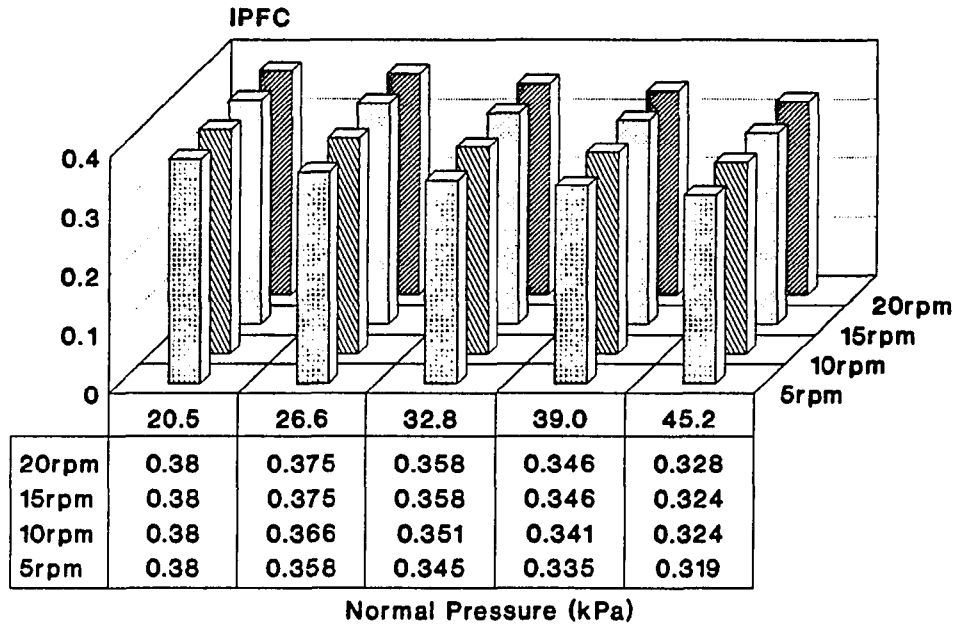


Figure 8.97 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PP with Agitation.

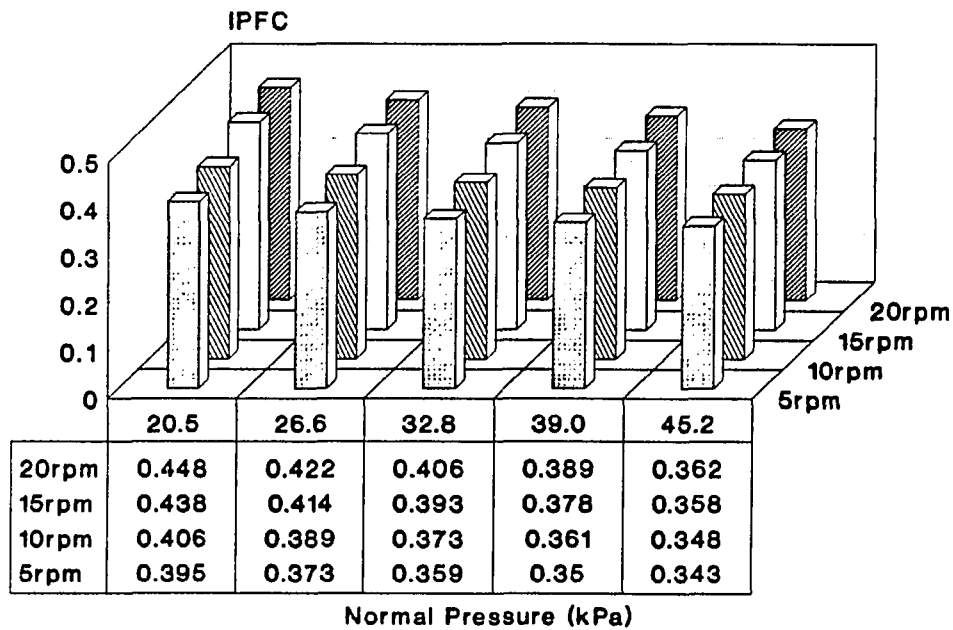


Figure 8.98 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PS with Agitation.

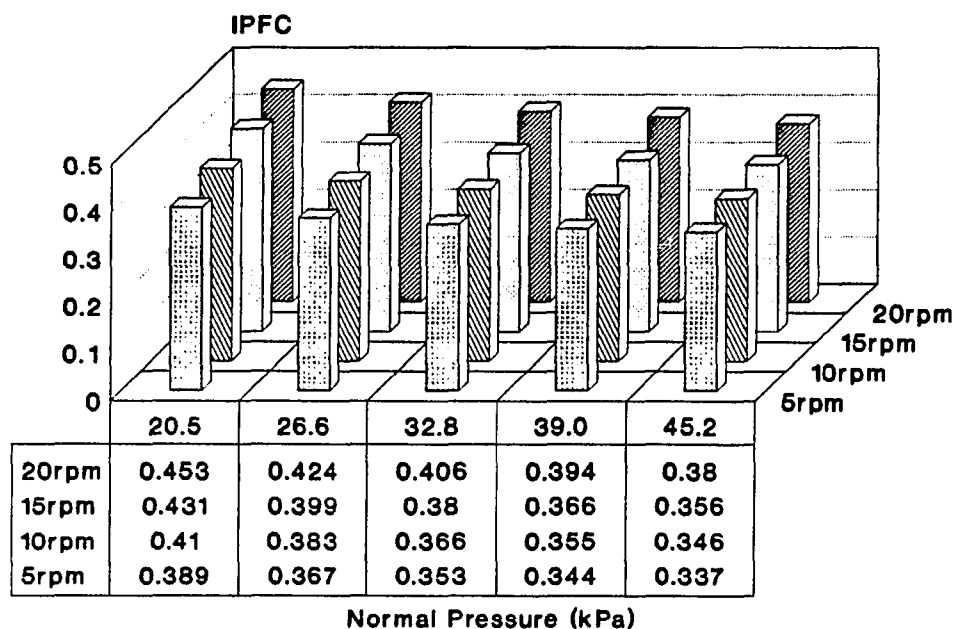


Figure 8.99 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for PA 6 with Agitation.

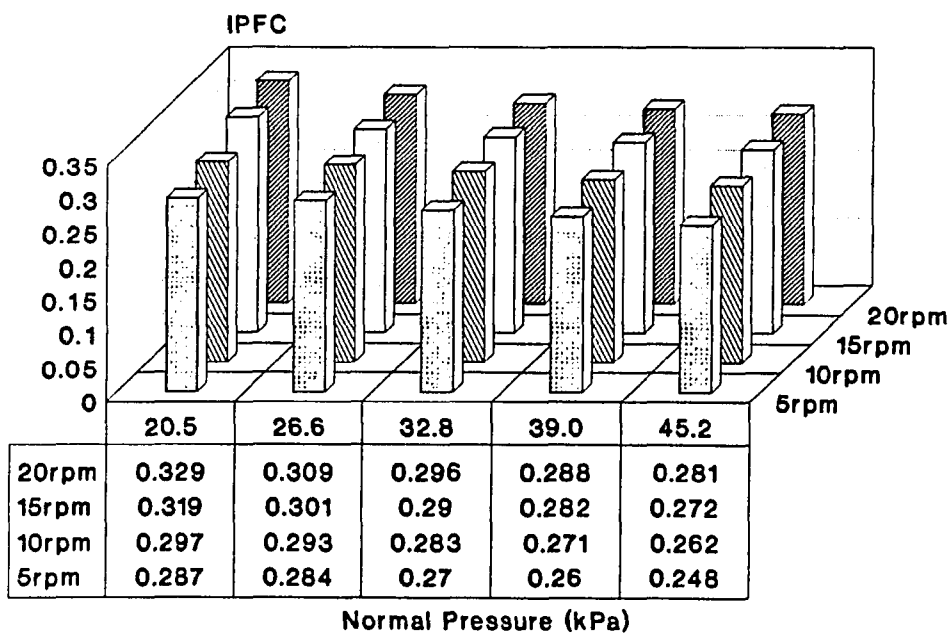


Figure 8.100 IPFC for Pellets Manufactured Using Die A231 as a Function of Normal Pressure for ABS with Agitation.

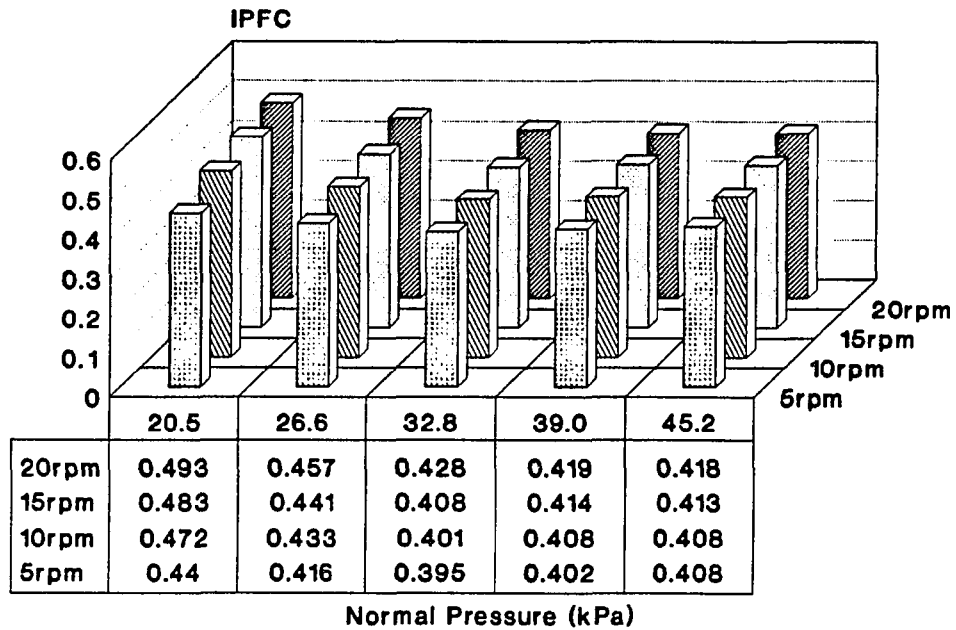


Figure 8.101 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PE with Agitation.

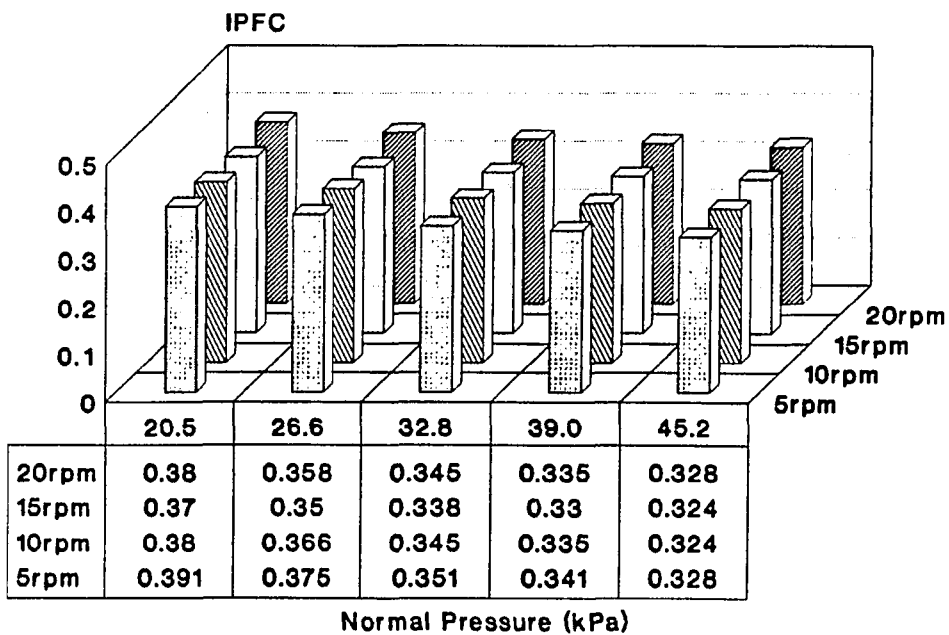


Figure 8.102 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PP with Agitation.

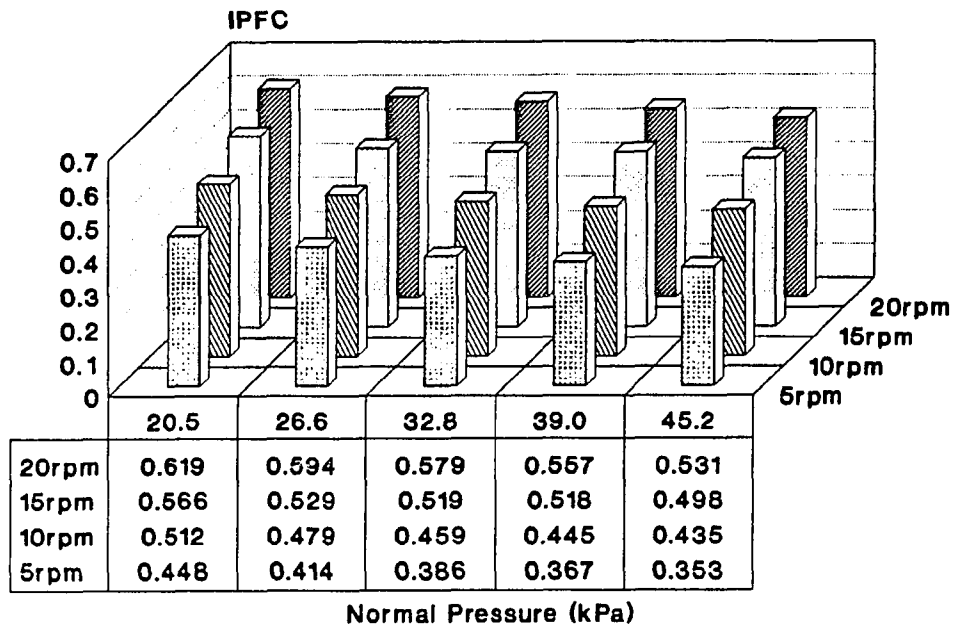


Figure 8.103 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PS with Agitation.

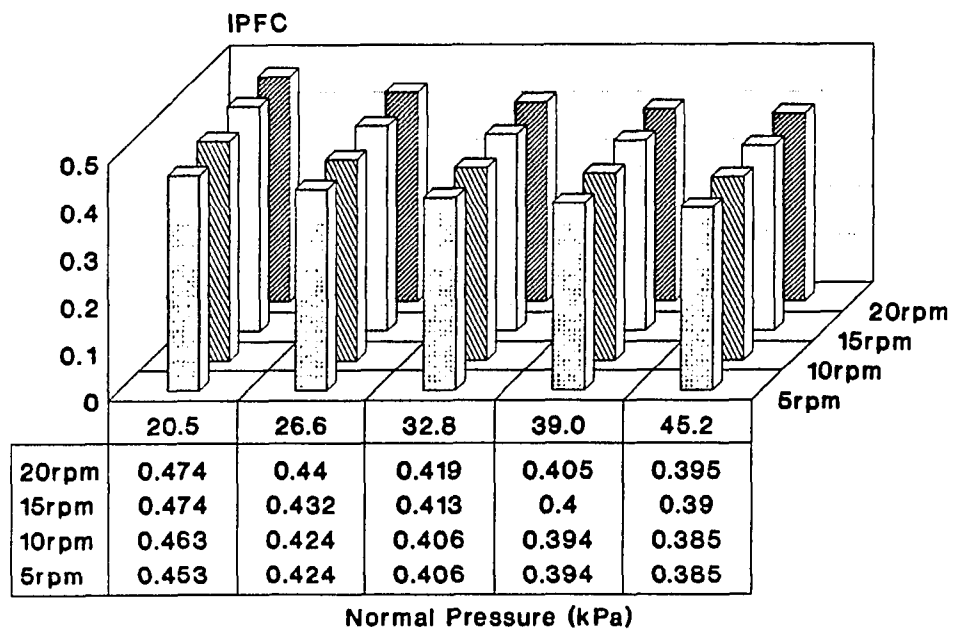


Figure 8.104 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for PA 6 with Agitation.

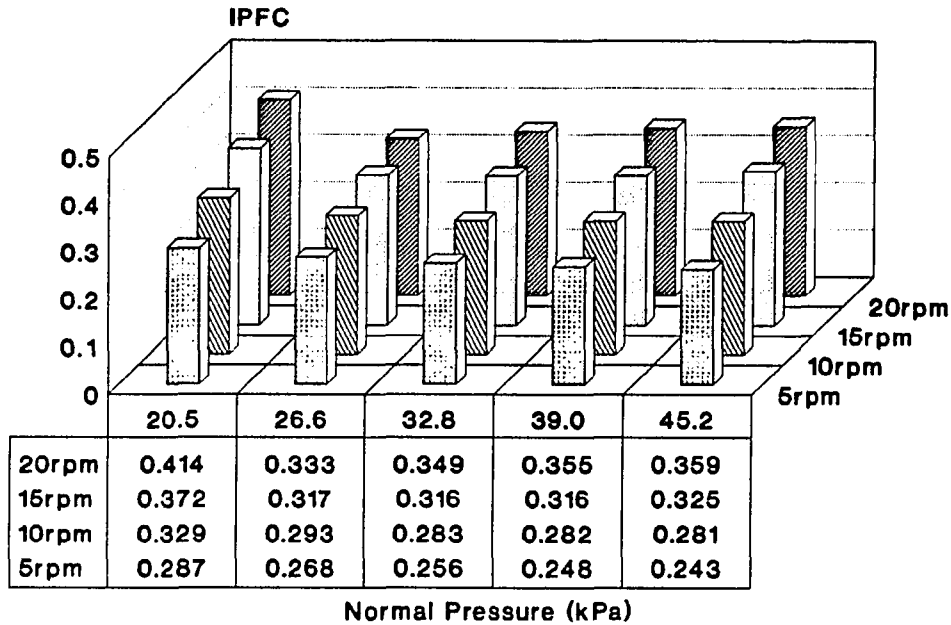


Figure 8.105 IPFC for Pellets Manufactured Using Die A241 as a Function of Normal Pressure for ABS with Agitation.

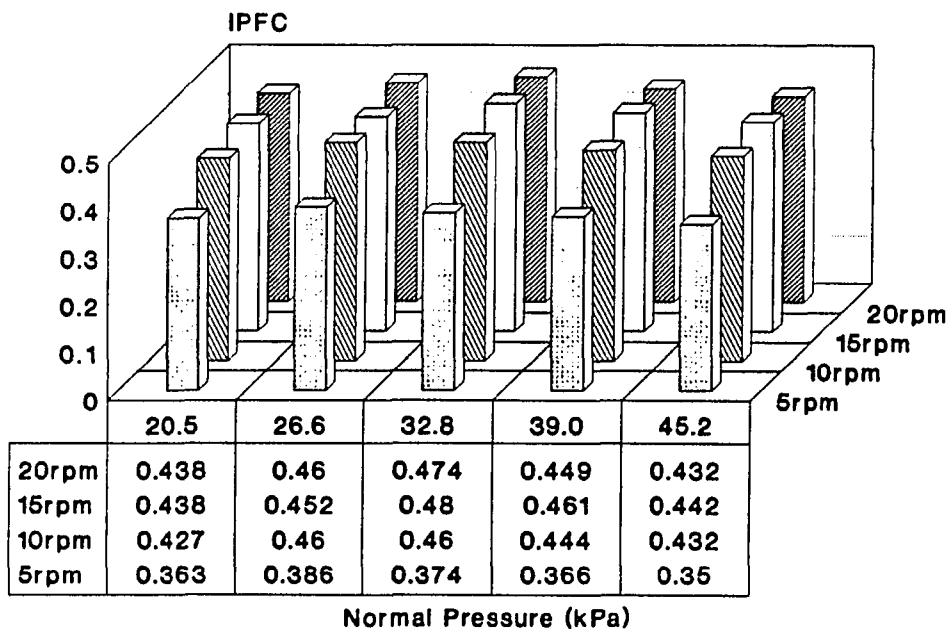


Figure 8.106 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM1 with Agitation.

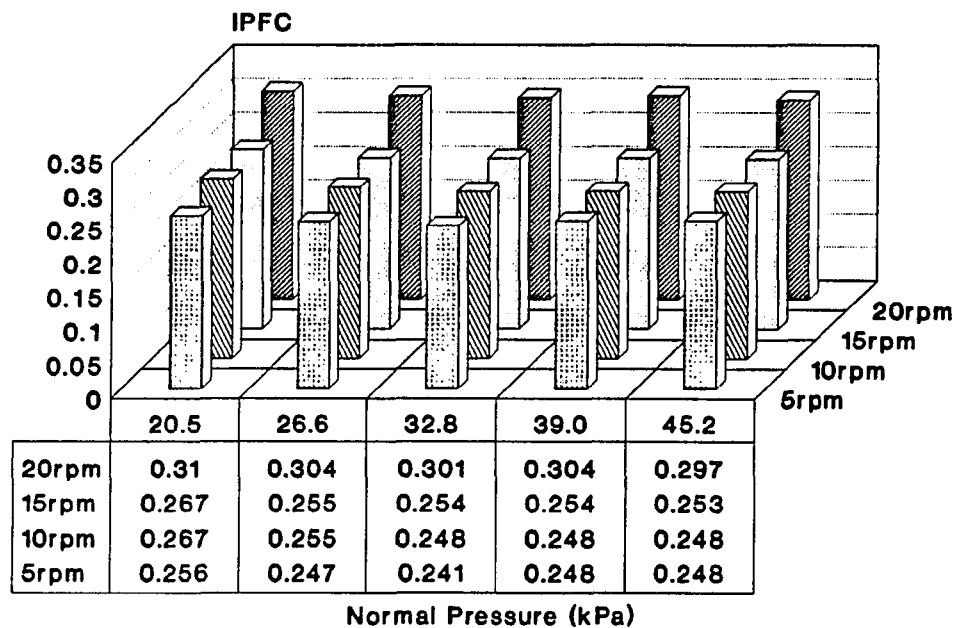


Figure 8.107 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM2 with Agitation.

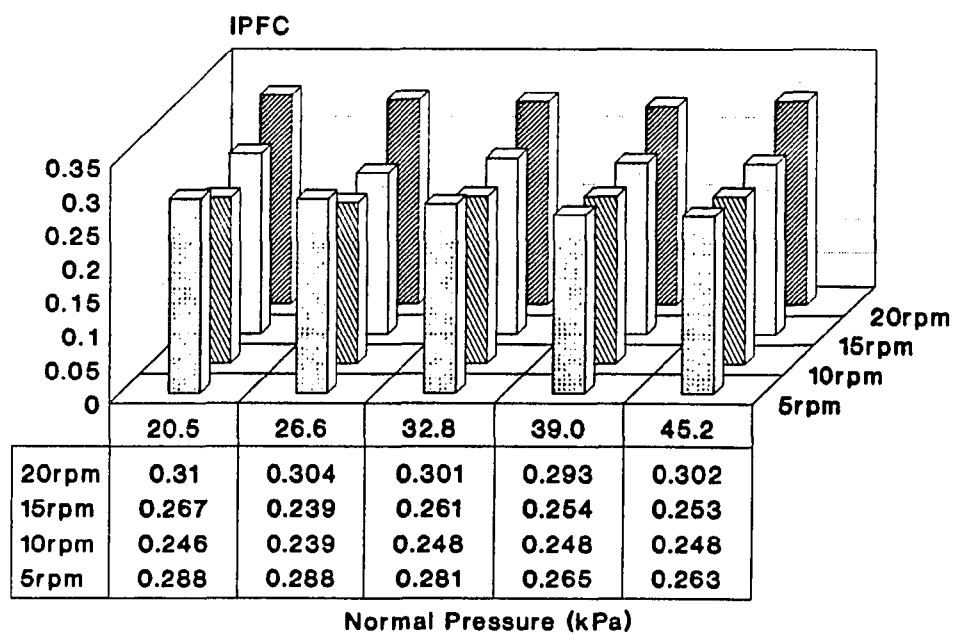


Figure 8.108 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM3 with Agitation.

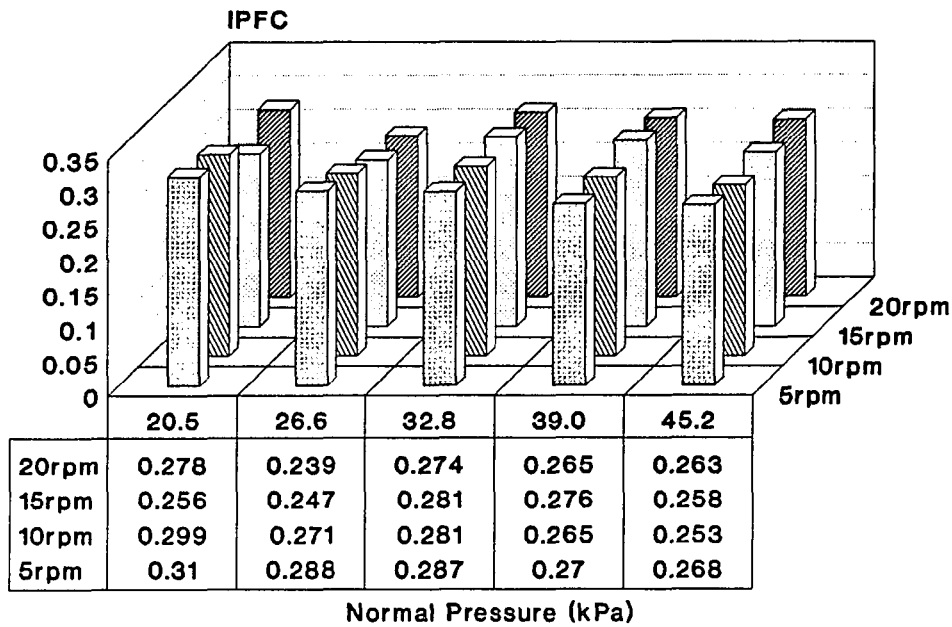


Figure 8.109 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM4 with Agitation.

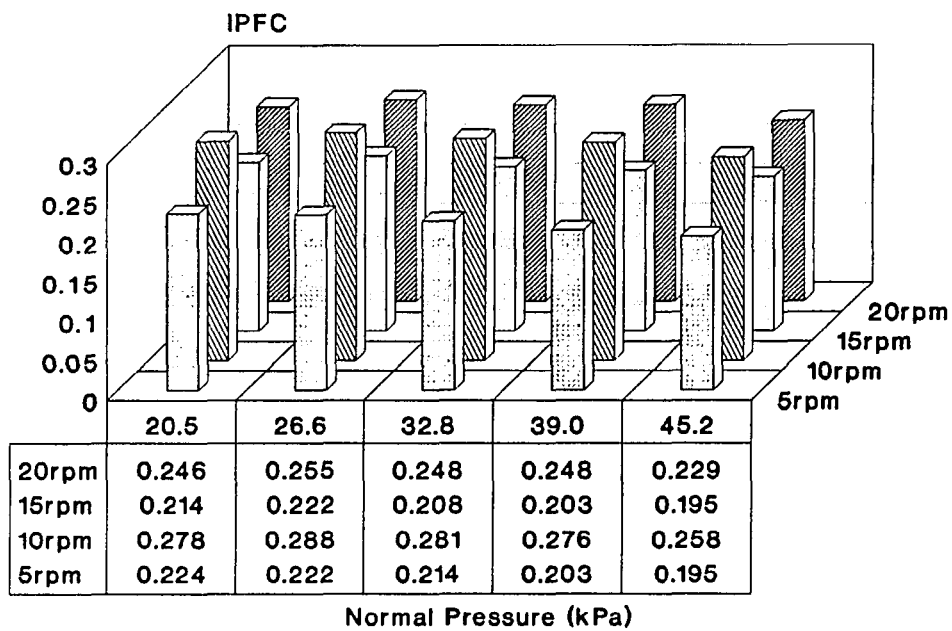


Figure 8.110 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for POM5 with Agitation.

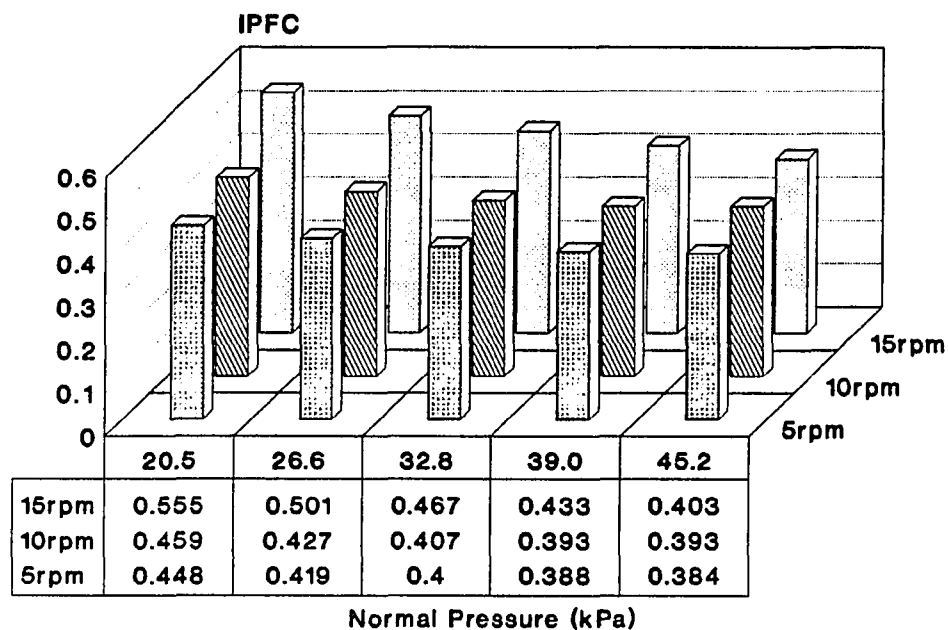


Figure 8.111 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM1 with Agitation.

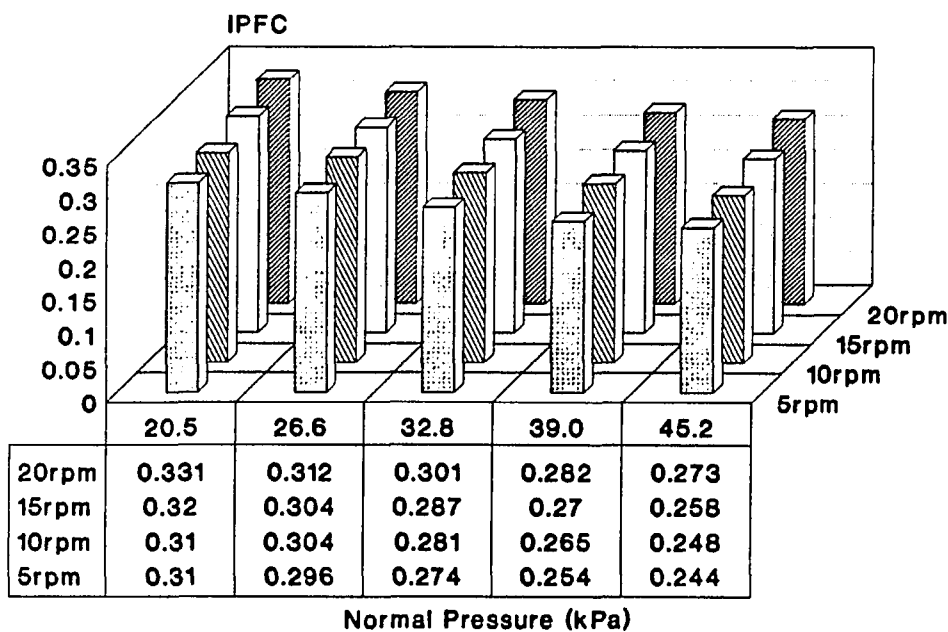


Figure 8.112 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM2 with Agitation.

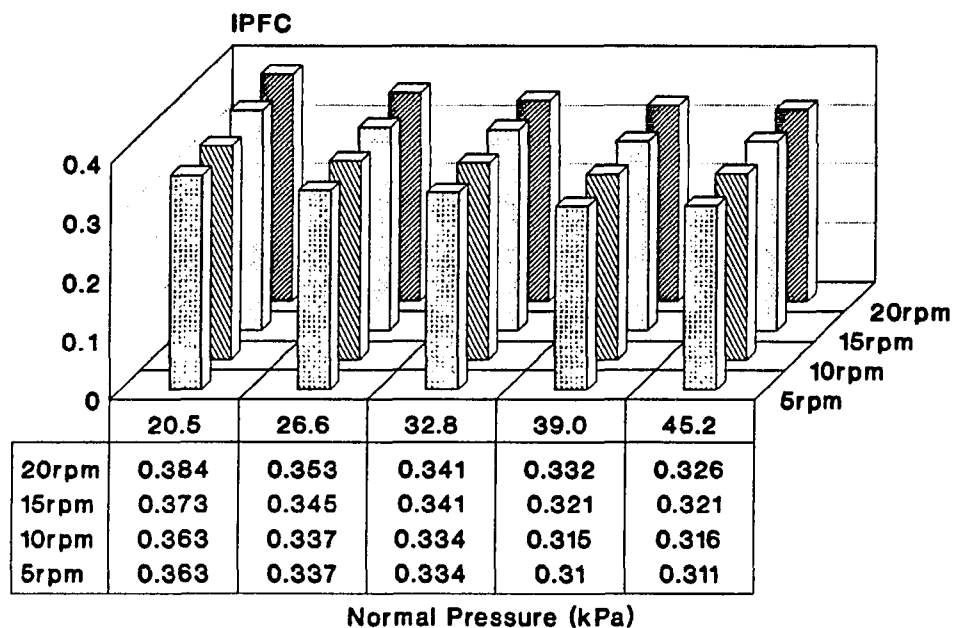


Figure 8.113 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM3 with Agitation.

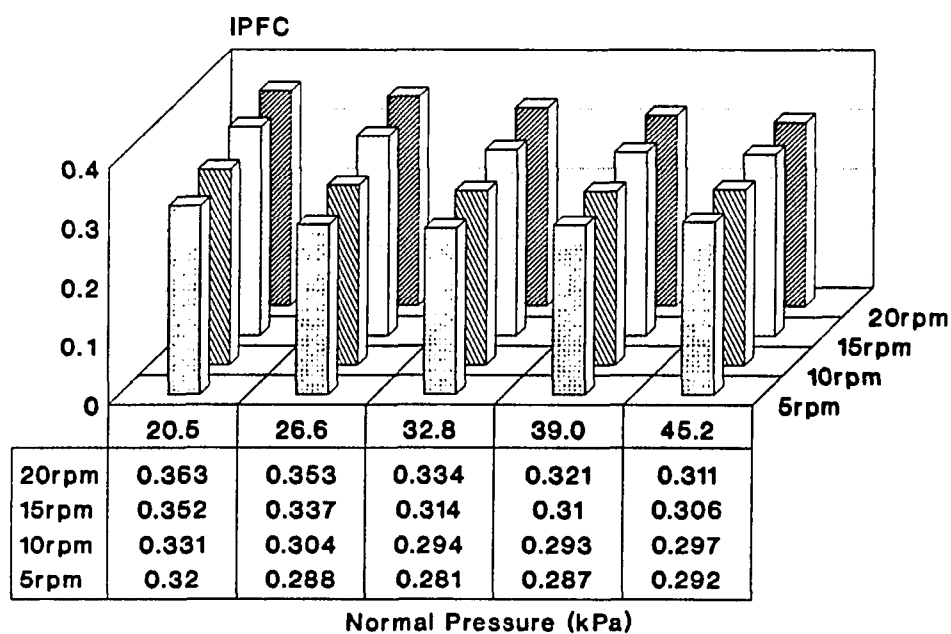


Figure 8.114 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM4 with Agitation.

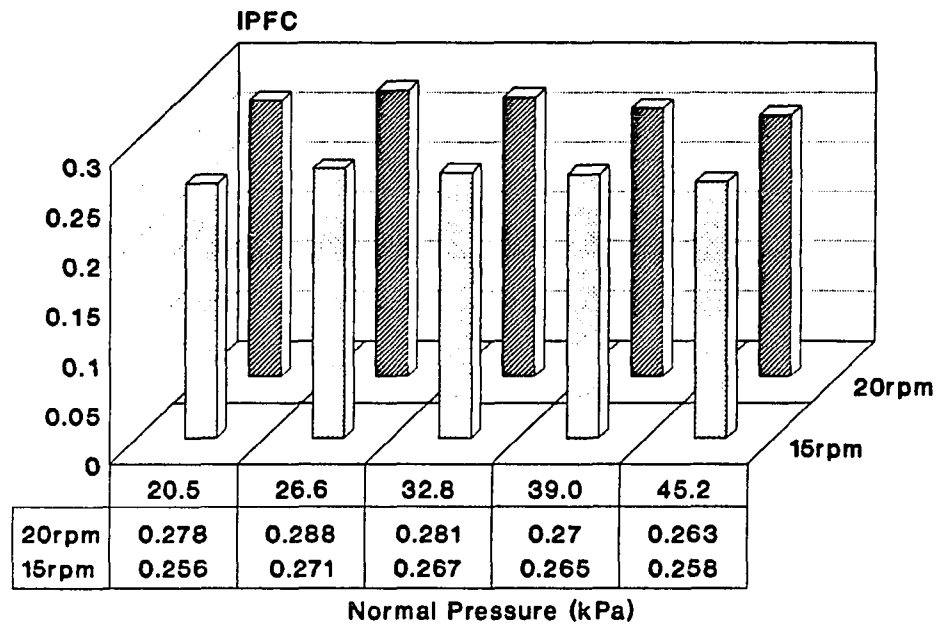


Figure 8.115 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for POM5 with Agitation.

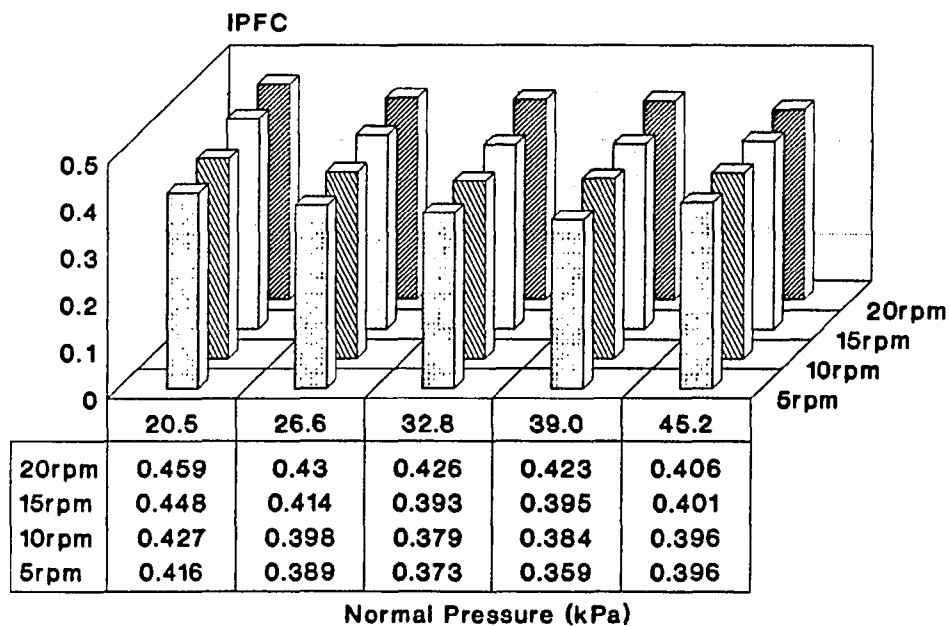


Figure 8.116 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PE with Agitation.

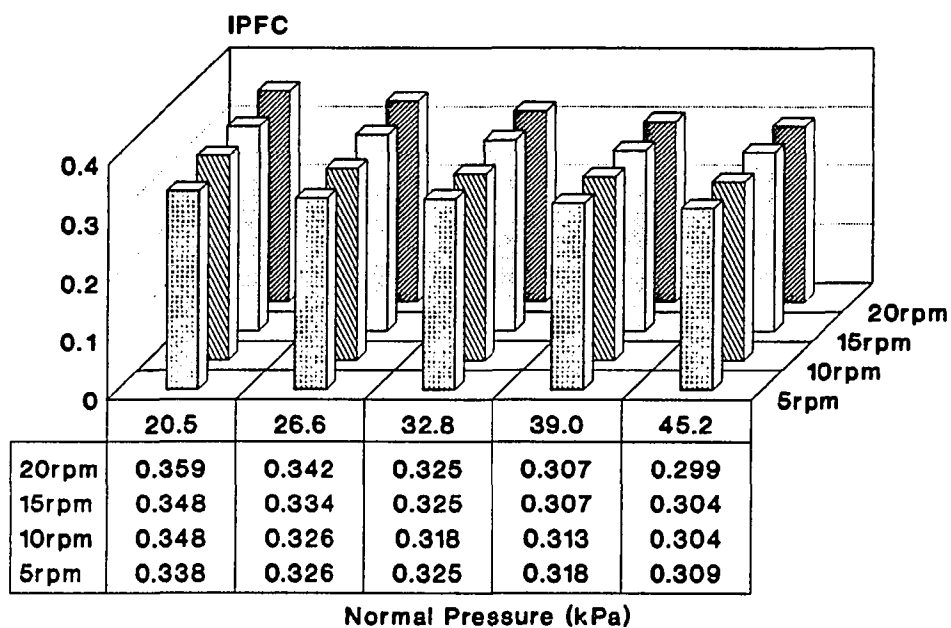


Figure 8.117 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PP with Agitation.

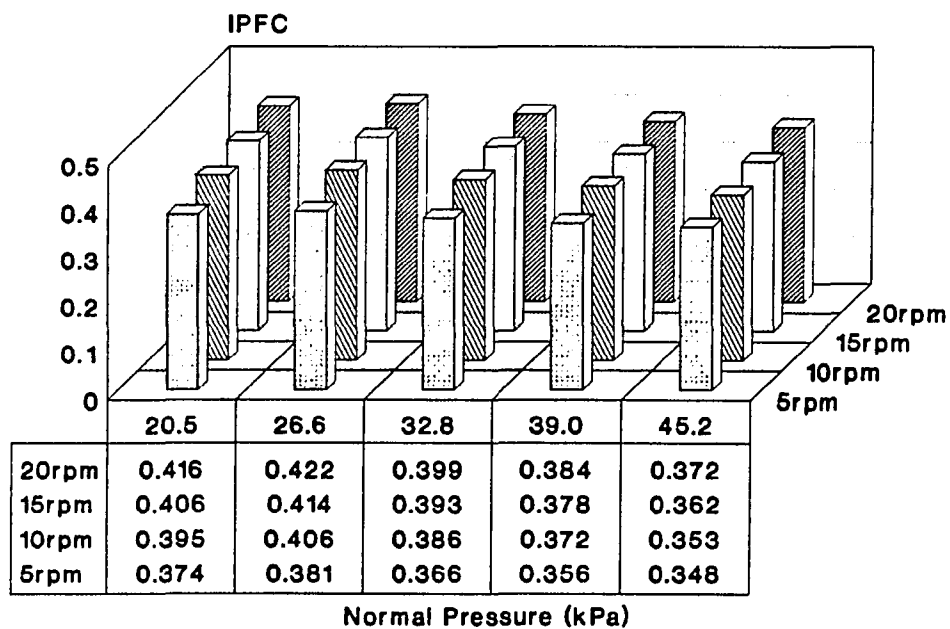


Figure 8.118 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PS with Agitation.

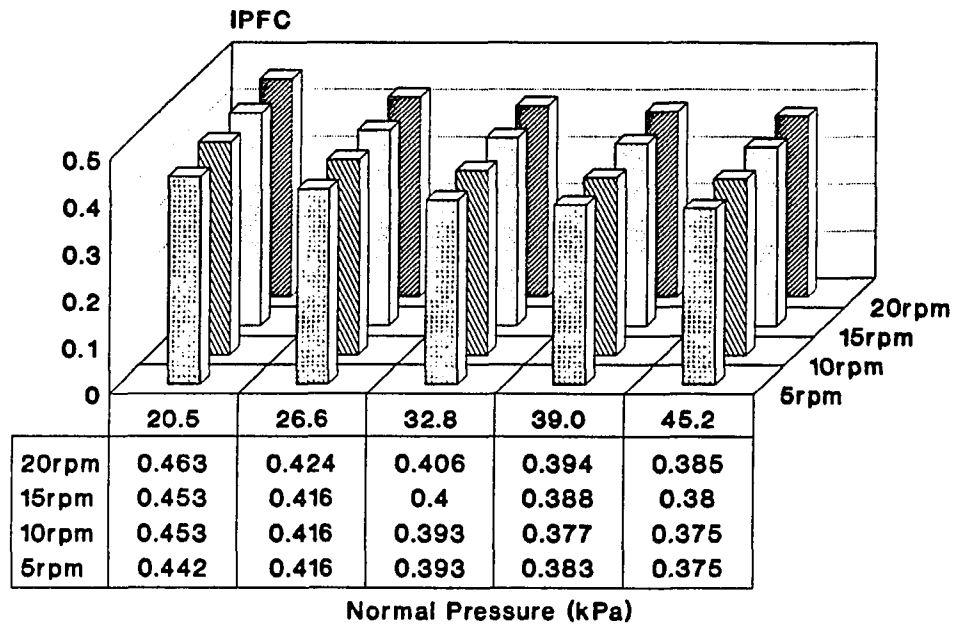


Figure 8.119 IPFC for Pellets Manufactured Using Die A311 as a Function of Normal Pressure for PA 6 with Agitation.

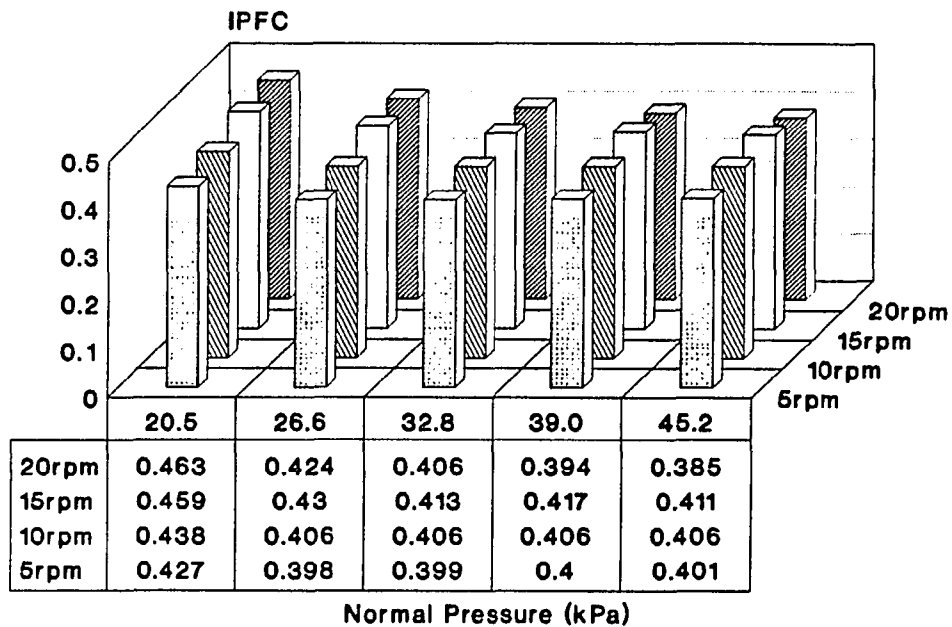


Figure 8.120 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for PE with Agitation.

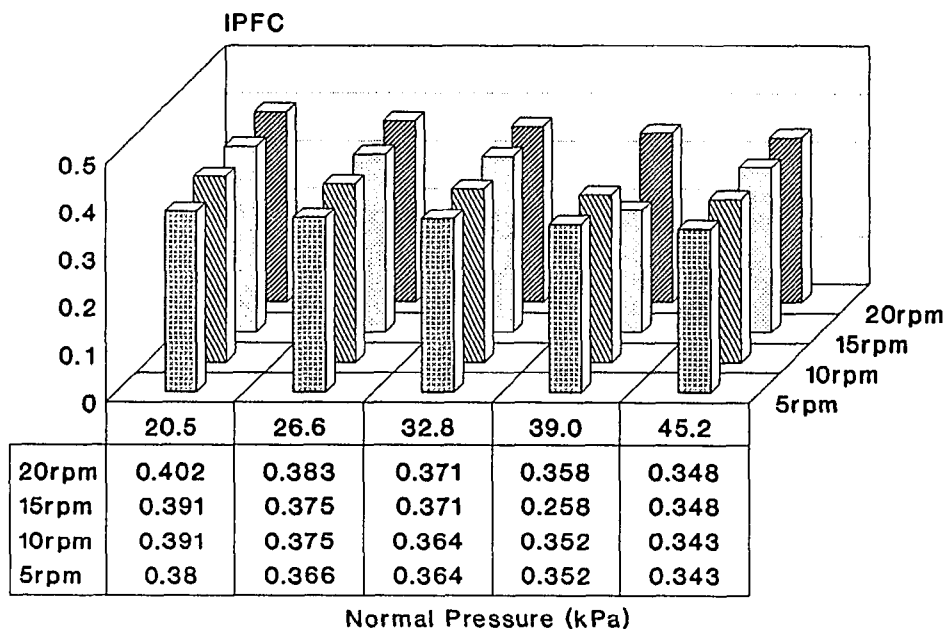


Figure 8.121 IPFC for Pellets Manufactured Using Die A411 as a Function of Normal Pressure for PP with Agitation.

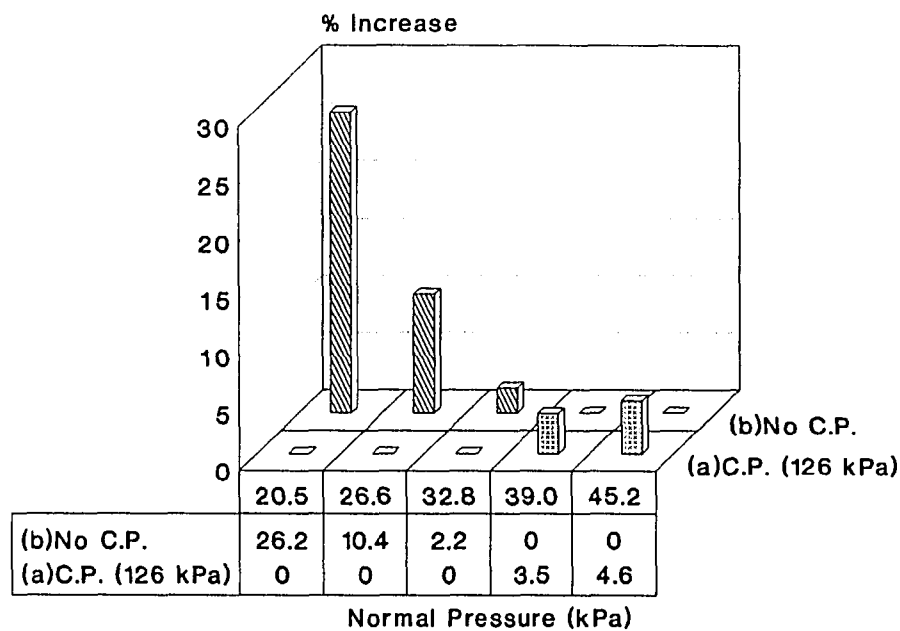


Figure 8.122 Effect of Consolidation Pressure on IPFC for Pellets Manufactured Using Die A211 of PE.

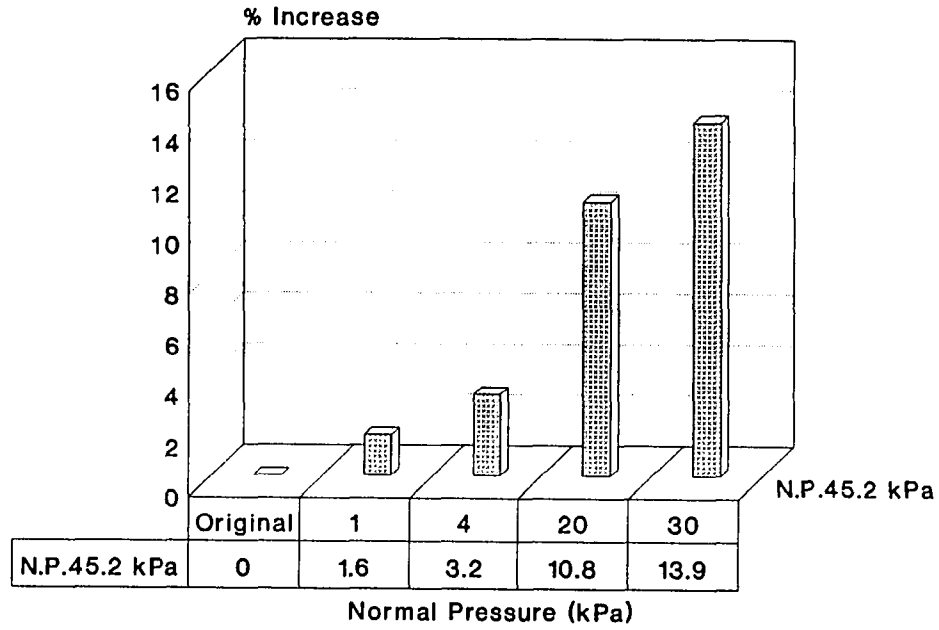


Figure 8.123 Effect of Consolidation Time for Pellets Manufactured Using Die A211 of PE at Consolidation Pressure 126.3kPa.

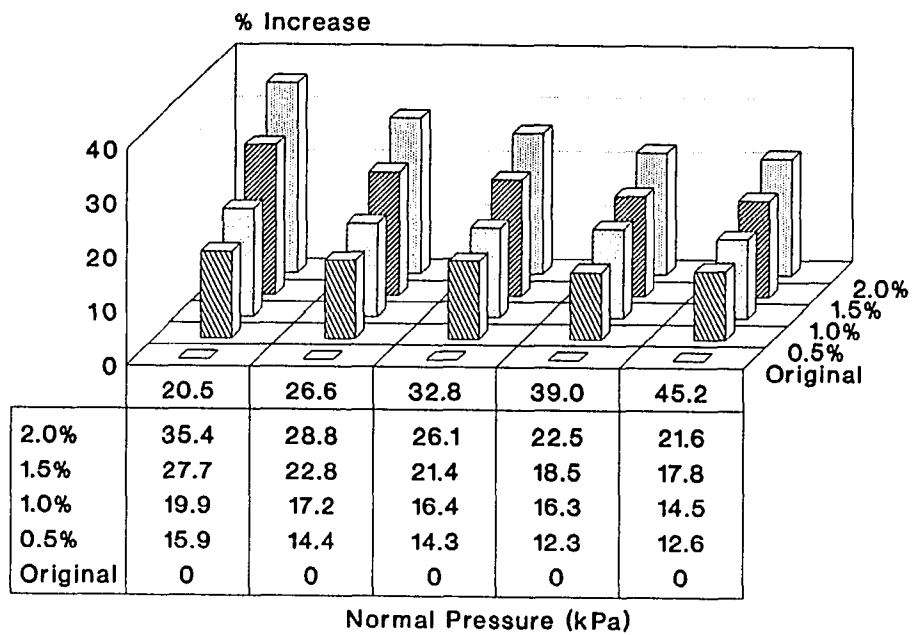


Figure 8.124 % Increase for Pellets with Circular Cross-Sections of PA 6 with Mica Clay.

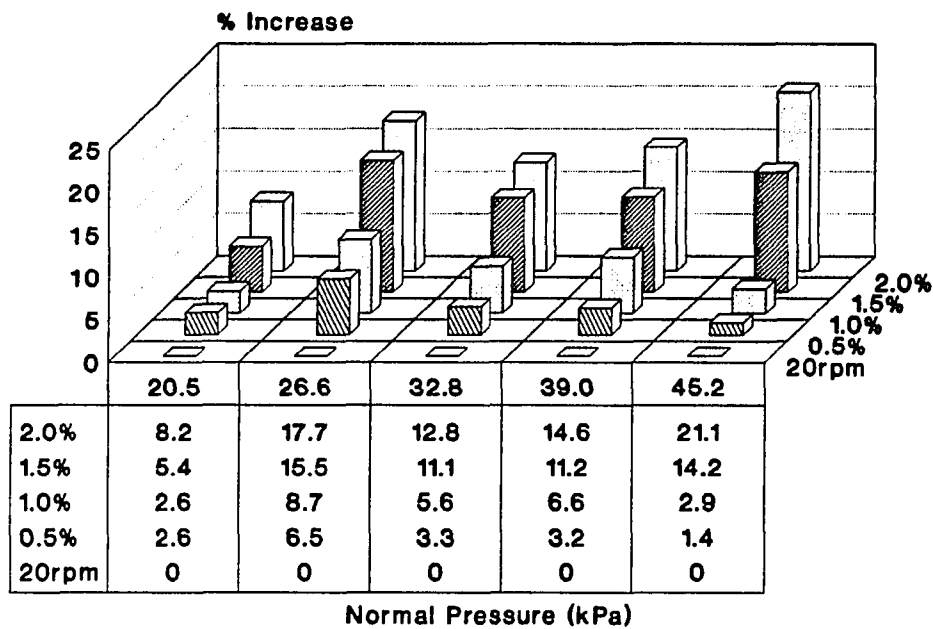


Figure 8.125 % Increase for Pellets Manufactured Using Die A241 of PA 6 with Mica Clay at Extruder Screw Speed 20rpm.

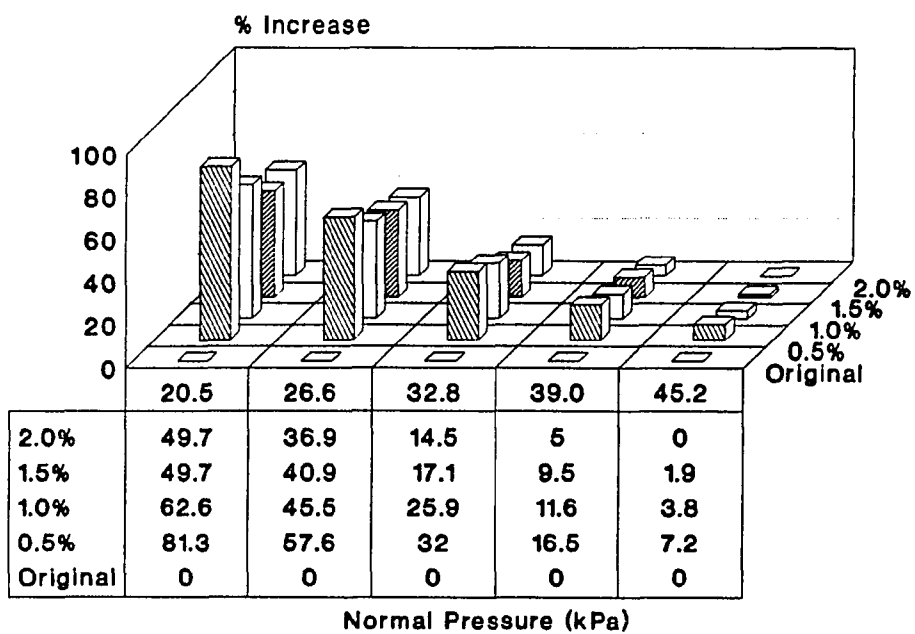


Figure 8.126 % Increase for Pellets with Circular Cross-Sections of POM3 with PBT Powder.

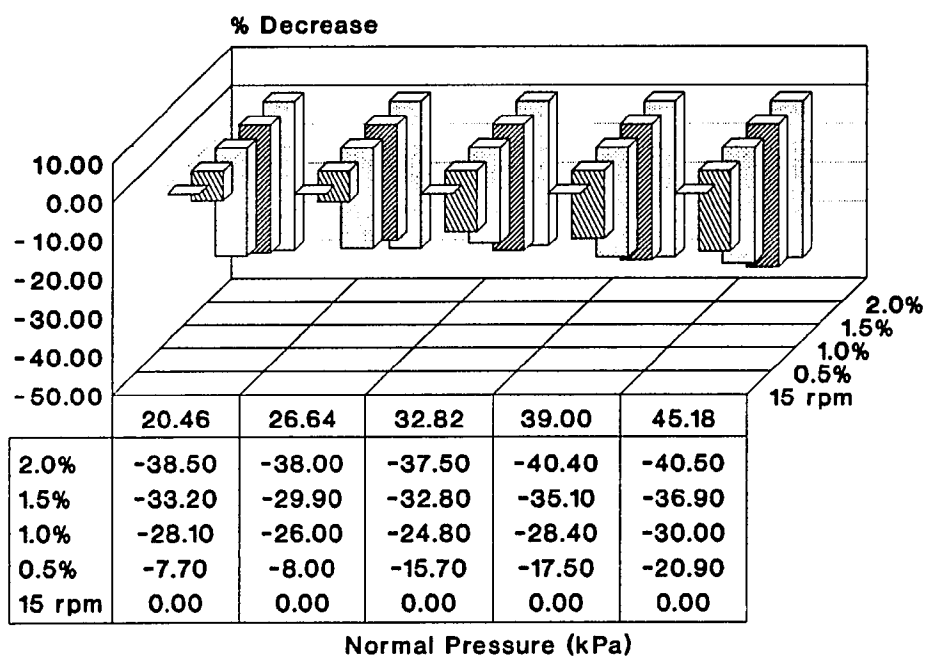


Figure 8.127 % Decrease for Pellets Manufactured Using Die A212 of POM3 with PBT Powder at Extruder Screw Speed 15rpm.

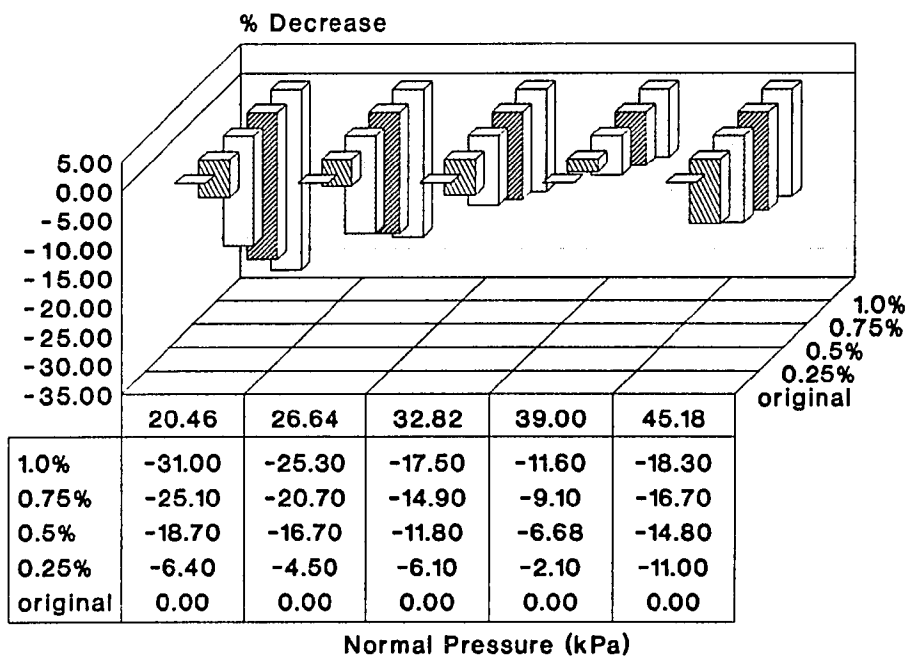


Figure 8.128 % Decrease for Pellets with Circular Cross-Sections of POM3 with Zinc Stearate.

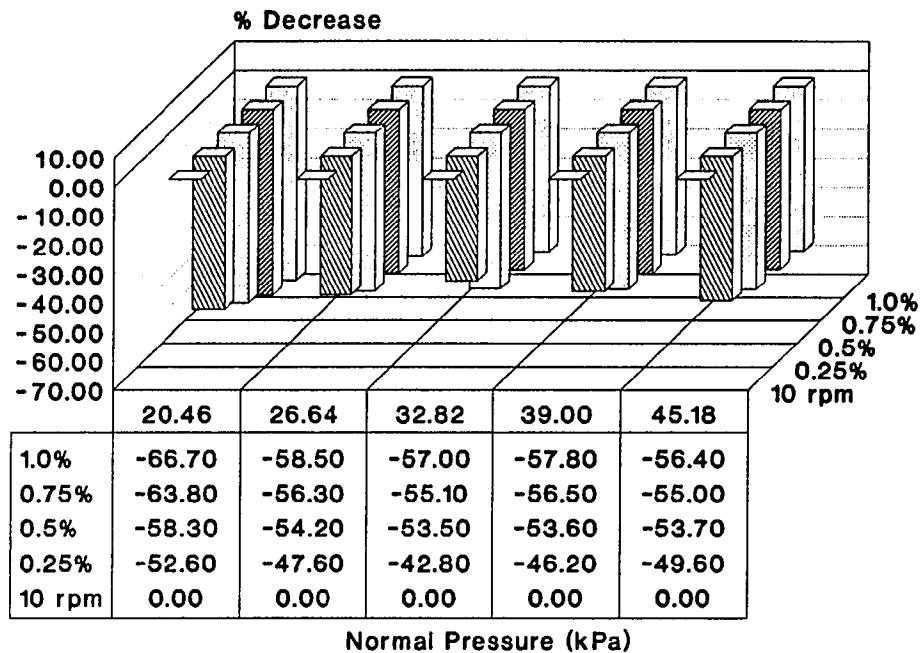


Figure 8.129 % Decrease for Pellets Manufactured Using A211 of POM3 with Zinc Stearate.

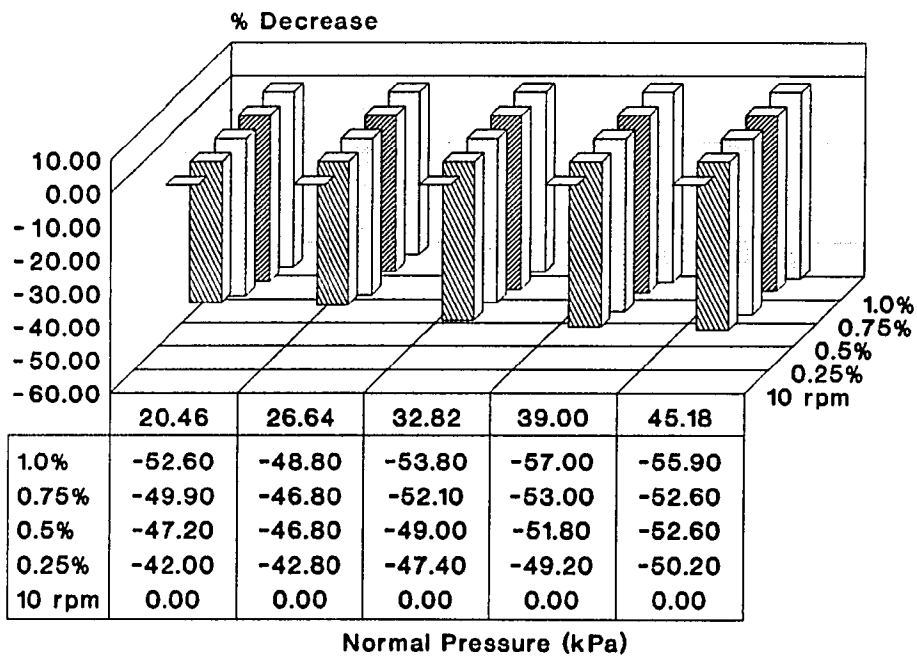


Figure 8.130 % Decrease for Pellets Manufactured Using A212 of POM3 with Zinc Stearate.

CHAPTER 9

THE SIMULATION OF THE PLASTICATING EXTRUSION PROCESS WITH EMPHASIS ON THE CONVEYING OF POLYMERIC PARTICULATES

9.1 Summary of the Simulation Procedure

The simulation computes the pressure rise in the solids conveying zone of a plasticating extruder from force and torque balances created by the motion of the plasticating screw in the extruder barrel. The integrity of the solid bed is then analyzed by studying the solid bed as a continuum and determining if rupture conditions exist.

The solids conveying zone extends from the hopper to the point where a melt film is formed on the barrel surface. The mathematical model of the solids conveying zone was developed by Darnel and Mol [16] and modified by Duvdevani et al. [47]. The pressure rise across the solid conveying zone is computed from,

$$\Delta P_s = P_o[\exp(\Phi L_f) - 1] \quad (9.1)$$

where,

$$\Phi = \left\{ \cos \theta - K \sin \theta - C \frac{f_s}{f_b} (K \sin \phi_s + C \cos \phi_s) - \frac{2D_c}{S_1} \cdot \frac{f_s}{f_b} (KC \tan \phi_s + H^2) \right\} \frac{f_b}{D_c H \sin \phi_a (H \cos \phi_a + K \sin \phi_a)} \quad (9.2)$$

$$\theta = \arctan \left[\frac{Q S_1}{N_s \pi D_B} \cdot \frac{1}{\pi S_1 D_c (D_B - D_c) \cdot \frac{Q}{N}} \right] \quad (9.3)$$

$$H = \frac{D_B - D_c}{D_B} \quad (9.4)$$

$$C = \frac{D_B - 2D_c}{D_B} \quad (9.5)$$

$$K = \frac{H(\tan\phi_a + f_s)}{1 - f_s \tan\phi_a} \quad (9.6)$$

$$\tan\phi_s = \frac{S_1}{\pi(D_B - 2D_c)} \quad (9.7)$$

$$\text{and } \tan\phi_a = \frac{S_1}{\pi(D_B - H)} \quad (9.8)$$

where,

P_o = pressure at feed zone entrance, psi

L_f = feed zone length, in

D_c = channel depth, in

S_1 = screw lead, in

Q = volumetric extruder output in feed zone, in³/min

N_s = frequency of screw rotation, rpm

D_B = barrel diameter, in

θ = angle of movement of the outer surface of the solid plug, radians

ϕ_s = helix angle at the screw root, degrees

and ϕ_a = helix angle of screw at the screw channel, degrees

Eq. 9.2 contains the coefficients of friction between the barrel and the particulate beds, f_b , and the screw and the particulate bed, f_s . It is clear that f_b causes motion, whereas, f_s , retards motion. Four possible motion situations exist [48] as shown in Figure 9.1. For the force balance on a differential element of the particulate bed.

Case 1

$F_L < F_O$; Stationary Plug; Friction Mobilized,

$$\frac{F_L}{F_O} = \exp[(C_1 f_{w1} - C_2 f_w) \frac{KL}{A}] \quad (9.9)$$

Case 2

$F_L > F_O$; Stationary Plug; Friction Mobilized,

$$\frac{F_L}{F_O} = \exp[(C_1 f_{w1} + C_2 f_w) \frac{KL}{A}] \quad (9.10)$$

Case 3

Plug moves in the direction of the upper plate,

$$\frac{F_L}{F_O} = \exp[(C_1 f_{w1} - C_2 f_{w2}) \frac{KL}{A}] \quad (9.11)$$

Case 4

Plug moves in the direction opposite of the upper plate,

$$\frac{F_L}{F_O} = \exp[(C_1 f_{w1} + C_2 f_{w2}) \frac{KL}{A}] \quad (9.12)$$

In the foregoing, different kinematic coefficients of frictions on the moving plate f_{w1} and the stationary walls f_{w2} exist. The moving plate exerts a force of $C_1 f_{w1} K(\frac{F}{A})$ in all cases, where C_1 is the portion of the "wetted" perimeter of the moving plate and f_{w1} is the kinematic coefficient of friction. The stationary channel walls in cases 1 and 2 exert a force $C_2 f_w K(\frac{F}{A})$, where f_w is the static coefficient of friction and C_2 is the portion of the "wetted" perimeter of the lower plate and side walls that is stationary. This force acts in the direction of increasing force. Thus it acts to the left in case 1 and to the right in case 2. Finally in cases 3 and 4 the stationary walls exert a force

$C_2 f_{w2} K\left(\frac{F}{A}\right)$, where f_{w2} is the kinematic coefficient of friction. This force acts in the direction opposite to the direction of motion of the plug. Case 3 is similar to the mechanism acting on the particulate bed. Hence, one can assume f_b equals f_{w1} , and f_s equals f_{w2} .

The torque at the barrel surface is calculated from,

$$T_B = \frac{1}{2} \pi D_B^2 f_b P_o \frac{\cos \theta}{\Phi} [\exp(\Phi L_f) - 1] \quad (9.13)$$

The power required to pump the solid pellets through the feed zone is computed from,

$$Z_F = (6.6606 \times 10^{-5}) \pi T_B N_s \quad (9.14)$$

Figure 9.2 shows typical cross-sections in the melting zone of a plasticating extruder [47] as compared to an idealized cross-section upon which the theoretical model is based, and it demonstrates the features of the melting mechanism. The width of the solid bed usually decreases along the extruder. The rate of decrease is highest when the channel depth does not decrease, but remains constant as is the case in the feed and metering sections of a standard metering type single screw. The reduced solid bed width in the down channel direction, for a parallel-constant depth channel is given by,

$$\frac{X_o}{W} = \frac{X_i}{W} \left(1 - \frac{\varphi \Delta z}{2D_c}\right)^2 \quad (9.15)$$

where X_i/W is the value at the entrance to the melting zone, W is the channel width, Δz an increment in the down channel distance, D_c , D_{cin} , and D_{cout} are the channel depths of a parallel channel and of a tapered channel at the entrance and exit of the

increment, respectively, and Ψ is a dimensionless group which is a measure of the rate of melting defined by,

$$\Psi = \frac{\varphi W^{1/2}}{\left(\frac{X_i}{W}\right)^{1/2} \frac{G}{D \sin}} \quad (9.16)$$

Eq. 9.16 contains the term φ a function of the physical properties and operating conditions. It is defined as,

$$\varphi = \left\{ \frac{V_{bx} U_2 \rho_m [k_m (T_b - T_m) + \frac{U_1}{2}]}{2 [C_{ps} (T_m - T_r) + \lambda^*]} \right\}^{1/2} \quad (9.17)$$

The thickness of the melt film above the solid bed on the barrel surface is calculated from,

$$\delta = \left\{ \frac{2k_m [k_m (T_b - T_m) + U_1] X}{[V_{bx} U_2 \rho_m C_{ps} (T_m - T_r) + \lambda^*]} \right\}^{1/2} \quad (9.18)$$

$$\lambda^* = \lambda + C_{pm} (T_{av} - T_m) \quad (9.19)$$

where U_1 and U_2 , are defined as,

$$U_1 = \frac{2K_3}{A_4^2} (A_4 + e^{-A_4} - 1) \quad (9.20)$$

$$U_2 = 2 \left(\frac{1}{1 - e^{-A_4}} - \frac{1}{A_4} \right) \quad (9.21)$$

$$A_4 = a \frac{T_b - T_m}{n} \quad (9.22)$$

- C_{ps} = specific heat of the solid, BTU/lb °F
 C_{pm} = specific heat of the melt, BTU/lb °F
 T_b = barrel temperature, °F
 T_m = melting temperature of the polymer, °F
 T_{av} = average temperature of the polymer in the film, °F
 V_{bx} = velocity component in the x direction of the inner surface of the barrel relative to screw, in/sec
 X = solid bed width, in
 X_i = solid bed width at the entrance of axial increment, in
 X_o = solid bed width at the exit of axial increment, in
 a = constant
 k_m = thermal conductivity of the melt, BTU/hr °F
 n = parameter in the "power law" model
 ρ_m = density of the melt, lb/ft³
 and λ = heat of fusion, BTU/lb

The term U_1 relates to the heat generated by viscous dissipation in the film, and the term U_2 is a measure of decrease in flow rate due to the modified velocity profile. From these, the width of the solid bed, the temperature of plastic melt beside it, and then the melt pressure are computed.

9.2 Geometry of the Screw

The objectives of PC EXTRUD[®] is either to quantitatively evaluate the performance characteristics of an existing screw or to design a new screw to an existing set of quantitative specifications. The Prodex extruder is a 2.5 inch diameter extruder. A photograph is shown in Figure 9.3. The specification of this Prodex

extruder may be described as follows. The maximum screw speed is 200 rpm. The mass flow rates range from 50 lb/hr to 300 lb/hr depending on the screw speed. There are six heating zones in the barrel. The entire screw is shown in Figure 9.4. The details of the screw geometry are shown in Figure 9.5. It has eight section zones. The screw may be defined geometrically as follows,

L =total length of the extruder, in

S_n =number of sections with different geometries in the plasticating extruder to be simulated

L_s =length of each geometrical section, in

D_{cn} =channel depth at the end of each geometrical section, in

N_t =number of channels (threads) in parallel

S_l =screw lead, in

C_f =channel flight width, in

and C_c =channel flight clearance, in

These geometric parameters determine the performance of the screw; and are varied depending upon the material being extruded and the operating requirements. The software can be used effectively to predict the performance of screw pump, in terms of pressure generation, temperature rise or mixing. The EXTRUD[®] can calculate and plot complete axial plastic melt pressure and temperature profiles, the relative width of the solid bed along the extruder, the power required to run the extruder and the cumulative heat transfer through the whole length of the extruder barrel.

9.3 Operating Variables

In addition, PC EXTRUD[®] also can be used to predict the effects of the following operating variables on the production rate and product quality.

1. changing flow rate,

2. changing screw speed,
3. changing barrel temperature,

It can evaluate these and other changes, quicker, faster and more accurately than with conventional methods. By utilizing the friction factor on both the barrel and the screw surfaces, it can compute the pressure rise across the solids conveying zone of the extruder. From the point where melting commences the extruder is subdivided into short axial increments in each of which constant conditions are assumed. An iterative approach is used to calculate steady-state conditions in each of these increments. In the melting section the thickness and temperature of the melt film above the solid bed on the barrel surface are calculated. In addition, the width of the solid bed, the temperature of the plastic melt beside it, and the plastic melt pressure are computed.

9.4 Simulation Input

The input data for PC EXTRUD[®] can be created by following the format of the input data as described in the Appendix A [57]. The material data bank developed from experimental work from the DATA BANK software [58] of Scientific Process & Research (SPR). It contains the physical processing properties and frictional properties. The input data for the simulation of the performance of plasticating extruders can be classified into three categories. The first is screw geometry, the second is material properties, and the last is the operating conditions. The input data is listed in Appendix B. There are eight geometrical section zones and six heating zones. The screw geometry is input to the computer as follows,

$L = 112.14$ inches, total length of the extruder

$D_B = 2.5$ inches, barrel inside diameter

$S_n = 8$, section number of screw

$L_{s1} = 19.8$ inches, length for first section of the screw

$S_{11} = 2.475$ inches, screw lead for first section

$D_{c1} = 0.437$ inch, channel depth at the end of first geometrical section

$L_{s2} = 27.55$ inches, length for second section of the screw

$S_{12} = 2.475$ inches, screw lead for second section

$D_{c2} = 0.15$ inch, channel depth at the end of second geometrical section

$L_{s3} = 16.6$ inches, length for third section of the screw

$S_{13} = 3.45$ inches, screw lead for third section

$D_{c3} = 0.450$ inch, channel depth at the end of third geometrical section

$L_{s4} = 2.475$ inches, length for fourth section of the screw

$S_{14} = 2.475$ in, screw lead for fourth section

$D_{c4} = 0.387$ inch, channel depth at the end of fourth geometrical section

$L_{s5} = 9.9$ inches, length for fifth section of the screw

$S_{15} = 2.475$ in, screw lead for fifth section

$D_{c5} = 0.437$ inch, channel depth at the end of fifth geometrical section

$L_{s6} = 3.125$ inches, length for sixth section of the screw

$S_{16} = 3.125$ in, screw lead for sixth section

$D_{c6} = 0.237$ inch, channel depth at the end of sixth geometrical section

$L_{s7} = 16.6$ inches, length for seventh section of the screw

$S_{17} = 3.45$ in, screw lead for seventh section

$D_{c7} = 0.213$ inch, channel depth at the end of seventh geometrical section

$L_{s8} = 4.95$ inches, length for eighth section of the screw

$S_{18} = 2.475$ in, screw lead for eighth section

$D_{c8} = 0.213$ inch, channel depth at the end of eighth geometrical section

$N_t = 1$, number of channels (threads) in parallel

$C_f = 0.30$ inch, channel flight width for whole screw

and $C_c = 0.0125$ inch, channel flight clearance for whole screw

The operating conditions for the simulations, except as stated, were,

$N_s = 50\text{rpm}$, screw speed

$G = 100\text{lb/hr}$, flow rate

$T_{b1} = 390\text{ }^\circ\text{F}$, barrel temperature for first heating zone

$T_{b2} = 400\text{ }^\circ\text{F}$, barrel temperature for second heating zone

$T_{b3} = 410\text{ }^\circ\text{F}$, barrel temperature for third heating zone

$T_{b4} = 420\text{ }^\circ\text{F}$, barrel temperature for fourth heating zone

$T_{b5} = 430\text{ }^\circ\text{F}$, barrel temperature for fifth heating zone

and $T_{b6} = 440\text{ }^\circ\text{F}$, barrel temperature for six heating zone

The material properties and frictional coefficients for acetal copolymer grade M90 were taken from the DATA BANK described as above. The input data for each simulation is shown in Appendix B.

9.5 Description of the Simulation Printout

After, the prepared data file is run by EXTRUD[®]. The resulting output of the computer is grouped sequentially as follows [57],

1. Printout of the input data. It includes physical properties, screw and hopper geometry and operating conditions.
2. Hopper, basically computes the pressure under the hopper and the height of the solid column above which there will be no further substantial increase in base pressure.
3. Solid conveying zone. Providing the following tabular information:

(a) LOCATION	axial location along screw, in
(b) PHI	angle of advancement of solid plug, degrees
(c) ROBP	bulk density of solid, lb/ft ³
(d) FRIB	coefficient of friction on barrel surface
(e) FRIS	coefficient of friction on screw surface
(f) TEMPERATURE	inner surface temperature of barrel, °F

BARREL

- (g) TEMPERATURE SCREW screw surface temperature, °F
- (h) POWER cumulative power consumption, HP
- (i) PRESSURE pressure at location L, psi

4. Delay, melting and melt pumping zones. Provides the following tabular information:

- (a) L axial location, in
- (b) TOUT melt pool temperature at location L, °F
- (c) X/W solid bed width
- (d) X/W -INJ solid bed width at the start of screw rotation in injection molding
- (e) GRATIO fraction of output still unmelted
- (f) PRESSURE REAL pressure at axial location L, psi
- (g) PRESSURE FULL pressure assuming solids conveying is not limiting performance, psi
- (h) POWER cumulative power consumed from hopper to axial location L, HP
- (i) HOUT channel depth at location L, in
- (j) TBAR pressure at location L, psi
- (k) TVISC pressure at location L, psi
- (l) DHEAT pressure at location L, psi
- (m) FILM TEMP pressure at location L, psi
- (n) TSCREW pressure at location L, psi
- (o) DELTA pressure at location L, psi
- (p) SOBVEF pressure at location L, psi
- (q) VMELTP melt pool velocity, in/min

5 Additional printout:

- (a) Minimum temperature - due to the presence of unmelted plastic, °F

- (b) Temperature fluctuation - due to the presence of unmelted plastic, °F
- (c) Flow index (N) representing the non-Newtonian character of the melt that is the shear rate dependence of shear stress as $\tau = m_o \dot{\gamma}^N$
- (d) Residence time: melt pool, HRS
- (e) Pressure fluctuation - at tip of screw due to flight, psi/cycle
- (f) Strength analysis of screw determines the maximum permissible channel depth an cooling hole diameter with the existing channel depth
- (g) Break down of power consumption according to its occurrence for solids conveying, melting, mixing, flight clearance, pressurization an mixing devices
- (h) Heat conduction through barrel in each header zone, BTU/min
- (i) Heat conduction over the whole barrel, BTU/min
- (j) Effect of regearing or gear changes on available power
- (k) Report on viscosity computation - average and maximum shear rate as well as average and maximum temperature at which viscosity was computed
- (l) Pressure rise or drop as well as temperature rise or drop through mixing section

9.6 Simulation Results

The purpose of using PC EXTRUD[®] for the simulation of plasticating extrusion enables the extruder designer and extrusion engineers to simulate the extruder, thereby reducing or eliminating the need for conducting costly experiments. The utilization of the mathematical model [49] involves the simulation of the performance of different size extruders with various screws and operating conditions to determine their relative performance in the desired application. This procedure will yield an optimized design and valuable information on the performance of the extruder under a variety of operating conditions.

In addition to the use of the PC EXTRUD[®] for the design of extruders, one can simulate the performance of an extruder and study the effect of changing one

variable at a time. Thus a great deal of insight may be gained on the process. It has been pointed out before that in the laboratory quite often it is impossible to change one variable without affecting others. The experimental separation of variables is almost impossible. Simulations with the aid of the mathematical model provide a means for separating the variables, allow the derivation of meaningful conclusions on the importance of each individual variable. It is the purpose of this work to discuss the effect of operating conditions and polymer properties on plasticating extrusion by performing simulations using the PC EXTRUD[®].

The prepared data files in appendix B are ready for input to PC EXTRUD[®]. All simulation results are included in appendix B. An example of the printout is as follows,

EXPERIMENT NUMBER 1.00 12.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.0 SECONDS

After this the screw geometry is typed out:

SECTION	LENGTH	CH.DEPTH		WIDTH		LEAD	BAR.	FLT.	NO OF	HOLE
#	(IN)	SOLID	MELT	SOLID	MELT		DIAM	WIDTH	HOLES	AREA
		(IN)	(IN)	(IN)	(IN)	(IN)	(IN)	(IN)		(SQIN)
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

This is followed by portion of the input data related to the hopper and solids conveying. Following this EXTRUD[®] performs a hopper analysis:

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !
 SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

The hopper analysis reveals that with the hopper geometry used the resin being processed requires a 186.01 inch high column in the hopper. A lower column of solids will effect solids conveying and with it the production rate of the extruder. Under these conditions the variation in column height can cause surging. On the other hand a higher column of solids will not affect the extruder performance. The hopper analysis is followed by the solids conveying zone analysis. It yields the angle of advancement of the solid bed along the solids conveying zone (PHI), the bulk density at points along the solids conveying zone of the extruder as effected by pressure and surface temperature (ROBP), the coefficient of friction on the barrel surface (FRIB) and on the screw surface (FRIS) as affected by the surface temperatures, pressure and resulting bulk density, the barrel and screw surface temperatures, cumulative power consumption from the downstream end of the hopper (POWER) and pressure buildup (PRESSURE). This is shown as follows,

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 67.00 DEG.F AND SCREW = 207.00 DEG.F

LOCATION	PHI	ROBP	FRIB	FRIS	TEMPERATURE	.DEG F	POWER	PRESSURE
IN	DEG	LB/CU. FT			BARREL	SCREW	HP	PSI
1.00	13.7	21.13	0.059	0.003	67.0	207.0	0.00	0.51
2.00	13.6	21.22	0.065	0.008	67.0	207.0	0.00	0.79
3.00	13.5	21.33	0.072	0.014	67.0	207.0	0.00	1.25
4.00	13.3	21.53	0.084	0.025	67.0	207.0	0.00	2.00

5.00	12.9	21.92	0.101	0.044	75.0	207.0	0.00	3.28
6.00	12.7	22.12	0.072	0.054	67.0	207.0	0.01	4.03
7.00	12.5	22.39	0.083	0.067	67.0	207.0	0.01	4.94
8.00	12.2	22.66	0.093	0.078	67.0	207.0	0.01	5.89
9.00	12.0	22.96	0.105	0.091	67.0	207.0	0.01	6.98
10.00	11.7	23.31	0.117	0.104	67.0	207.0	0.02	8.23
10.90	11.4	23.66	0.129	0.117	330.0	207.0	0.03	9.53

The solid conveying zone is followed by the delay zone which contains no melt pool only the melt film on the barrel surface which develops to its full thickness along this zone. The delay zone is followed by the melting zone.

The following table yields the melt temperature in the melt pool (TOUT) along the extruder at every location (L), the relative width of the solid bed (X/W) along the extruder, its value in noncontinuous extrusion that is injection molding (X/W INJ), solids content at every point (GRATIO), REALPRESSURE in the case of possible solids conveying problems, FULL PRESSURE when solids conveying problems are eliminated. The cumulative power consumption by the rotating screw (POWER), channel depth (HOUT), barrel temperature (TBAR), viscosity of the melt pool along the extruder (TVISC), the incremental heat transferred through the barrel (D.HEAT) and the maximum melt film temperature at the barrel surface (FILM TEMP). D.HEAT is positive during barrel cooling that is when heat is flowing out through the barrel and negative during barrel heating when heat is flowing into the extruder:

L	TOUT	X/W	X/W	GRATIO	PRESSURE	POWER	HOUT	TBAR	TVISC	D.HEAT	FILM
IN	DEG F	SOLID			PSI	HP	IN	DEG F	LB.SEC	BUT/IN	TEMP
					REAL	FULL			/SQ. IN	. MIN	DEG F
13.10	342.5				471.	471.	0.437	349.0	0.0811		
15.10	364.4				837.	837.	0.437	380.8	0.0389		
17.10	371.3				1071.	1071.	0.437	390.6	0.0903		

18.10	359.9	.879	.879	.732	1111.	1111.	0.2	0.437	390.6	0.1863	-32.5	391.
19.80	361.7	.830	.830	.691	1179.	1179.	0.4	0.437	390.6	0.1851	-2.2	391.
24.80	373.3	.763	.763	.655	1379.	1379.	1.1	0.385	394.7	0.1522	2.8	394.
26.10	378.0	.746	.746	.645	1431.	1431.	1.2	0.372	395.5	0.1232	3.5	395.
31.10	391.2	.674	.674	.601	1646.	1646.	1.9	0.320	398.6	0.1098	2.1	398.
36.10	398.9	.596	.596	.546	1899.	1899.	2.5	0.267	401.5	0.1027	1.0	401.
41.10	403.6	.508	.508	.478	2200.	2200.	3.1	0.215	404.4	0.0985	-0.5	404.
46.10	406.3	.402	.402	.390	2527.	2527.	3.7	0.163	407.2	0.0964	-2.6	407.
47.35	406.7	.373	.373	.363	2599.	2599.	3.8	0.150	408.1	0.0960	-4.0	408.

SECONDARY CHANNEL BEGINS

52.35	404.0	.185	.374	.185	2953.	2953.	4.3	0.150	410.6	0.1020	-8.2	410.
57.35	408.0	.077	.188	.077	3282.	3282.	4.6	0.150	413.5	0.1001	-2.7	413.
62.35	413.1	.003	.010	.003	3520.	3520.	5.06	0.150	416.3	0.0959	3.4	416.
63.95	415.3	.000	.000	.000	3576.	3576.	5.6	0.150	417.4	0.0944	1.8	417.

SECONDARY CHANNEL ENDS

65.19	417.6	.000	.000	.000	3644.	3644.	5.7	0.269	418.2	0.0876	2.2	417.
66.42	419.1	.000	.000	.000	3687.	3687.	5.8	0.387	418.2	0.0932	1.7	417.
71.37	422.9	.000	.000	.000	3820.	3820.	6.0	0.412	421.6	0.0925	1.6	417.
76.32	426.1	.000	.000	.000	3939.	3939.	6.1	0.437	424.4	0.0915	1.5	417.
77.89	427.2	.000	.000	.000	3981.	3981.	6.2	0.338	425.4	0.0862	1.7	417.
79.45	428.7	.000	.000	.000	4040.	4040.	6.3	0.238	426.3	0.0815	2.1	417.

FLUTED SECTION WITH 1. PAIRS OF FLUTES

96.05	428.7	.000	.000	.000	4039.	4039.	6.3	0.213	431.1	0.0815	2.1	417.
-------	-------	------	------	------	-------	-------	-----	-------	-------	--------	-----	------

101.00	437.9	.000	.000	.000	4288.	4288.	6.6	0.213	438.3	0.0803	2.1	417.
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MINIMUM TEMPERATURE = 437.908 DEG F

TEMP FLUCTUATION = 0.000 DEG F

FLOW INDEX (N) = 0.763

GRATIO INJ. = 0.000

RESIDENCE TIME:

MELT POOL = 0.050008345 HRS

TORQUE = 8303.5 INCH. POUNDS

The simulation also reveals that due to the presence of unmelted pellets in the extrudate a 0.000 °F temperature fluctuation will be experienced. Without the solids conveying problem the solid totally melt downs. The torque and the break down in power consumption is printed out as follows,

POWER BREAK-DOWN:

SOLIDS CONV = 0.027 HP

MELTING = 3.545 HP

MIXING = 1.463 HP

FLIGHT CLEAR = 1.303 HP

COMPRESSION = 0.195 HP

MIXING DEVICE = 0.060 HP

PRESSURE FLUCTUATION = 170.41 PSI/CYCLE

TOTAL CONDUCTED HEAT THROUGH BARREL= -89.1 TO -21.0 BTU/MIN OR

-2.10 TO -0.49 HP

The above gives the heat conduction through the barrel. Positive values for heat represent heat conducted out through the barrel that is cooling while negative values represent heat conducted into the extruder from the barrel that is heating the polymer. It shows that between 0.49 and 2.1 HP were supplied through the barrel in addition to the 5.1 HP used by the motor to rotate the screw.

MAXIMUM SCREW SPEED, RPM:	50.0	75.0	100.0	125.0	150.0	175.0	200.0
POWER CONSUMPTION, % OF AVAILABLE:	6.6	9.9	13.2	16.5	19.8	23.1	36.3

The above yields the effect of regearing the extruder. It shows that since the extruder has a 100 rpm maximum screw speed its full power rating can not be obtained except

by regearing to have a maximum speed of 50 rpm. The effect of intermediate gear ratios is also given. The above table assumes a DC drive the power of which linearly increases with rotational speed.

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE) :

MAXIMUM PERMITTED COOLING HOLES DIAMETER IS 1.100 INCHES
MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.641 INCHES

The strength analysis of the screw with the material used to construct the screw (4140 steel) reveals that processing the resin in question with the above barrel temperature profile and operating conditions the screw can be deepened from the present 0.4370 inches to 0.641 inches without endangering the integrity of the screw. It also reveals that without deepening the channel the screw can be cored to a 1.10 inch diameter with the additional strength of the screw into which the 0.4370 inch deep channel has been cut. This however is valid only for the resin grade in question and for the barrel temperatures used. Should the barrel temperature be lowered, power consumption will rise lowering the permitted channel depth accordingly.

Next statistical information is provided on the viscosity data used by the simulation. It yields the shear rate and temperature ranges at which viscosity had to be computed in the simulation.

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
770.55	342.5	0.0588104
8.18	390.6	0.1541261

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	441.3	0.1012381
230.69	329.0	0.1049526

AT 50.00 RPM & 100.00 LB/HR PRODUCTION RATE
HEAD PRESSURE IS 4288. PSI.

9.6.1 Varying the Screw Speed

The screw speed is the single most important variable, because it can be controlled best and is also the most often varied.

The screw speed was ranged from 30rpm to 70rpm for acetal copolymer grade M90 at the same barrel temperature, flow rate, material properties, and frictional coefficient. Appendix B represents the operating conditions for acetal copolymer grade M90 with screw speeds from 30 rpm to 70rpm. Appendix B shows the operating conditions for acetal copolymer grade M90 with a screw speed of 30rpm. The solids bed has some fraction unmelt at the end of the extruder. The screw is good enough to endure the strength under this operating conditions. The power consumed 3.4 HP for the plasticating extrusion process. Appendix B shows the operating conditions for acetal copolymer grade M90 with a screw speed of 40rpm. The solids bed melt down occurs at an axial screw position of 67 inches. The screw is good enough to endure the strength under this operating conditions. The power consumed 4.85 HP for the plasticating extrusion process. Appendix B shows the operating conditions for acetal copolymer grade M90 with a screw speed of 50rpm. The solids bed melt down occurs at an axial screw position of 63.95 inches. The head pressure at the exit of the extruder is 4288 psi. The screw is good enough to endure the strength under this operating conditions. The power consumed 8.4 HP for the plasticating extrusion process. Appendix B shows the operating conditions for acetal copolymer grade M90 with a screw speed of 60rpm. The solids bed melt down occurs at an axial screw position of 57.5 inches. The head pressure at the exit of the extruder is 5297 psi. The screw is good enough to endure the strength under this operating conditions. The power consumed 9.0 HP for the plasticating extrusion process. Appendix B shows the operating conditions for acetal copolymer grade M90 with a screw speed of 70rpm. The solids bed melt down occurs at an axial screw position of 52.5 inches. The head pressure at the exit of the extruder is 6158 psi. The screw is

good enough to endure the strength under this operating conditions. consumed 7HP for the plasticating extrusion process.

9.6.2 Varying the Flow Rate

The flow rates was ranged from 80lb/hr to 120 lb/hr for acetal copolymer grade M90 at the same barrel temperature, screw speed, material properties, and frictional coefficient. Appendix B represents the operating conditions for acetal copolymer grade M90 with flow rates from 80lb/hr to 120 lb/hr. Appendix B shows the operating conditions for acetal copolymer grade M90 with flow rates at 80 lb/hr. The solids bed melt down occurs at an axial screw position of 57.5 inches. The extrudate discharge pressure is 4707 psi. The screw is good enough to endure the strength under this operating conditions. The power consumed 6.3 HP for the plasticating extrusion process. Appendix B shows the operating conditions for acetal copolymer grade M90 with flow rates at 90 lb/hr. The solids bed melt down occurs at an axial screw position of 62.4 inches. The extrudate discharge pressure is 4501 psi. The screw is good enough to endure the strength under this operating conditions. The power consumed 6.4 HP for the plasticating extrusion process. Appendix B shows the operating conditions for acetal copolymer grade M90 with flow rates at 100 lb/hr. The solids bed melt down occurs at an axial screw position of 64 inches. The extrudate discharge pressure is 4288 psi. The screw is good enough to endure the strength under this operating conditions. The power consumed 6.6 HP for the plasticating extrusion process. Appendix B shows the operating conditions for acetal copolymer grade M90 with flow rates at 110 lb/hr. The solids bed melt down occurs at an axial screw position of 76.3 inches. The extrudate discharge pressure is 4024 psi. The screw is good enough to endure the strength under this operating conditions. consumed 7.2 HP for the plasticating extrusion process. Appendix B shows the operating conditions for acetal copolymer grade M90 with flow rates at 120 lb/hr. The solids bed melt

down occurs at an axial screw position of 101 inches. The screw is good enough to endure the strength under this operating conditions. The power consumed 8.4 HP for the plasticating extrusion process.

9.6.3 Varying the IPFC

By inputting the IPFC instead of the barrel friction in simulation and systematically reducing the barrel diameter from 2.5 inches to 1.75 inches. The effect of the IPFC on the conveying capacity of the solids can be determined.

The IPFC instead of barrel friction was ranged from 0.05 to 0.25 lb/hr for acetal copolymer grade M90 at the same barrel temperature, screw speed, flow rate, and material properties. Appendix B represents the operating conditions for acetal copolymer grade M90 with IPFC from 0.05 to 0.25. Appendix B shows the IPFC is 0.05 for acetal copolymer grade M90 at barrel diameter 2.5 inches. The solid conveying capacity seems to rupture. Appendix B shows the IPFC is 0.10 for acetal copolymer grade M90 at barrel diameter 2.5 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.15 for acetal copolymer grade M90 at barrel diameter 2.5 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.20 for acetal copolymer grade M90 at barrel diameter 2.5 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.25 for acetal copolymer grade M90 at barrel diameter 2.5 inches. The solid conveying capacity is free from rupture.

The IPFC instead of barrel friction was ranged from 0.05 to 0.25 for acetal copolymer grade M90 at the same barrel temperature, screw speed, flow rate, and material properties. Appendix B represents the operating conditions for acetal copolymer grade M90 with IPFC from 0.05 to 0.25. Appendix B shows the IPFC is 0.05 for acetal copolymer grade M90 at barrel diameter 2.25 inches. The solid conveying capacity seems to rupture. Appendix B shows the IPFC is 0.1 for acetal

copolymer grade M90 at barrel diameter 2.25 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.15 for acetal copolymer grade M90 at barrel diameter 2.25 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.20 for acetal copolymer grade M90 at barrel diameter 2.25 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.25 for acetal copolymer grade M90 at barrel diameter 2.25 inches. The solid conveying capacity is free from rupture.

The IPFC instead of barrel friction was ranged from 0.05 to 0.25 for acetal copolymer grade M90 at the same barrel temperature, screw speed, flow rate, and material properties. Appendix B represents the operating conditions for acetal copolymer grade M90 with IPFC from 0.05 to 0.25. Appendix B shows the IPFC is 0.05 for acetal copolymer grade M90 at barrel diameter 2.0 inches. The solid conveying capacity seems to rupture at this moment. Appendix B shows the IPFC is 0.1 for acetal copolymer grade M90 at barrel diameter 2.0 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.15 for acetal copolymer grade M90 at barrel diameter 2.0 inches. The solid conveying capacity is free from rupture. Appendix B shows the IPFC is 0.20 for acetal copolymer grade M90 at barrel diameter 2.0 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.25 for acetal copolymer grade M90 at barrel diameter 2.0 inches. The solid conveying capacity is free from rupture.

The IPFC instead of barrel friction was ranged from 0.05 to 0.25 for acetal copolymer grade M90 at the same barrel temperature, screw speed, flow rate, and material properties. Appendix B represents the operating conditions for acetal copolymer grade M90 with IPFC from 0.05 to 0.25. Appendix B shows the IPFC is 0.05 for acetal copolymer grade M90 at barrel diameter 1.75 inches. The solid conveying capacity seems to rupture. Appendix B shows the IPFC is 0.1 for acetal

copolymer grade M90 at barrel diameter 1.75 inches. The solid conveying capacity is also to rupture. Appendix B shows the barrel friction is 0.15 for acetal copolymer grade M90 at barrel diameter 1.75 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.20 for acetal copolymer grade M90 at barrel diameter 1.75 inches. The solid conveying capacity is free from rupture. Appendix B shows the barrel friction is 0.25 for acetal copolymer grade M90 at barrel diameter 1.75 inches. The solid conveying capacity is free from rupture.

9.7 Simulation Discussion

9.7.1 Effect of Screw Speed

In Figure 9.6 the pressure is presented as a function of axial screw position for different screw speeds for acetal copolymer grade M90. At a high frequency of screw rotation, the axial pressure profiles exhibit a maximum. The relative width of the solid bed (X/W) along the extruder as a function of axial screw position is presented in Figure 9.7 for acetal copolymer grade M90. The relative width of solid bed is decreasing while increasing the screw speed.

9.7.2 Effect of Flow Rate

In plasticating extrusion the effect of flow rate on the melting behavior, pressure, temperature, temperature fluctuation of the extrudate, and power consumption is of considerable interest. Running the simulation at various flow rates while keeping all other variables, such like frequency of screw rotation, screw geometry, and flight clearance constant enables information to be obtained on the ratio of width of the solid bed to the width of the screw channel, its thermal and pressure history while traveling through the extruder, as well as on the extrudate discharge pressure, representing the pressure drop requirements from the die.

Figure 9.8 the pressure is presented as a function of axial screw position for different flow rates for Acetal copolymer grade M90 at 415°F barrel temperature

with constant screw speed. These pressure profiles increase a monotonically at low flow rates. Figure 9.9 represents the relative width of solid bed as a function of axial screw distance for acetal copolymer grade M90 at various flow rates with constant screw speed. It can be seen that at low flow rates the relative width of solid bed decreases rapidly. At low flow rates a considerable amount of heat is generated, which soon increases the melt temperature in the extruder to above the barrel temperature.

9.7.3 Effect of IPFC

By inputting the IPFC instead of the barrel friction in the simulation and systematically reducing the barrel diameter, the effect of the IPFC on the conveying capacity of the solids can be determined.

Figure 9.10 presented the IPFC as a function of axial screw position for acetal copolymer grade M90 at same channel depths. It is clear that solid bed is inhibited rupture by increasing the IPFC value.

From the results presented in Figures 9.10, where full conveying conditions exist the solid bed will convey as a continuum. However, when no conveying conditions exist the solid bed may partially convey, that is, it may rupture. Clearly rupture of the solids bed is most likely to occur near the screw surface. It is also clear that solid bed rupture may be inhibited by increasing the IPFC value, which has been the focus of this dissertation.

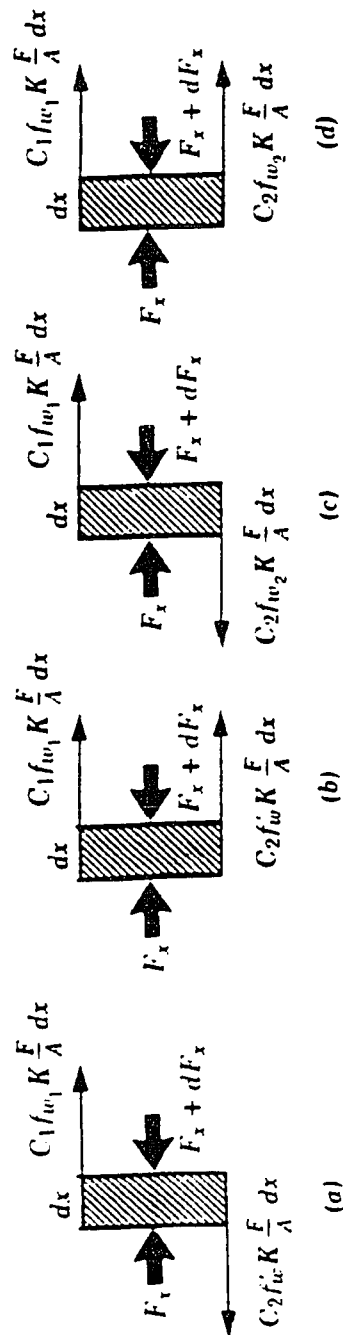


Figure 9.1 Force Balances on a Differential Element of Particulate Bed, (a) Stationary Solids, $F_o > F_L$, (b) Stationary Solids, $F_o > F_L$, (c) Solids Move at Constant Velocity in the Position X-Direction, (d) Solids Move at Constant Velocity in the Negative X-Direction.
(From Tadmor, Z., and Gogos, C. G. [48])

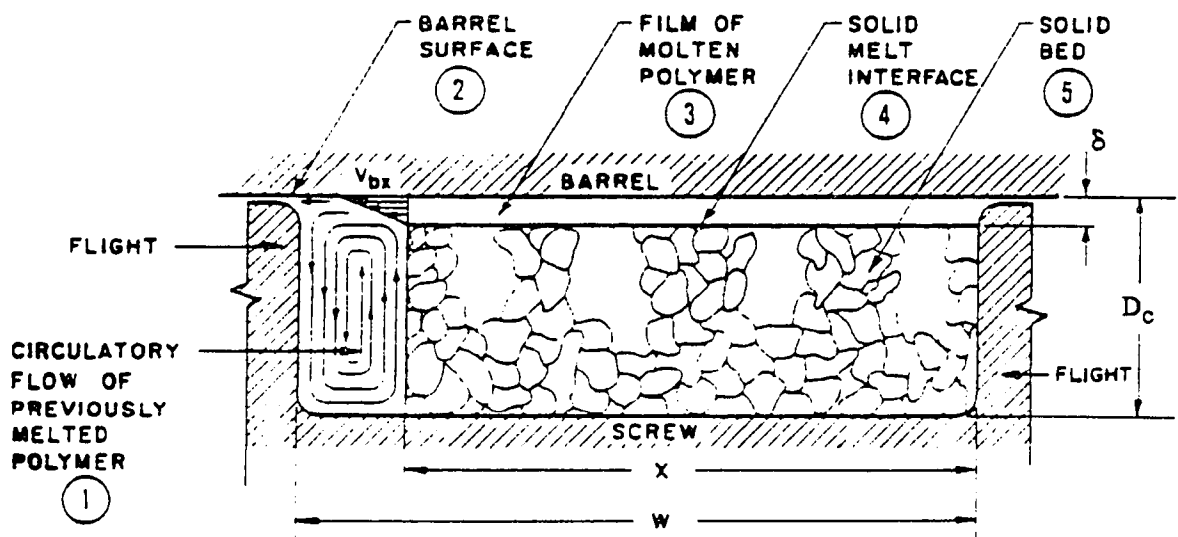


Figure 9.2 Idealized Channel Cross-Section Perpendicular to the Flights Compared to Real Cross-Sections in the Melting Zone.

(From Tadmor, Z., Duvdevani, I. J., and Klein, I, 7, 198, 1967)

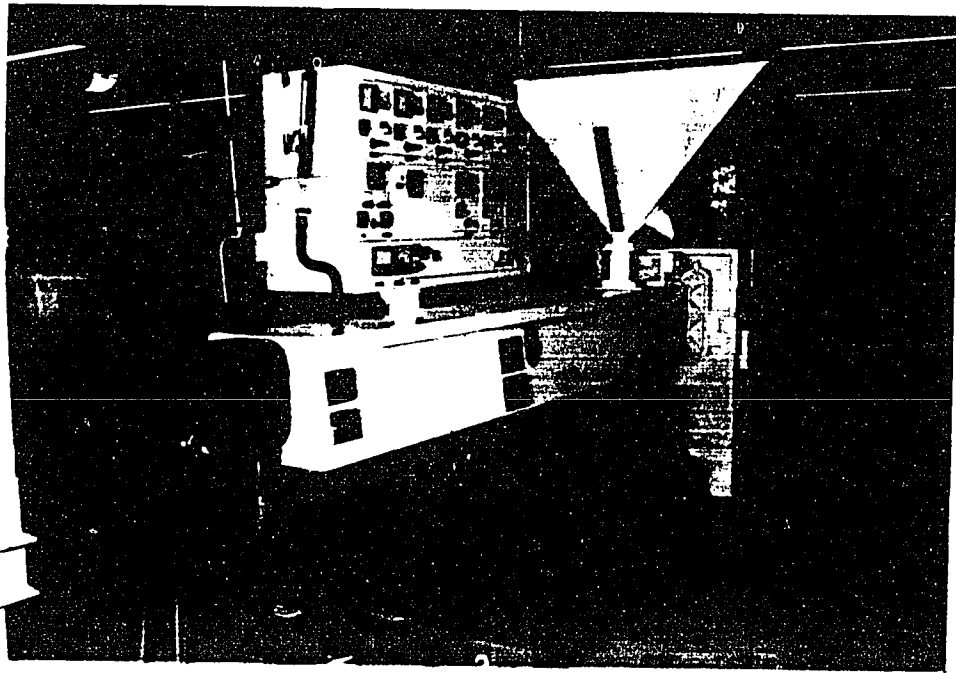


Figure 9.3 Extruder Manufactured by Prodex Co.

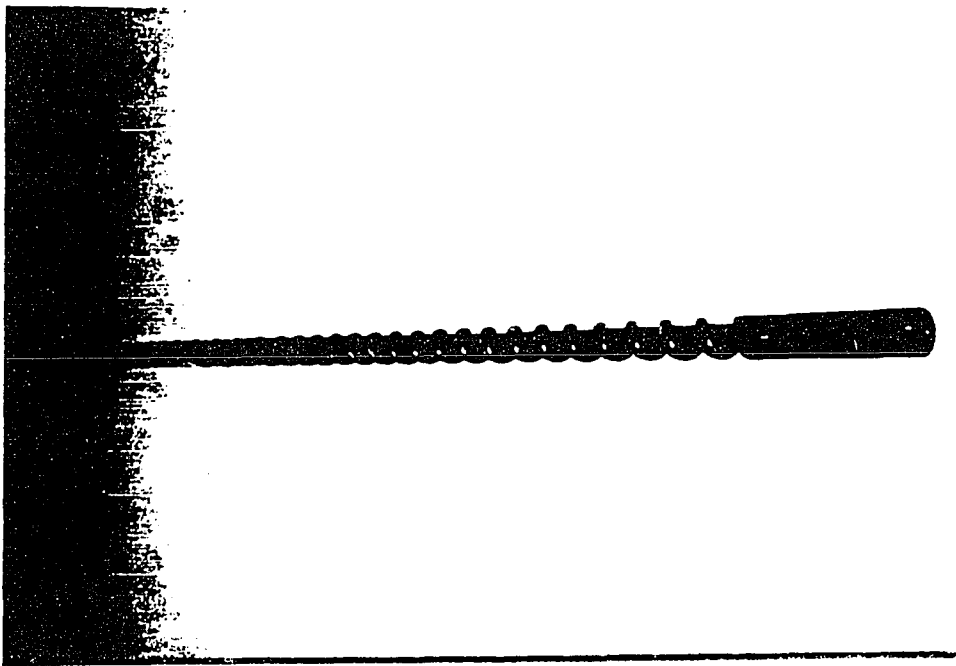
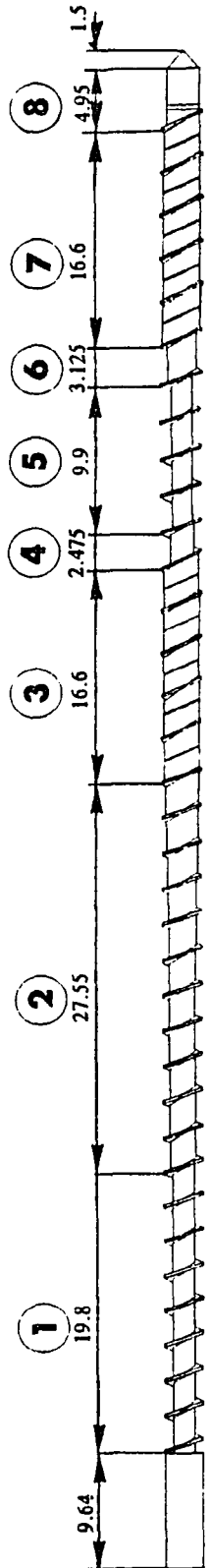


Figure 9.4 Screw Manufactured by Prodex Co.



No	LEAD	CH.DEPTH		FLT. WIDTH	HELIX ANGLE	FLT. CLE.
		SOLID	MELT			
1.	2.475	0.437	0.0	0.300	17.6	0.0125
2.	2.475	0.150	0.0	0.300	17.6	0.0125
3.	3.45	0.150	0.450	0.300	23.5	0.0125
4.	2.475	0.387	0.0	0.300	17.6	0.0125
5.	2.475	0.437	0.0	0.300	17.6	0.0125
6.	3.125	0.237	0.0	0.300	19.4	0.0125
7.	3.45	0.213	0.0	0.300	23.5	0.0125
8.	2.475	0.213	0.0	0.300	17.6	0.0125

Figure 9.5 Details of Prodex Screw

Barrel Diameter = 2.5 inches
Flow Rate = 100 lb/hr
Material: M90

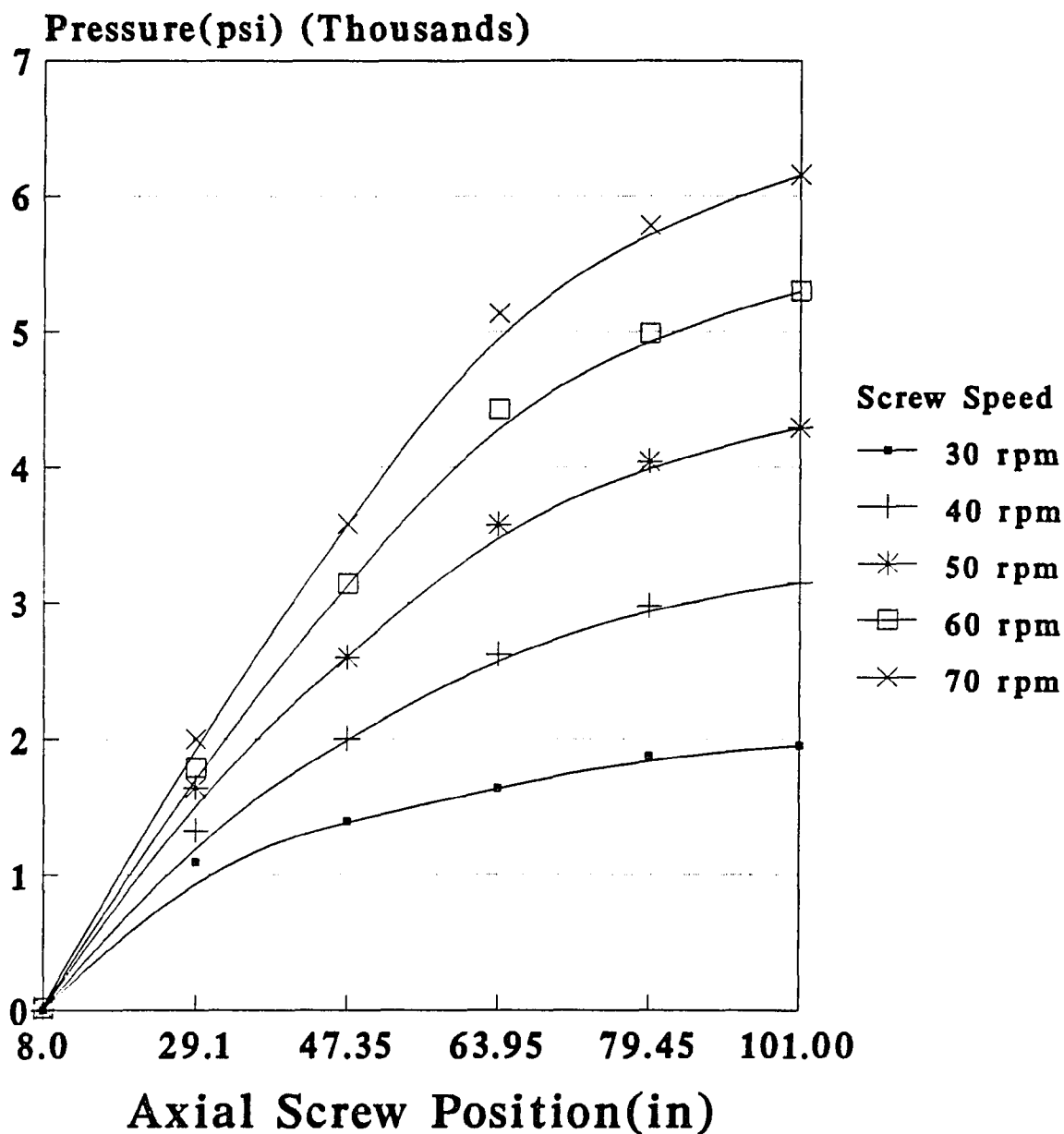


Figure 9.6 The Pressure as a Function of Axial Screw Position for Different Screw Speeds for Acetal Copolymer Grade M90.

Barrel Diameter = 2.5 inches
Flow Rate = 100 lb/hr
Material: M90

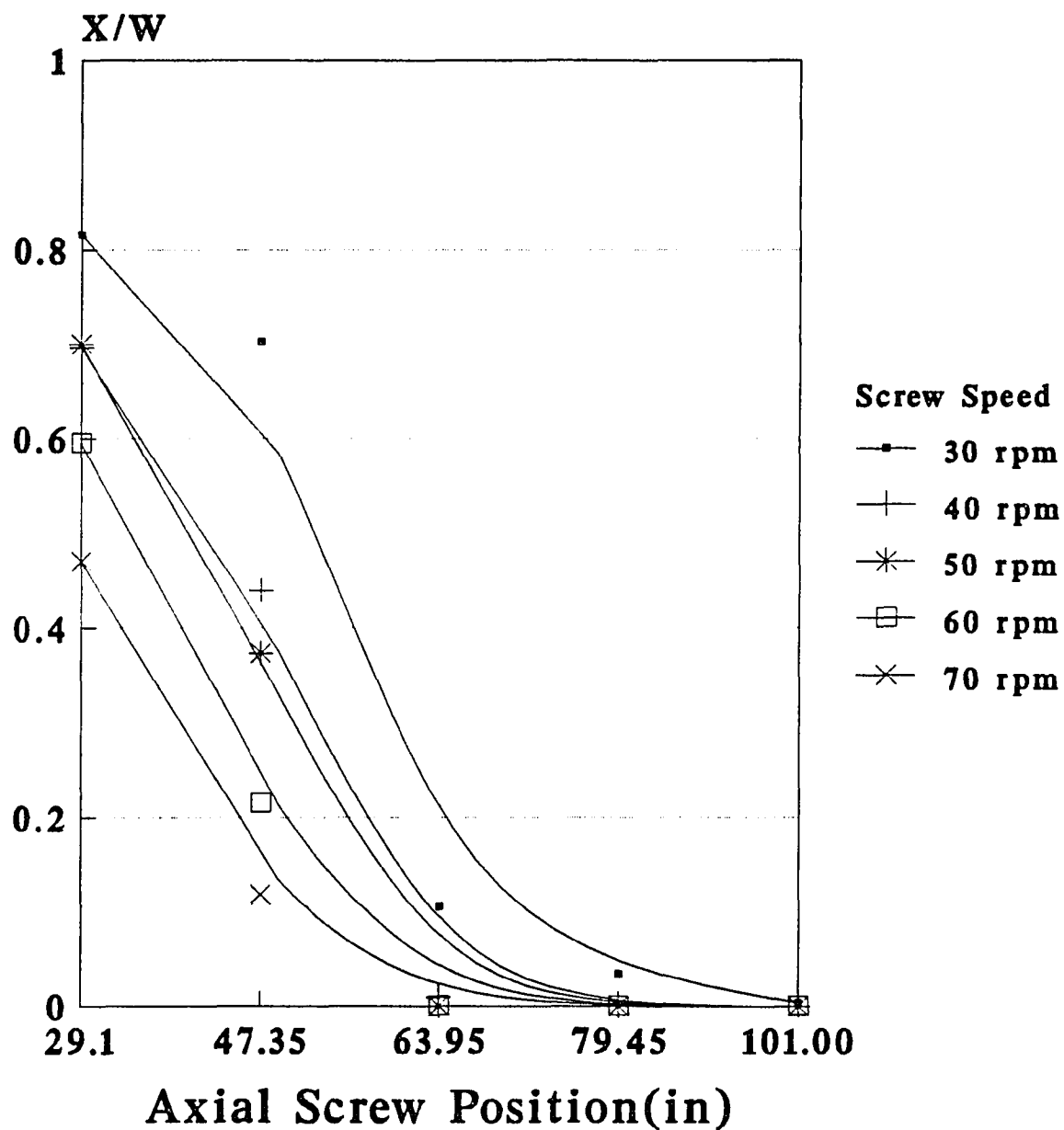


Figure 9.7 The Solid Bed Ratio as a Function of Axial Screw Position for Different Screw Speeds for Acetal Copolymer Grade M90.

Barrel Diameter = 2.5 inches
Screw Speed = 50 rpm
Material: M90

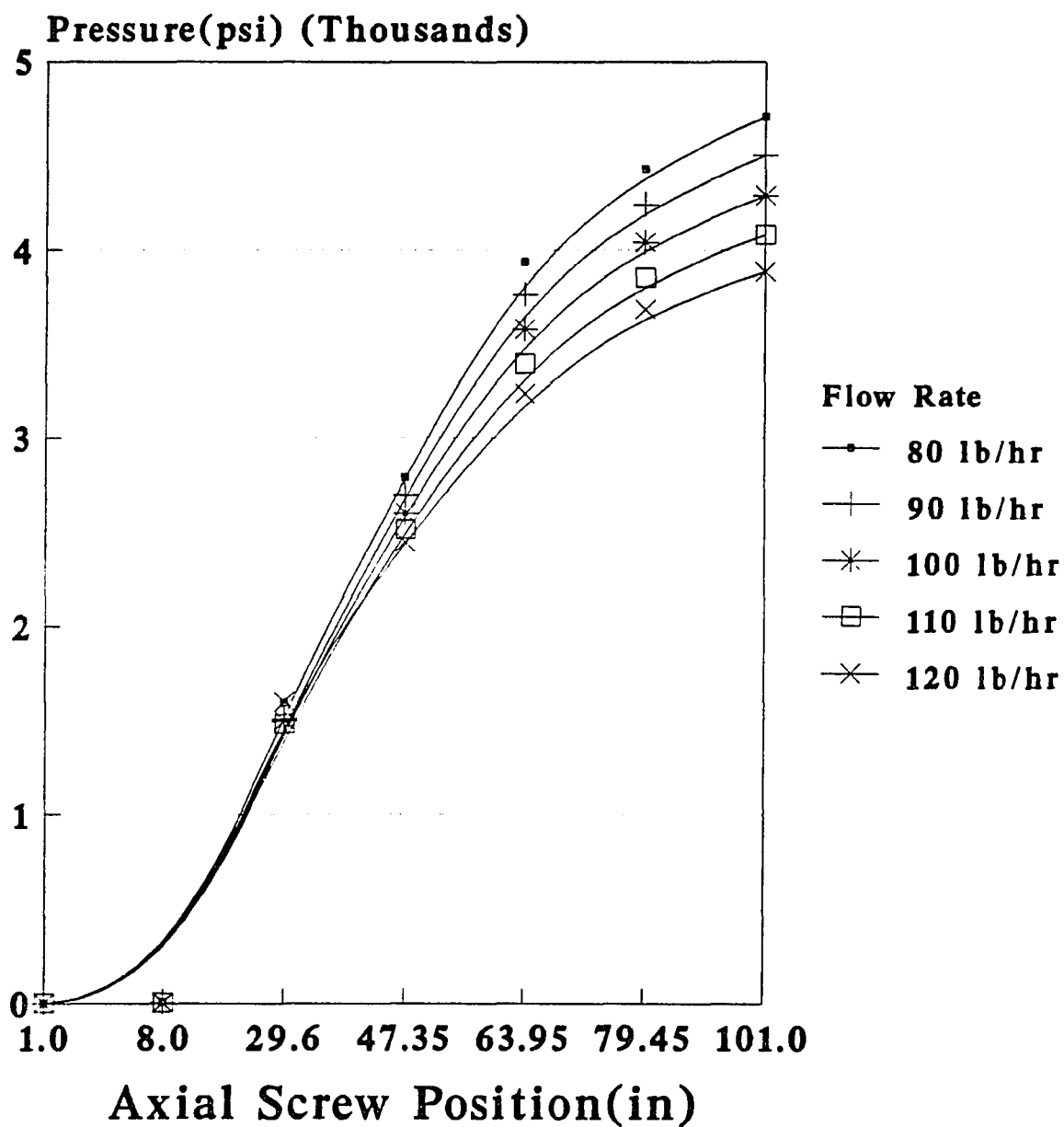


Figure 9.8 The Pressure as a Function of Axial Screw Position for Different Flow Rates for Acetal Copolymer Grade M90.

Barrel Diameter = 2.5 inches
Screw Speed = 50 rpm
Material: M90

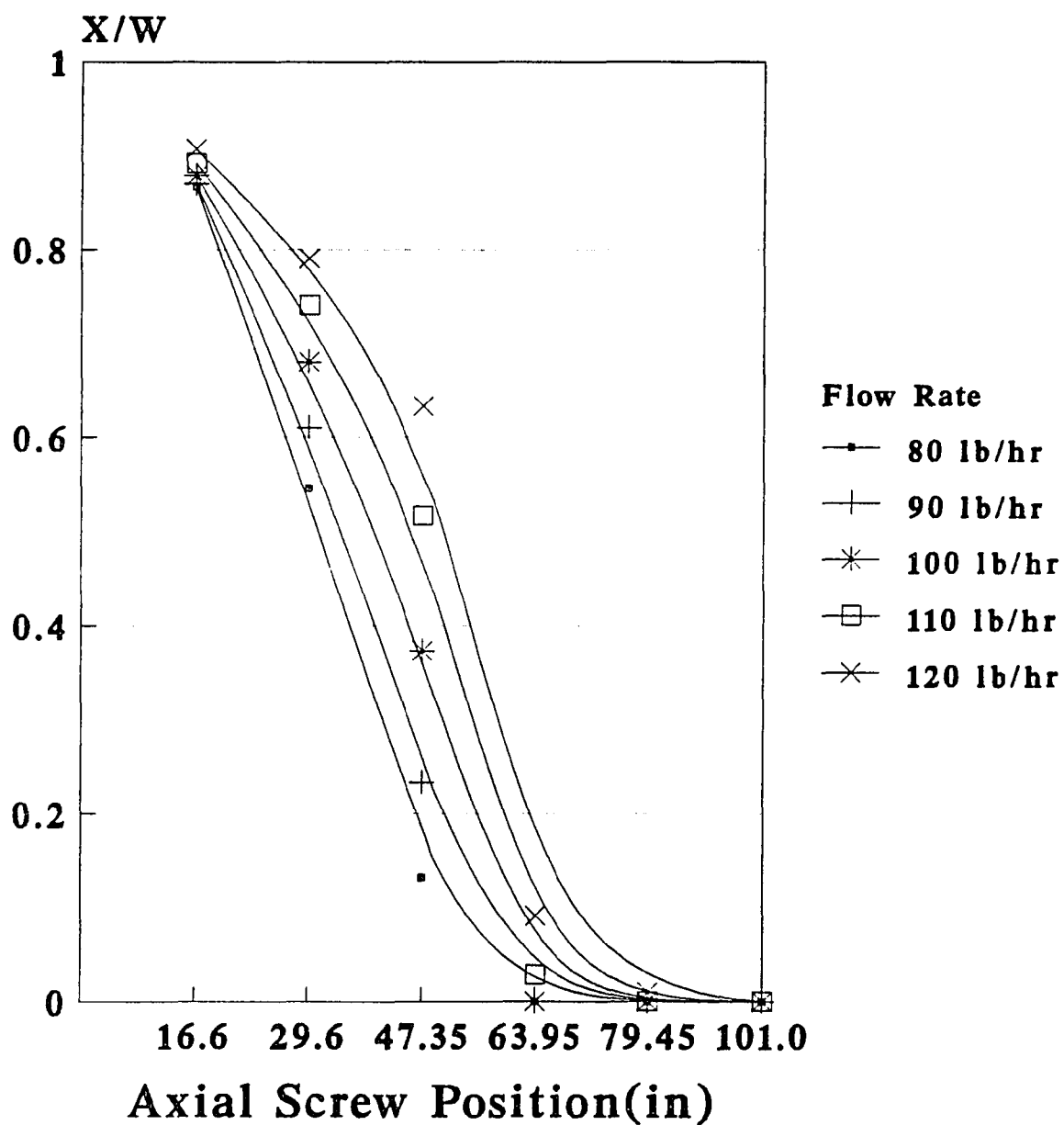


Figure 9.9 The Solid Bed Ratio as a Function of Axial Screw Position for Different Flow Rates for Acetal Copolymer Grade M90.

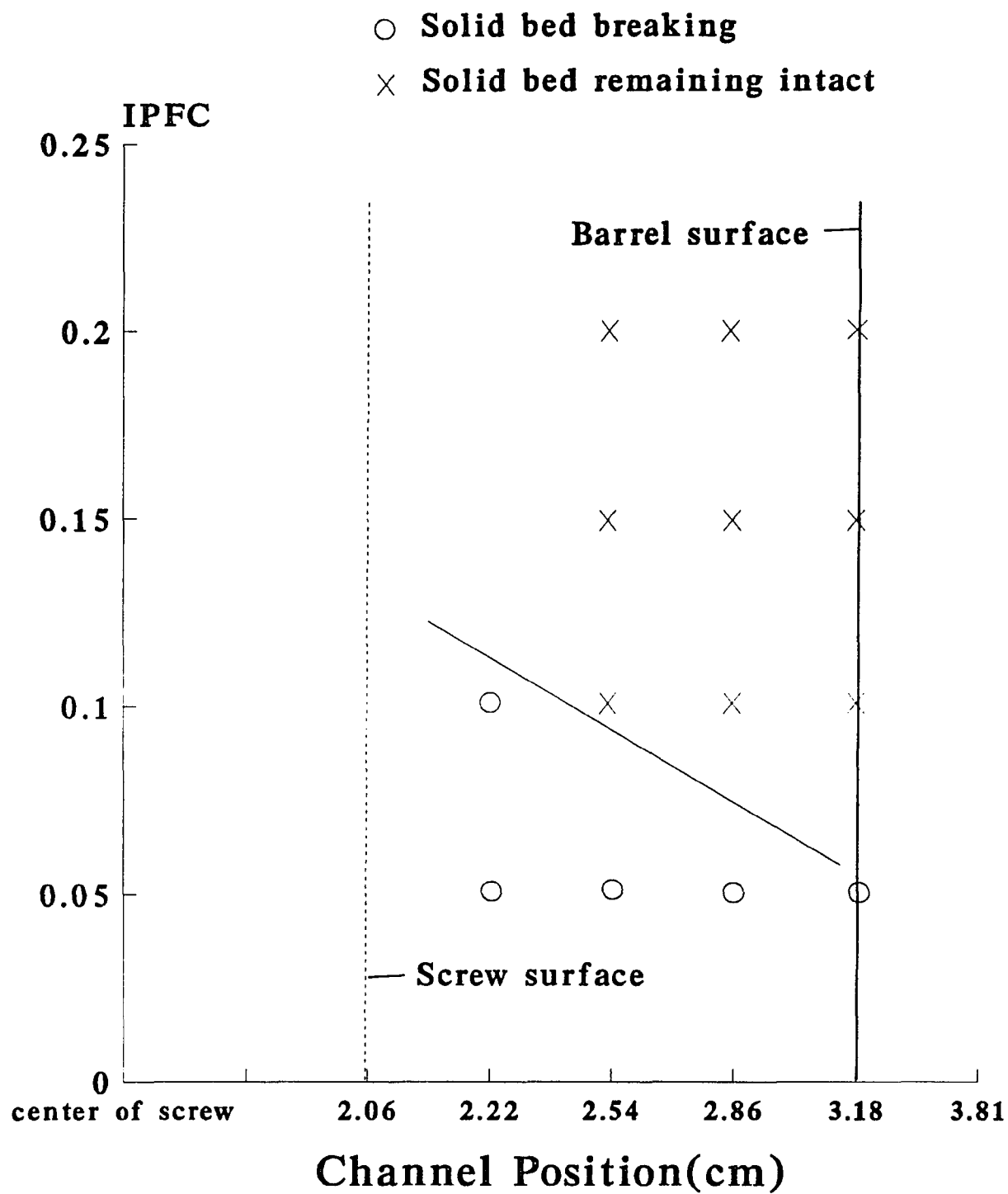


Figure 9.10 The IPFC as a Function of Axial Screw Position at Same Channel Depth for Acetal Copolymer Grade M90

CHAPTER10

POSTLUDE

10.1 Conclusions

1. Increasing the IPFC ensures that solid bed rupture will be reduced under given operating conditions. This has been shown by numerical simulation and experimental operation of a plasticating extruder. This conclusion was found to be true under all conditions of operation tested. Thus the use of profiled pellets may be expected to reduce the propensity to surge of plasticating extruders.

2. The IPFC has been shown to increase if pellets with profiled cross-sections constitute the feedstock, rather than pellets with circular cross-sections. The highest IPFCs were obtained with pellets of a bilobal cross-sections. The average IPFC of pellets with bilobal cross-sections is 56 % increase than pellets with circular cross-sections. Pellets with trilobal and quadrilobal cross-sections exhibited IPFCs greater than those obtained with pellets of circular cross-sections. The average IPFC of pellets with trilobal and quadrilobal cross-sections is 20% and 34% increase than pellets with circular cross-sections, respectively. Thus pellets with bilobal cross-sections have been isolated as the most likely to obtain surging.

3. Agitation of the particulate continuum prior to measurement of the IPFC ensured closer packing of the particulates and caused an increase in the IPFC. The average IPFC of bilobal pellets with agitation is 89% greater than the pellets with circular cross-sections. The average IPFC of trilobal and quadrilobal pellets with agitation is 51% and 62% increase than the pellets with circular cross-sections. Thus vibration in the feed this at area of the extruder would be expected to improve the conveying capacity and to remove some causes of surging.

4. Consolidation of the particulate continua prior to measurement of the IPFC for specified times at specified pressures did not significantly change the value of the IPFC measured. The consolidation time had a weak influence on the IPFC, increasing only 13% after 30 hours. This implies that profiled pellets will not cause bridging in hoppers and silos to any greater degree than pellets with circular cross-sections.

5. The presence of external lubricants on the surface of the pellets has a significant effect on the IPFC, which is reduced up to 45%. It is clear that the function of external lubricants promote slippage. However, the IPFC of the pellets with bilobal cross-sections is still greater than that of pellets with circular cross-sections. So, greater conveying capacity and a reduction in surging propensity are to be expected.

6. The presence of mineral powder in the form of mica clay intermixed with the pellets cause an increase in IPFC value up to 35%. This implies that during the compounding of mica clay into PBT improved conveying is to be expected. It also implies that the addition of small quantities of mica clay powder could eliminate nonblesome surging.

7. The presence of polymeric powder, PBT powder, intermixed with the pellets cause an increase in the IPFC value up to 20%. This implies that when extruding polymers some feedstock should be in the form of powder if surging occurs. Its addition will minimize surging and improve operation variability.

10.2 Future Work

10.2.1 Additional Profile Shapes

Although bilobal, trilobal and quadrilobal pellet cross-sections have been developed and tested to date, a host of others are possible. Some additional cross-sections for profiled pellets are presented in Figure 10.1. They could be rectangular, square, triangular, crescent or star. The most important consideration for choosing the shape is the ability to interlock, from any adjacent partition.

10.2.2 Additional Resin

To date, the IPFCs of acetal copolymer, high density polyethylene, polypropylene, polystyrene, nylon 6 and acrylonitrile-butadiene-styrene have been measured in the tests. Additional polymers of interest are low density polyethylene, linear low density polyethylene, ethylene-vinyl acetate, ionomer, polymethylpentene, polyvinyl chloride, polyvinylidene chloride, polyvinylacetate, styrene acrylonitrile, polymethylmethacrylene, polyethylene terephthalate, polybutylene terephthalate, polyarylate, polycarbonate, polyethersulfone, polyphenylene oxide, polyvinylidene fluoride, nylon 6/6, polyphenylene sulfide, and polyethorioide. So, their behavior is also of high importance. The benefits in terms of an increase in the interparticulate friction coefficient are expected to be as great, since it is the shape and the material which determines the IPFC. A full range of materials, with varying moduli, both filled and unfilled, need to be evaluated to determine the full advantages of profiled pellets.

10.2.3 Additional Resin Grades

To date only one grade of each of the test resins has been evaluated. Many grades exist in use however. Extensive testing of all grades needs to be performed. For example, for nylon 6 over one hundred grades are in common use and require

testing. However, since it is the pellet cross section and not the ingredients which most influence the IPFC increases are to be anticipated.

10.2.4 Field Trials

To date most of the work performed has been in the laboratory, and not in production extruders. Although all of the results have validated the initial hypothesis that the interparticulate friction coefficient will increase, it has not been demonstrated comprehensively that there are benefits to the extrusion process. Work must be performed to complete the overall objective, which was to enhance the output of extruders by delaying the onset of surging. Thus field trials must be extensively conducted, for a variety of pellet cross-sections, and a variety of generic resin types with different kinds of extruders. The procedures for field trial can be summarized as the following.

1. The pellets with a circular cross-section for all test samples including acetal copolymer, polyethylene, polypropylene, polystyrene, nylon 6 and ABS must be extruded on the Prodex extruder, which should be operated for specified time period to determine the throughput rate.
2. The pellets with higher IPFC values, such as the pellets with bilobal, trilobal, quadrilobal cross-sections for all test materials must be extruded on the Prodex extruder, which should be operated for the same time period as step 1 to determine the throughput rate, then compared to the equivalent results in step 1.
3. Since the grooved feed sections increase initial compression and increase conveying, outputs are improved greatly. The pellets with circular cross-sections for all materials should be extruded using helical grooved feed throats extruder and the extruder should be operated for a specified time period to determine the throughput rate, then compared to the equivalent results in step 1.

4. The pellets with bilobal, trilobal, quadrilobal cross-sections, and those pellets with new cross-sections for all test materials should be extruded with a helical grooved feed throat extruder and this extruder should be operated for specified time period to determine the throughput rate, then compared to equivalent results in step 2.
5. Since the barrier screws are designed to separate the solid bed from the melt pool, they inhibit solid bed breakup. The pellets with circular cross-section should be extruded for all test materials on barrier screw extruders, including the Hartig MC-3 screw, Maxmelt screw, the Barr-2 screw, the "Efficient" screw, and the VPB screw and the extruders operated for specified time period to determine the throughput rate, Then these results should be compared to the equivalent results in step 1.
6. The pellets with bilobal, trilobal, quadrilobal cross-sections, and those pellets with new shape on the barrier screw extruders, including the Hartig MC-3 screw, Maxmelt screw, the Barr-2 screw, the "Efficient" screw, and the VPB screw, and then operated those extruders for specified time period to determine the throughput rate, then compared to the equivalent results in step 2.
7. The pellets with circular cross-section should be extruded for all test materials in the barrier screws with grooved feed throats extruders and the extruders operated for a specified time period to determine the throughput rate. These results should then be compared to the equivalent results step 1.

The pellets with bilobal, trilobal, quadrilobal cross-sections, and those pellets with new shapes should be extruded on the barrier screws with grooved feed throats extruders and the extruders operated for a specified time period to determine the throughput rate. These results should then be compared to the equivalent results in step 2.

Completing the experiments above, a detailed comparison under various operating condition can be made to determine how the IPFC effects the throughput of different kinds of extruders.

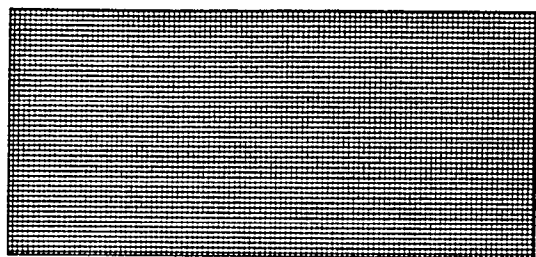
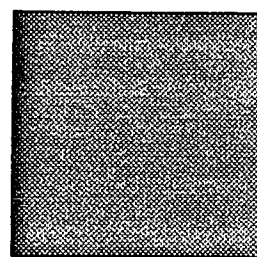
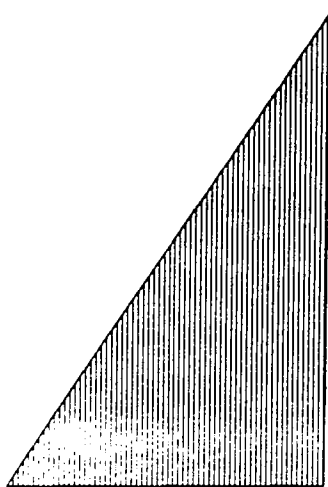
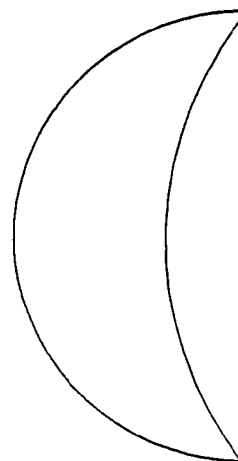
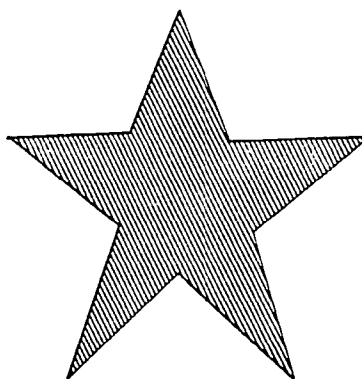
**(a)****(b)****(c)****(d)****(e)**

Figure 10.1 Additional Pellet Cross-Sections, (a) Rectangular, (b) Square, (c) Triangular, (d) Crescent, (e) Star.

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APPENDIX A

The structure of the data file is described as below. It consists of data lines. Each line consists of one or more data fields. Each field can contain one of 3 possible data types:

1. A Fixed Point variable which must not contain a decimal point, (I).
2. A Floating Point variable which does contain a decimal point. If decimal point is absent it is assumed to be at the right hand end of the number, (F).
3. A Character String, (A).

The data file starts with 3-SPEC lines which specify the data file in generalities, and 27 line to describe the screw geometry, barrel temperature, plastic physical properties, frictional coefficient between barrel and screw, and operating condition for running the simulation by using the EXTRUD¹®.

The 1st spec line describes the mode of running the simulations. This can be either Batch (B) or Conversational (C). The line, therefore, consists of a single field containing at least a single character.

The 2nd spec line includes 11 field. Each field is described as below.

- | | |
|-----------|---|
| 1st field | Output device number : 6 (for PC) is the user terminal designation. For batch use number: 7 (for PC). OUTDEV |
| 2nd field | Input device number: 5 (for PC) is the user terminal designation; The device refers only to individual changes to be made at the end of the run in the input option. For batch mode use number: 18 (for PC). The list of variables that can be changed follows this section describing the input data file. INDEV |
| 3rd field | 0 for viscosity function in English units; viscosity (LB.SEC/IN ²) & temperature (°F).
1 for viscosity function in poise and temperature in (°C).
2 for all input and output in metric units, except resin properties which remain in English units. POISE |

¹ Note: EXTRUD[®] is the Registered Trademark of Scientific Process and Research, Somerset, New Jersey.

- 3 resin properties in metric unit as well.
- 4th field 0 if melting does not continue in plugged channel (usually the case for harder solids).
1 if melting to continue in a plugged channel(for soft solids). IPLUG
- 5th field 0 if positive pressures only are to be printed
1 if negative pressures to be printed also. IFRES
- 6th field 0 if X/W for plugged channel= .99 otherwise, insert maximum X/W permitted. XTST
- 7th field line number at which reading of data will stop. A diagnostic tool. SCARD
- 8th field 0 for mixing in relief section.
1 for no mixing (for hard solids). MIXREL
- 9th field 1 for SDS[®] Screw² . IFRECS
- 10th field Number of sections with dual channel for melt and solids.(Must be used for barrier type screws) MLTCHL
- 11th field Code number for material of which screw is constructed. ITAU

The 3rd spec line indicated that if user wish to make changes of individual input variables in list form and then put YES, if user do not and then put NO.

The 27th lines of the input data must according to the format described as follows, respectively.

² Patented U.S. and other countries.

1st LINE
 FORMAT(I,6F,10I)
 (Mandatory)

- 1st field 1 for complete printout of every increment computed.
 0 for shortened printout with every 5th increment printed.
 -n for short printout with suppressed heading, every n-th axial increment printed out; n, must be an integer. IPLOT
- 2nd field Run identification number, can be any positive number. ID
- 3rd field Number of parallel flights. NFLT
- 4th field Screw lead at entrance to first geometric section (inches), (mm). SLEAD
- 5th field Barrel diameter (inches), (mm). DBAR
- 6th field Flight width (inches), (mm). FLWD
- 7th field Radial flight clearance (inches), (mm). FLCL
- 8th field Number of geometric sections.
- 9th field 1 for delay in melting start to be computed.
 0 if calculation suppressed. DLY
- 10th field 1 for injection molding to be computed.
 -1 if C_p vs T has no maximum, e.g. ABS, Polystyrene for injection molding.
 0 for continuous extrusion. INJ
- 11th field 0 if both barrel heating and efficient cooling available.
 1 if no efficient barrel cooling available - only heating.
 2 adiabatic in melt pool, not in melt film.
 3-7 approaches adiabatic in melt film. COOL
- 12th field 0 if barrel and screw temperature in data file to be used.
 1 if barrel temperature profile to be optimized with respect to maximum melting rate in the melting zone.
 2 if screw and barrel temperature to be optimized to maximize solid conveying. OPT
- 13th field 0 for single viscosity function with resin data supplied by user.
 1 if polymer exhibits melt fracture with discontinuity between 2 viscosity functions.

- 2 for 2 viscosity ranges to be used for better representation of flow property data without melt fracture, for example to describe the low shear rate Newtonian viscosity range.
- n for resin data from SPR list of physical properties other than friction. MLFR
- 14th field 0 in case of plasticating extrusion.
1 in case of melt extrusion.
-1 in case of semi-melted feed. MLTX
- 15th field This field used only for the computation of delay in melting start.
0 for no target and no die specification (rate mode).
1 if series of statistically distributed simulations to be generated from a single set of data.
-1 for extruder-die combination with production rate to be computed by the computer & die characteristic equation given in 11th line.
-2 for extruder-die combination with die characteristic given as a single point: output-temperature-pressure drop in 11th line.
-3 for extruder-die combination using cylindrical die. SERIES
- 16th field 0 in the absence of mixing devices.
1 if mixing rings are present.
2 if torpedo (unflighted section) is present.
3 if fluted section is present-simple computation. Can also be simulated by more accurate method using melt channel.
-n if more than one type of mixing device is present(n= number of mixing devices in the screw). RGN
- 17th field 0 for low density Polyethylene.
1 for high density Polyethylene.
2 for Polypropylene and Nylon.
3 for rigid PVC, Polystyrene, Polycarbonate, Polymethylmethacrylate, Polyacrylonitrile.
4 for 50% longer delay zone than for 3.
5 for 100% longer than for 3.
6 for 150% longer than for 3.
-1 for 50% shorter than for 0.
100 no melting starts at all. IDL

2nd LINE
FORMAT(10F)
(Optional)

- | | |
|------------|--|
| 1st field | Length of 1st geometrical section from downstream or exit end of hopper. SECTION(1) |
| 2nd field | Channel depth at the end of 1st geometrical section from flight tip to screw root. HSEC(1) |
| 3rd field | Length of 2nd geometrical section. SECTION(2) |
| 4th field | Channel depth at the end of 2nd geometrical section. HSEC(2) |
| 5th field | Length of 3rd geometrical section. SECTION(3) |
| 6th field | Channel depth at the end of 3rd geometrical section. HSEC(3) |
| 7th field | Length of 4th geometrical section. SECTION(4) |
| 8th field | Channel depth at the end of 4th geometrical section. HSEC(4) |
| 9th field | Length of 5th geometrical section. SECTION(5) |
| 10th field | Channel depth at the end of 5th geometrical section. HSEC(5) |
- 1st field on the next line continued as above for 6th through 10th geometrical section.

LINE 2A
 FORMAT (15F)
 (Optional)

(Replaces 2nd LINE when screw lead is not constant)

(May consist of more than one line if the number of Geometrical Sections is more than 5.)

All dimensions on this line are in inches or millimeters.

1st field	Length of 1st geometrical section from downstream or exit end of hopper. SECLN (1)
2nd field	Channel depth at the end of 1st geometrical section from flight tip to screw root (flight clearance not included). HSEC (1)
3rd field	Screw lead at end of 1st geometrical section. SLD (1)
4th field	Length of 2nd geometrical section. SECLN (2)
5th field	Depth at the end of 2nd geometrical section. HSEC (2)
6th field	Screw lead at end of 2nd geometrical section. SLD (2)
7th field	Length of 3rd geometrical section. SECLN (3)
8th field	Depth at the end of 3rd geometrical section. HSEC (3)
9th field	Screw lead at end of 3rd geometrical section. SLD (3)
Etc.	up to 5 geometrical sections per line.

The only limitation of the data supplied by this line is that the first geometrical section must always be a constant depth section. If compression actually starts at the beginning of the screw, an imaginary constant depth section of zero length has to be introduced.

1st LINE, 4h field (SLEAD) represents screw lead at start of 1st section.

LINE 2B
 FORMAT(10F)
 (Optional)

Used only together with LINE 2C and only when MLTCHL
 2nd spec LINE, 10th field is non-zero.

1st field	Width of melt channel at end of 1st geometric section at which it is present, (Fraction of Total) WM (1)
2nd field	Depth of melt channel at end of 1st geometric section at which it is present, (in.), (mm.) HM (1)
3rd field	Width of melt channel at end of 2nd geometric section at which it is present, (Fraction of Total) WM (2)
4th field	Depth of melt channel at end of 2nd geometric section at which it is present, (in.), (mm.) HM (2)
	.
	.
	.
	.
9th field	Width of melt channel at end of 5th geometric section at which it is present, (Fraction of Total) WM (5)
10th field	Depth of melt channel at end of 5th geometric section at which it is present, (in.), (mm.) HM (5)

up to 5 geometric sections per line.

LINE 2C
FORMAT(2I, 4F)
(Optional)

1st field	Section number where melt channel starts, JJM0
2nd field	Section number where melt channel ends, JJMEND
3rd field	Width of melt channel at start of JJM0-th geometric section (fraction of total), WM0
4th field	Depth of melt channel at start of JJM0-th geometric section (in.), (mm.), FWMLT
5th field	Flight Width of auxiliary flight (in), (mm), FWMLT
6th field	Radial clearance of auxiliary flight (in), (mm), FCLMLT

LINE 2D
FORMAT (15F)
(Optional)

(Replaces 2nd LINE when flight width is not constant)
 (May consist of more than one line if the number of
 geometrical sections is more than 5.)

All dimensions on this line are in inches or millimeters.

1st field	Length of 1st geometrical section from downstream or exit end of hopper. SECTION (1)
2nd field	Channel Depth at the end of 1st geometrical section from flight tip to screw root. (flight clearance not included). HSEC (1)
3rd field	Flight width at end of 1st geometrical section. FLT (1)
4th field	Length of 2nd geometrical section. SECLLEN (2)
5th field	Depth at the end of 2nd geometrical section. HSEC (2)
6th field	Flight width at end of 2nd geometrical section. FLT (2)
7th field	Length of 3rd geometrical section. SECLLEN (3)
8th field	Depth at the end of 3rd geometrical section. HSEC (3)
9th field	Flight width at end of 3rd geometrical section. FLT(3)
Etc.	up to 5 geometrical sections per line.

The only limitation of the data supplied by this line is that the first geometrical section must always be a constant depth section. If compression actually starts at the beginning of the screw, an imaginary constant depth section of zero length has to be introduced.

1st LINE, 6th field (FLTWID) represents regative of FLT (0), ie. flight width at start of 1st section under the hopper.

3rd LINE
 FORMAT
 (Mandatory)

The 3rd line consists of the material properties, it includes thermal conductivity of melt, density of solid bed, heat capacity of melt, heat capacity of solid polymer, heat of fusion, temperature of polymer fed to the extruder and shear rate. This line is mandatory, and the format(7F) of line presented as below,

1st field

Thermal conductivity of melt (Btu/hr. ft^{°F}),(W/m.°C). THCONO

2nd field

Density of solid bed (lb/ft³),(g/cm³). RHOSOL

3rd field

Heat capacity of melt ((Btu/lb^{°F} or cal/g^{°C}),(J/Kg.°K). HETCAM

4th field

Heat capacity of solid polymer ((Btu/lb^{°F} or cal/g^{°C}),(J/Kg.°K).
 HETCAS

5th field

Heat of fusion ((Btu/lb),(J/Kg). HETFUS

6th field

Temperature of polymer fed to the extruder(°F),(°C). TSOLID

7th field

0 if shear rate for start of second Newtonian region is 100,000 per sec.
 Otherwise insert known value for shear rate. GAMAX

4th LINE
 FORMAT(9F)
 (Mandatory)

The 4th line describes the melting point for polymer, This line is mandatory, and the format(7F) of line presented as below,

1st field	R_0
2nd field	T_{M0}
3rd field	R_1
4th field	R_2
5th field	R_{12}
6th field	T_{M1}
7th field	T_{M2}

Defined as:

$$RHO = R_0 + R_1 * P + R_2 * T + R_{12} * P * T$$

$$T_M = T_{M0} + T_{M1} * P + T_{M2} * P^2$$

where: P = pressure (lb./sq. in.), (bar)

T = melt temperature (°F), (°C)

RHO = melt density (lb./ft³), (g/cm³)

T_M = melting point (°F), (°C)

5th LINE
 FORMAT (9F)
 (Mandatory)

The 5th line describes the coefficients of flow equation and shown as below,

1st field	A(i)
2nd field	A ₁ (i)
3rd field	A ₂ (i)
4th field	A ₁₁ (i)
5th field	A ₂₂ (i)
6th field	A ₁₂ (i)
7th field	A ₁₄ (i)
8th field	ATD(i) coefficient of temperature degradation
9th field	ASD -coefficient of shear degradation

where, coefficients of viscosity equation are defined as:

$$\ln \text{VISC} = A(i) + A(i) \cdot \ln \gamma + A_{11}(i) \cdot \ln^2 \gamma + A_2(i) \cdot T + A_{22}(i) \cdot T^2 + A_{12}(i) \cdot T \cdot \ln \gamma + A_{14}(i) \cdot T \cdot \ln P + A_{14}(i) \cdot \ln P + ATD \cdot \text{Theta} + ASD \cdot \text{Theta} \cdot \text{TAU}$$

where,

VISC	= Viscosity (lb.sec./in ²), (Poise)
γ	= true (Rabinowitsch corrected) shear rate (sec ⁻¹)
T	= melt temperature (F), (C)
P	= Pressure (psi), (bar)
Theta	= Residence Time in melt pool (hr)
TAU	= shear stress (psi), (bar)

LINE 5A
FORMAT(I,5(I,F))
(Optional)

It described mixed feed and shown as below,

1st field	Number of components in resin feed, MATS
2nd field	Resin number of first component in resin feed, INGRID(1)
3rd field	Fraction of first component in feed, FRA(1)
4th field	Resin number of second component in feed, INGRID(2)
5th field	Fraction of second component in feed, FRA(2)
6th field	Resin number of 3rd component in feed, INGRID(3)
7th field	Fraction of 3rd component in feed, FRA(3)
8th field	Resin number of 4th component in feed, INGRID(4)
9th field	Fraction of 4th component in feed, FRA(4)
10th field	Resin number of 5th component in feed, INGRID(5)
11th field	Fraction of 5th component in feed, FRA(5)

6th LINE
 FORMAT (4F, 4I)
 Mandatory

For a general case

1st field C0 (F), (C)

2nd field C1

3rd field C2 (1/in), (1/mm)

For T_{bar} defined by equation: $T_{\text{bar}} = C0 [1 - C1 \cdot \exp(-C2 \cdot x)]$

For a special case with constant barrel temperature profile set:
 $C0 = T_{\text{bar}}$; $C1$ and $C2 = 0$.

If you wish to enter barrel temperatures as point values, $C0$, $C1$ and $C2$ will be disregarded by the program. See 5th field of this 6th LINE.

where:

T_{bar} = barrel temperature at each axial location (F), (C).

x = axial distance from the beginning of first Geometrical Section to the middle of increment (inches).

4th field P0 Pressure at entrance to extruder (psi), (bar) or at any arbitrary point where $x = 0$. This can be used in describing the operation of a partial extruder. Cramer feeder primarily effects bulk density and not entrance pressure.

5th field 0 if Tbar equation above is used for barrel temperature.
 n for barrel temperature profile to be supplied as point value with EXTRUD[®] computing Tbar at each axial location through linear interpolation. (n = number of points at which barrel temperature is supplied, n must be bigger than 2, 20 maximum). Barrel temperatures and locations are supplied on 7th LINE.
 IPOE

Note: For temperature given as point values use 7th LINE.

For heater zones use special instructions for 6th and 7th LINES following description of 7th LINE.

6th field	0	for normal printout with highest accuracy.
	1	for solids conveying computed at lower accuracy.
	2	computed viscosities not printed out either.
	3	melting also computed at lower accuracy.
	4	temperature also computed at lower accuracy. ITOL
7th field	0	when no friction coefficients for solids are available and solids conveying computations are not desired.
	1	when any friction coefficients for solids on screw and barrel surfaces are supplied and the temperature of solid plug surface is calculated by the program. ISOL
8th field	n	for frictional property material number of data from SPR friction data file on barrel surface if surfaces are different, below 2 psi if 2 pressure ranges are used. NFRICB
9th field	n	for frictional property material number of data from SPR friction data file on screw surface if surfaces are different, below 2 psi if 2 pressure ranges are used. NFRICS
10th field	n	for frictional property material number of data from SPR friction data file on barrel surface above 2 psi pressure. NFRCBH
11th field	n	for frictional property material number of data from SPR friction data file on screw surface above 2 psi pressure. NFRCSH

Line 6A
 FORMAT (8F)
 (Optional)

To maintain constant temperatures over each heater zone, the 1st and 5th field on this line must be set as follows:

1st Field	C0	Insert -1 for constant temperature zones.
5th field	IPOE	Number of constant temperature zones.

7th LINE
 Barrel Temperature Defined by Points Along Barrel
 FORMAT (8F)
 (Optional)

(Read-in only if 5th field in 6TH LINE (IPOE) was other than 0)

- | | |
|-----------|---|
| 1st field | Barrel temperature (°F) at zero axial location. Replaced in the hopper area by cooling water temperature as defined by AXDTM in 9th LINE 5th field. TBR(1). |
| 2nd field | Axial location (in.), (mm.) (0.0). AXD(1) |
| 3rd field | Barrel temperature at a point down-channel from 1st point (°F), (°C). TBR (2) |
| 4th field | Axial location of 2nd point (in.), (mm.). AXD(2) |
| 5th field | Barrel temperature at 3rd point (°F), (°C). TBR(3) |
| 6th field | Axial location of 3rd point (in.), (mm.). AXD(3) |
| 7th field | Barrel temperature at 4th point (°F), (°C). TBR(4) |
| 8th field | Axial location of 4th point (in.), (mm.). AXD(4) |

Coolant temperature along AXDTM-9th LINE, 5th field representing length of cooled hopper zone of barrel downstream of hopper will take precedence over high barrel temperatures supplied in this line, i.e., high barrel temperature will be disregarded in Solids Conveying Zone.

LINE 7A
FORMAT (8F)
(Optional)

1st field	Barrel temperature of first zone (°F), (°C). TBR(1)
2nd field	Axial location of downstream end of first zone (in.), (mm.). AXD(1)
3rd field	Barrel temperature of second zone (°F), (°C). TBR(2)
4th field	Axial location of downstream end of second zone (in.), (mm.). AXD(2)
etc.	up to 4 temperature zones per line.

9th LINE
 FORMAT (10F)
 (Mandatory)

1st field		Screw Speed (rpm). RPM
2nd field		Output (Production Rate) (lb./hr.), (Kg/hr.) (disregarded if run in extruder-die combination mode). OUTPUT
3rd field	0 1	for most materials; for rigid materials in pellet form.
4th field		Soak Time per cycle for injection molding (sec.). SOKTIM
5th field		Axial length of cooled barrel from start of first geometrical section (in.), (mm.). AXDTM. Overrides Barrel Temperature given in LINE 6 or 7.
6th field		Reciprocating Length for injection molding (in.), (mm.). RECLLEN
7th field		Injection Pressure (psi), (bar). PRESIN
8th field		Flight Width at barrel surface (in.), (mm.). FLTWB
9th field		Radial Length of tapered flight width (in.), (mm.). HFTPR
10th field		Flight Wear, radial (in.), (mm.) WEAR

10th LINE
 FORMAT (30A2)
 (Mandatory)

Columns 2 through 60: Any text identifying run, the material or the extruder such as:
 MARLEX 6002 FOR LINE 3.

Pressure Mode
 11th LINE
 FORMAT (7F)
 (Optional)

Need only if the output of the extruder is to be computed as an extruder-die combination, and if the 15th field on the 1st LINE is -1, the coefficients of the die characteristics are described by the following equation:

$$\text{PDROP} = (a_1 + a_2 * T + a_3 * T^2) * (\text{OUTPUT})^{(b_1 + b_2 * T + b_3 * T^2)} * \exp(c/T_{\text{abs}})$$

where: PDROP = pressure drop across die (psi), (bar)
 T = extrudate temperature (°F), (°C)
 OUTPUT = output lb./hr.), (Kg/hr)
 T_{abs} = absolute temperature (°R), (°K)

1st field	a ₁	(psi), (bar)	DIECOE (1)
2nd field	a ₂	(psi/°F), (bar/°C)	DIECOE (2)
3rd field	a ₃	(psi/°F ²), (bar/°C ²)	DIECOE (3)
4th field	b ₁	---	DIECOE (4)
5th field	b ₂	(°F ⁻¹), (°C ⁻¹)	DIECOE (5)
6th field	b ₃	(°F ⁻²), (°C ⁻²)	DIECOE (6)
7th field	c	(°F), (°C)	DIECOE (7)

For Single Point Die Performance
 (15th field of 1st LINE =-2)
 (Optional)

When the performance of the extruder with a die at one set of operating conditions is known, EXTRUD[®] must be supplied with the Production Rate (OUTPUT), Melt Temperature (TOUT), and Pressure Drop along the die.

1st field	Output (lb./hr.), (Kg/hr.).	DIECOE (1)
2nd field	Melt Temperature (°F), (°C).	DIECOE (2)
3rd field	Pressure drop along die (psi), (bar).	DIECOE (3)

For Die with One or More Cylindrical Holes
 (15th field of 1st LINE =-3)
 (Optional)

1st field	Discharge Pressure of Die (psi), (bar).	DIECOE (1)
2nd field	Die Radius (in.), (mm).	DIECOE (2)
3rd field	Die Length (in.), (mm).	DIECOE (3)
4th field	Melt Temperature in Die (°F), (°C).	DIECOE (4)
5th field	Number of cylindrical holes.	DIECOE (5)

Mixing Devices
 12th LINE
 FORMAT (10I)
 (Optional)

Need only if Mixing Devices are present and if 16th field on LINE 1 (IRING) is 1, 2, 3 or -N.

The location of each mixing device has to be listed by its section number in increasing order.

1st field Section number of 1st mixing device. KRING (1)
 2nd field Section number of 2nd mixing device. KRING (2)
 3rd field Section number of 3rd mixing device. KRING (3)
 Etc. up to 10 per line.

Each mixing device counts as a Geometrical Section and its length has to be given on the 2nd LINE. The channel depth at the end of the mixing section must be equal to the depth at the beginning of the next Geometrical Section. For the simulation of the performance of a screw with mixing devices, information on the number of parallel holes and on the size of each hole must also be given on the 8th LINE if 16th field on LINE 1 is 1, 2 or 3.

13th LINE
 FORMAT (5 [2F,I])
 (Optional)

Needed only if the 16th field on LINE 1 (IRING) is -N. The 12th LINE must be followed by one or more lines describing: number of parallel holes PH (i), hole area HA (i), and type (1, 2 or 3) KR (i) for each mixing device sequentially, up to five mixing devices per line.

PH (1) HA (1) KR (1) ----- PH (5) HA (5) KR (5)

Fluted Mixing Sections

Line 13A

FORMAT (I,2F,I,7F)

(Optional)

Needed only for FLUTED MIXING SECTIONS

- | | |
|------------|--|
| 1st field | KROS1 - Indicator of inlet channel (flute) geometry. |
| 2nd field | WMAD1 - Width of inlet channel at barrel surface (in), (mm)
Use maximum value if changing. |
| 3rd field | HMAD1 - Depth of inlet channel (in), (mm)
Use maximum value if changing. |
| 4th field | KROS2 - Indicator of outlet channel geometry. |
| 5th field | WMAD2 - Width of outlet channel at barrel surface (in), (mm)
Use maximum value if changing. |
| 6th field | HMAD2 - Depth of outlet channel (in), (mm)
Use maximum value if changing. |
| 7th field | FCLE1 - Radial clearance of barrier from inlet to outlet channel (in), (mm). |
| 8th field | FCLE2 - Radial clearance of flight separating pairs of flutes (in), (mm). usually: FCLE2 < FCLE1 |
| 9th field | FWI1 - Width of barrier from inlet to outlet channel (in), (mm). |
| 10th field | FWI2 - Flight separating flute pairs (in), (mm). |
| 11th field | ANGMAD - Angle between screw axis and flute (degrees) |

All the above variables are also included in the INPUT list and can be changed when EXTRUD[®] says: TYPE IN INPUT.

On the PC in graphical/conversational mode detailed explanation can be obtained on the meaning of the above variables.

Values for KROS1 & KROS2

Cross Section is ellipse	1
Cross Section is rectangle with circular bottom	
HMAD _x < WMAD _x	2
HMAD _x > WMAD _x	3
Cross Section is rectangle	4

Note: The number of parallel inlet flutes must be given as PARHOL on 8th LINE, 4th field if IRING = 3 (RNG =3) (1st LINE, 16th field) or as PH(1) on 13 th LINE if more than one type of mixing device is present in the screw (IRING = negative), where I refers to 1st, 2nd etc. mixing device from the hopper to the end of Screw.

Entrance pressure to the fluted section must always be positive. If this is not the case, operating conditions must be changed until entrance pressure becomes positive, e.g. RPM increased, OUTPUT decreased etc.

14th LINE
 FORMAT (3F)
 (Optional)

Needed only for the case of partially melted feed, this line must be inserted giving X/W, GRATIO, and melt input temperature (°F), (°C) for the feed.

1st field X/W at inlet.
 2nd field GRATIO fraction of solids at inlet.
 3rd field TIN melt inlet temperatures (°F), (°C).

Target
 15th LINE
 FORMAT (1)
 (Optional)

Needed only if the Target option is used that is a series of simulations is to be generated automatically and only if the 15th field on the 1st LINE is 1.

1st field Number of variables to be varied simultaneously in the series.

16th LINE
 FORMAT (11I)
 (Optional)

Needed only with 15th LINE.
 (1 line for each variable)

1st field Code number defining variable.
 2nd field n - the subscript number* defining the location of variable.
 3rd to 11th Section no. of up to 9 additional sections whose depth (HSEC), length (SECLN) or lead (SLD) varies together with that of the reference section in 2nd field or mixing ring no. whose number of holes vary (PH), or heater number whose barrel temperature varies (TBR) together with that of the reference section in 2nd field.

* 0 if not applicable.

17th LINE
 FORMAT (6F)
 (Optional)

May consist of several lines.

Needed only with 15th & 16th LINES.

1st field The center point around which the first variable will be varied.
 2nd field Step size for the first variable.
 3rd field Center point for second variable.
 4th field Step size for second variable.
 Etc. Up to 3 variable per LINE.

LINE 17A
 FORMAT (1)
 (Optional)

1st field Number of Responses to be collected simultaneously in the series.

LINE 17B
 FORMAT (20I)
 (Optional)

Needed only with 15th line and
 when the value in LINE 17A is not 0.

1st field Code number defining 1st response to be collected in a summary table.
 See next page for definition of codes.
 2nd field Axial Location*, (in), (mm) at which 1st response is to be collected
 3rd field Code number defining 2nd response.
 4th field Axial location*, (in), (mm) at which 2nd response is to be collected
 Etc. Up to 10 responses per line.

Solids Conveying Data
18th LINE
FORMAT (8F)
(Mandatory)

- 1st field Maximum diameter of hopper (in.), (mm).
If hopper is not circular, take hydraulic diameter (4 x cross-sectional area of the hopper, divided by its perimeter). DHOP
- 2nd field Bulk density (lb./ft.³), (g/cm³). ROB
- 3rd field Constant term in coefficient of friction function on barrel surface, FRIB0. Must be 0 if friction data to be used from SPR list. If FRIB0 is other than 0 in this field, this value will replace the value given in the SPR list. All other coefficients in the friction equation will remain as given in the data base.
- 4th field Constant term in coefficient of friction function on screw surface, FRIS0. Equation defining the Coefficient of Friction on the Barrel also defines the Coefficient of Friction on the screw. If friction data to be taken from SPR list, FRIS0 must be 0. If other than 0 this value will replace that given in the data base. All other coefficients will be taken from the SPR data base.
- 5th field Static coefficient of friction of solid feed on the hopper surface.
(0 if not available).
- 6th field Thickness of barrel wall in cooled hopper section (in), (mm.). WBAR
- 7th field Average temperature of cooling medium for hopper(°F), (°C)
Important for Solid Conveying computation. TBW
- 8th field Pellet diameter (in), (mm.). DPEL

19th LINE
 FORMAT (8F)
 (Mandatory)

- 1st field Thermal conductivity of barrel metal (Btu/hr.ft.°F), (W/m.°C).
 (Typical for steel 25 BTU/hr.ft.°F or 14.457W/m.°C). TCONB
- 2nd field Thermal conductivity of solid plastic at feed temperature
 (Btu/hr.ft.°F), (W/m.°C). TCONS.
- 3rd field Angle of repose of the feed (degrees). ANGREP
 (0 if not available).
- 4th field Height of the solids in the hopper* (in.), (mm.). HSH
- 5th field Height of the tapered portion hopper (in.), (mm.).
 (0 if not available). HOPT
- 6th field Hopper Diameter adjacent to barrel (in.), (mm.). DHOPX
- 7th field Barrel wall thickness from controller sensor to inner surface of barrel
 following the cooled hopper section (in.), (mm). If set to 0, program
 assumes that inner barrel surface temperature equals the barrel
 temperature given. WBAR1
- 8th field Height of lower portion of hopper with constant small diameter (in.),
 (mm.). HOPST

* If height of solids in hopper is set to zero (left blank), the critical solids level is computed and the corresponding maximum hopper base pressure is used. If height is supplied for the solids in the hopper, the corresponding pressure at the base of the hopper is computed.

20th LINE
 FORMAT (7F)
 (Mandatory)

1st field Coefficient Rb1 in the bulk density expression:
 (use 0 if Rb1 not available)

$$RHO_{bp} = RHO_{sol} - (RHO_{sol} - RHO_{b0}) * \exp(-R_{b1} * P)$$

Where: RHO_{bp} =Bulk density at pressure P (lb./ft³), (g/cm³)

RHO_{sol} =Density of sol plastic at room temperature (lb./ft³),
 (g/cm³)

RHO_{b0} =Bulk density when P = 0 (lb./ft³), (g/cm³)

P =Pressure (psi), (bar)

Followed by 6 fields defining the first 6 terms of the coefficient of friction equation on the barrel surface (optional, remains zero if properties from SPR data file).

(Optional)

2nd field FRIB1

3rd field FRIB11

4th field FRIB12

5th field FRIB13

6th field FRIB2

7th field FRIB22

where the coefficients of friction are defined 18-th LINE.

21st LINE
FORMAT (6F)
(Optional)

Defining the 7th through 12th term of the coefficient Friction equation on the Barrel surface.

1st field	FRIB23
2nd field	FRIB3
3rd field	FRIB33
4th field	FRB111
5th field	FRB333
6th field	FRB112

22nd LINE
FORMAT (6F)
(Optional)

Defining the 13th through 18th term of the coefficient of Friction equation on the Barrel surface.

1st field	FRB113
2nd field	FRB123
3rd field	FRB223
4th field	FRB221
5th field	FRB331
6th field	FRB332

23rd LINE
FORMAT (6F)
(Optional)

Defining the 1st through 6th term of the coefficient of Friction equation on the Screw surface.

1st field	FRIS1
2nd field	FRIS11
3rd field	FRIS12
4th field	FRIS13
5th field	FRIS2
6th field	FRIS22

24th LINE
FORMAT (6F)
(Optional)

Defining the 7th through 12th term of the coefficient of Friction equation on the Screw surface.

1st field	FRIS23
2nd field	FRIS3
3rd field	FRIS33
4th field	FRS111
5th field	FRS333
6th field	FRS112

25th LINE
 FORMAT (6F)
 (Optional)

Defining the 13th through 18th term of the coefficient of Friction equation on the Screw surface.

1st field	FRS113
2nd field	FRS123
3rd field	FRS223
4th field	FRS221
5th field	FRS331
6th field	FRS332

Injection Molding
 26th LINE
 FORMAT (8F)
 (Optional)

Needed only for injection molding and only if SHOT size, CYCLE time, and Screw Rotation Time (EXTIM) are to be supplied.

1st field	Shot size (oz.), (g).	SHOT
2nd field	Total Cycle time (sec/cycle).	CYCLE
3rd field	Screw Rotation Time (sec/cycle).	EXTIM

When this 26th line is non-zero, the values given for OUTPUT (9th LINE, 2nd field) and for Soak Time (9th LINE, 4th field) are disregarded. Both variables are now internally computed by EXTRUD from the molding data given in this line. If this 26th line is zero, then the OUTPUT and SOAK TIME values are taken from the 9th line.

Namelist
27th LINE

Needed only if 3rd SPEC LINE was YES.

This LINE starts in column 2 with \$ followed by the word "INPUT", a space, and the list of variables to be varied separated by a comma. The list can contain as many sublines as needed but should end with a space followed by\$ (DOLLAR SIGN< not ESC mode). Every subline must start in column 2. Each line except the last must end with a comma.

Column: 123456789.....etc.....80
 \$INPUT RPM =60., OUTPUT =189 (space) \$

If no more changes are requested, instead of a list of Input Variables, BEND =-1 should be entered.

APPENDIX B

INPUT DATA
(I) Varying Screw Speed

```
*****
*           Barrel Diameter :      2.5 inches          *
*           Material :           Acetal copolymer grade M90 *
*           Screw Speed :        30 rpm                *
*           Flow Rate :          100 lb/hr             *
*****
```

C

6 5 0 1 1 0.999 0 0 0 1 1

Y

```
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
30.0 100.0 1 0.0 4.60 0.0 0.0 0.30
```

M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER

7

```
21.15284 0 0.0 0.0 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0
```

```
*****           Screw Speed :           40 rpm           *****
```

C

6 5 0 1 1 0.999 0 0 0 1 1

Y

```
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
40.0 100.0 1 0.0 4.60 0.0 0.0 0.30
```

M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER

7

```
21.15284 0 0.0 0.0 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0
```



```

*****          Screw Speed :          50 rpm          *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 100.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.0 0.0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****          Screw Speed :          60 rpm          *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
60.0 100.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.0 0.0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```
*****          Screw Speed :          70 rpm          *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
70.0 100.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.0 0.0 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0
```

INPUT DATA

(II) Varying Flow Rate

```

*****
*           Barrel Diameter :      2.5 inches          *
*           Material :           Acetal copolymer grade M90 *
*           Screw Speed :        50 rpm                *
*           Flow Rate :          80 lb/hr              *
*****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 200 100
50.0 80.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.0 0.0 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

*****           Flow Rate :           90 lb/hr           *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 200 100
50.0 90.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.0 0.0 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****          Flow Rate :          100 lb/hr          *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 100.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.0 0.0 0.0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****          Flow Rate :          110 lb/hr          *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 110.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.0 0.0 0.0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****          Flow Rate :          120 lb/hr          *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 120.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.0 0.0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

INPUT DATA

(III) Varying IPFC

```

*****
*           Barrel Diameter :      2.5 inches           *
*           Material :           Acetal copolymer grade M90      *
*           Screw Speed :        50 rpm                 *
*           Flow Rate :          100 lb/hr              *
*           IPFC :                0.05                 *
*****

```

C

6 5 0 1 1 0.999 0 0 0 1 1

Y

-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3

19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475

3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475

0.5 0.45 0.5 0.30

3 3 0.5 0.15 0.15 0.1625

0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

415.0 0.0 0.0 0.0 6 0 1 368 368 368 368

390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165

430.0 85.82 440.0 103.475

-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100

50.0 100.0 1 0.0 4.60 0.0 0.0 0.30

M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER

7

21.15284 0 0.05 0.10 0 0.45 75

25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0

0.0

***** IPFC : 0.10 *****

C

6 5 0 1 1 0.999 0 0 0 1 1

Y

-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3

19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475

3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475

0.5 0.45 0.5 0.30

3 3 0.5 0.15 0.15 0.1625

0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

415.0 0.0 0.0 0.0 6 0 1 368 368 368 368

390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165

430.0 85.82 440.0 103.475

-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100

50.0 100.0 1 0.0 4.60 0.0 0.0 0.30

M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER

7

21.15284 0 0.10 0.10 0 0.45 75

25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0

0.0

```

*****      IPFC :                0.15      *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 100.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.15 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****      IPFC :                0.20      *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 100.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.20 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****      IPFC :                0.25      *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.475 2.50 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.475 27.55 0.150 2.475 16.6 0.15 3.45 2.475 0.3875 2.475 9.9 0.4375 2.475
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.475
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 100.0 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.5 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.25 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****
*          Barrel Diameter :      2.25 inches          *
*          Material :            Acetal copolymer grade M90      *
*          Screw Speed :         50 rpm                *
*          Flow Rate :           87.8 lb/hr            *
*          IPFC :                 0.05                 *
*****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.225 2.250 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.225 27.55 0.15 2.225 16.6 0.15 3.45 2.225 0.3875 2.225 9.9 0.4375 2.225
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.225
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 87.8 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.25 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.05 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```



```

***** IPFC :                0.10                *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.225 2.250 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.225 27.55 0.15 2.225 16.6 0.15 3.45 2.225 0.3875 2.225 9.9 0.4375 2.225
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.225
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 87.8 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.25 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.10 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

***** IPFC :                0.15                *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.225 2.250 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.225 27.55 0.15 2.225 16.6 0.15 3.45 2.225 0.3875 2.225 9.9 0.4375 2.225
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.225
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 87.8 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.25 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.15 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

***** IPFC :                0.20                *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.225 2.250 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.225 27.55 0.15 2.225 16.6 0.15 3.45 2.225 0.3875 2.225 9.9 0.4375 2.225
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.225
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 87.8 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.25 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.20 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

***** IPFC :                0.25                *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 2.225 2.250 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 2.225 27.55 0.15 2.225 16.6 0.15 3.45 2.225 0.3875 2.225 9.9 0.4375 2.225
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 2.225
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 87.8 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.25 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.25 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****
*           Barrel Diameter :       2.0 inches           *
*           Material :             Acetal copolymer grade M90      *
*           Screw Speed :          50 rpm                 *
*           Flow Rate :             75.6 lb/hr            *
*           IPFC :                  0.05                 *
*****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.975 2.0 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.975 27.55 0.15 1.975 16.6 0.15 3.45 1.975 0.3875 1.975 9.9 0.4375 1.975
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.975
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 75.6 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.0 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.05 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****      IPFC :                0.10                *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.975 2.0 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.975 27.55 0.15 1.975 16.6 0.15 3.45 1.975 0.3875 1.975 9.9 0.4375 1.975
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.975
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 75.6 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.0 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.10 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

***** IPFC :                0.15                *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.975 2.0 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.975 27.55 0.15 1.975 16.6 0.15 3.45 1.975 0.3875 1.975 9.9 0.4375 1.975
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.975
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 75.6 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.0 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.15 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

***** IPFC :                0.20                *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.975 2.0 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.975 27.55 0.15 1.975 16.6 0.15 3.45 1.975 0.3875 1.975 9.9 0.4375 1.975
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.975
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 75.6 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.0 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.20 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****      IPFC :                0.25      *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.975 2.0 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.975 27.55 0.15 1.975 16.6 0.15 3.45 1.975 0.3875 1.975 9.9 0.4375 1.975
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.975
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 75.6 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 2.0 INCHES OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.25 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0
    
```

```

*****
*          Barrel Diameter :      1.75 inches          *
*          Material :           Acetal copolymer grade M90      *
*          Screw Speed :       50 rpm                  *
*          Flow Rate :         63.5 lb/hr              *
*          IPFC :              0.05                   *
*****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.725 1.75 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.75 27.55 0.15 1.75 16.6 0.15 3.45 1.75 0.3875 1.75 9.9 0.4375 1.75
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.75
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 63.5 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 1.75 INCH OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.05 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0
    
```

```

***** IPFC :                0.10                *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.725 1.75 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.75 27.55 0.15 1.75 16.6 0.15 3.45 1.75 0.3875 1.75 9.9 0.4375 1.75
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.75
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 63.5 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 1.75 INCH OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.10 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

***** IPFC :                0.15                *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.725 1.75 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.75 27.55 0.15 1.75 16.6 0.15 3.45 1.75 0.3875 1.75 9.9 0.4375 1.75
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.75
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 63.5 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 1.75 INCH OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.15 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****      IPFC :                0.20      *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.725 1.75 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.75 27.55 0.15 1.75 16.6 0.15 3.45 1.75 0.3875 1.75 9.9 0.4375 1.75
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.75
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 63.5 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 1.75 INCH OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.20 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

```

*****      IPFC :                0.25      *****
C
6 5 0 1 1 0.999 0 0 0 1 1
Y
-5 1.0 1.0 1.725 1.75 0.30 0.0125 -8 1 0 0 2 -70 0 0 3
19.8 0.4375 1.75 27.55 0.15 1.75 16.6 0.15 3.45 1.75 0.3875 1.75 9.9 0.4375 1.75
3.125 0.2375 3.125 16.6 0.2125 3.45 4.95 0.2125 1.75
0.5 0.45 0.5 0.30
3 3 0.5 0.15 0.15 0.1625
0.0 0.0 0.0 0.0 0.0 0.0 70.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
415.0 0.0 0.0 0.0 0.0 6 0 1 368 368 368 368
390.0 15.2 400.0 32.855 410.0 50.51 420.0 68.165
430.0 85.82 440.0 103.475
-2000.0 120.0 0.0 1 0.914 0.0 0.0 0.0 0.0 200 100
50.0 63.5 1 0.0 4.60 0.0 0.0 0.30
M90 SIMULATE IN 1.75 INCH OF TWO-STAGE SCREW EXTRUDER
7
21.15284 0 0.25 0.10 0 0.45 75
25.0 0.20 0.0 36.0 24.0 3.6833 0.05 8.0
0.0

```

OUTPUT OF SIMULATION

(I) Varying Screw Speed

1MS30

EXPERIMENT NUMBER 1.01 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 30.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 120.00 DEG.F AND SCREW = 207.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	40.3	21.10	0.025	0.001	131.2	207.0	0.00	0.38
2.00	40.3	21.10	0.024	0.001	134.9	207.0	0.00	0.42
3.00	40.2	21.12	0.024	0.003	136.3	207.0	0.00	0.47
4.00	40.2	21.12	0.024	0.003	137.3	207.0	0.00	0.52
5.00	40.0	21.15	0.036	0.004	108.1	207.0	0.00	0.57
FRICTION COEFFICIENT ON BARREL SURFACE MUST BE HIGHER THAN ON SCREW SURFACE								
FRIS=	0.422595E-02		FRIB=		0.217960E-02			
6.00	40.0	21.15	0.002	0.004	70.0	207.0	0.00	0.58
7.00	40.0	21.15	0.001	0.004	70.0	207.0	0.00	0.57
7.82	40.0	21.15	0.001	0.004	70.0	207.0	0.00	0.56
8.01	40.0	21.15	0.001	0.004	70.0	207.0	0.00	0.56
8.21	40.0	21.15	0.001	0.004	70.0	207.0	0.00	0.55
8.24	40.0	21.15	0.001	0.004	329.8	207.0	0.00	0.55

L IN	TOUT DEG F	X/W SOLID	X/W	GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB./SQ.IN	D.HEAT BTU/IN	FILM TEMP DEG F	
					REAL	FULL						
10.90	342.5				0.	360.	0.437	349.0	0.0916			
12.60	342.5				0.	654.	0.437	349.0	0.1008			
14.60	355.5				0.	936.	0.437	368.1	0.1004			
16.10	349.0	.943	.943	.833	0.	995.	0.06	0.437	380.8	0.1981	-24.8	381.
19.80	353.8	.866	.866	.763	0.	1023.	0.27	0.437	391.8	0.2323	-3.4	391.
24.10	365.8	.843	.843	.754	0.	1056.	0.50	0.393	394.3	0.1692	1.2	394.
29.10	378.7	.816	.816	.736	0.	1094.	0.77	0.340	397.3	0.1507	1.1	397.
34.10	388.0	.788	.788	.718	0.	1206.	1.0	0.288	400.2	0.1390	1.0	400.
39.10	395.0	.759	.759	.700	0.	1318.	1.3	0.236	403.1	0.1309	0.9	403.
44.10	400.5	.726	.726	.683	0.	1397.	1.5	0.184	406.0	0.1251	0.8	405.
47.35	403.5	.702	.702	.669	0.	1396.	1.7	0.150	408.1	0.1220	-2.7	408.
-----SECONDARY CHANNEL BEGINS-----												
52.35	389.6	.458	.925	.458	0.	1408.	1.9	0.150	410.4	0.1404	-15.8	410.
57.35	390.9	.259	.632	.259	0.	1504.	2.1	0.150	413.2	0.1406	-9.8	413.
62.35	396.7	.135	.411	.135	0.	1610.	2.2	0.150	416.1	0.1337	-6.0	416.
63.95	398.5	.105	.350	.105	0.	1638.	2.2	0.150	417.1	0.1315	-5.4	417.
-----SECONDARY CHANNEL ENDS-----												

65.19	400.9	.096	.096	.095	0.1662.	2.3	0.269	418.0	0.1227	0.4	418.
66.42	403.3	.102	.102	.092	0.1685.	2.3	0.387	418.7	0.1273	0.3	419.
71.37	408.9	.063	.063	.056	0.1758.	2.4	0.412	421.3	0.1242	-0.1	421.
76.32	413.9	.034	.034	.030	0.1823.	2.8	0.437	424.2	0.1208	1.0	424.
FILM THICKNESS IS 0 - TBAR= 0.4247E+03											
FILM THICKNESS IS 0 - TBAR= 0.4247E+03											
77.89	415.8	.028	.028	.028	0.1846.	2.9	0.338	425.3	0.1145	2.3	425.
79.45	417.7	.025	.025	.025	0.1875.	3.0	0.238	426.2	0.1091	2.4	426.

FLUTED SECTION WITH 1. PAIRS OF FLUTES											
96.05	438.8	.025	.025	.018	0.1874.	3.0	0.213	431.0	0.1091	2.4	426.

101.00	438.5	.004	.004	.004	0.1953.	3.4	0.213	438.3	0.0983	1.7	438.

MINIMUM TEMPERATURE= 437.120 DEG F
 TEMP FLUCTUATION= 1.376 DEG F
 FLOW INDEX (N)= 0.826
 GRATIO INJ.= 0.004
 RESIDENCE TIME:
 MELT POOL= 0.052195735 HRS

TORQUE = 7106.8 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.000 HP
 MELTING = 2.286 HP
 MIXING = 0.452 HP
 FLIGHT CLEAR = 0.589 HP
 COMPRESSION = 0.052 HP
 MIXING DEVICE= 0.024 HP
 PRESSURE FLUCTUATION= 63.72 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -224.2 TO -163.8 BTU/MIN OR
 -5.28 TO -3.86 HP

MAXIMUM SCREW SPEED,RPM: 30.0 58.3 86.7 115.0 143.3 171.7 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 3.4 6.6 9.8 13.0 16.2 19.4 22.6

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.672 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
403.44	376.9	0.0611026
1.27	380.8	0.1945229

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
22.82	439.0	0.0947747
125.59	329.0	0.1295692

SELECT ONE OF THE FOLLOWING:

1 - Data Analysis
 2 - Run New Simulation
 3 - EXIT
 :

1MS40

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 40.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 96.00 DEG.F AND SCREW = 207.00 DEG.F

LOCATION	PHI	ROBP	FRIB	FRIS	TEMPERATURE, DEG F	POWER	PRESSURE
IN	DEG	LB/CU.FT			BARREL	SCREW	HP
1.00	20.8	21.12	0.045	0.003	101.9	207.0	0.00
2.00	20.7	21.15	0.046	0.004	103.6	207.0	0.00
3.00	20.6	21.21	0.050	0.008	104.5	207.0	0.00
4.00	20.4	21.32	0.056	0.013	104.9	207.0	0.00
5.00	20.2	21.42	0.062	0.019	92.2	207.0	0.00
6.00	20.1	21.48	0.030	0.022	70.0	207.0	0.00
6.55	20.1	21.48	0.029	0.022	70.0	207.0	0.00
7.05	20.1	21.48	0.028	0.022	70.0	207.0	0.00
7.55	20.0	21.51	0.028	0.024	70.0	207.0	0.00
8.05	20.0	21.51	0.027	0.024	70.0	207.0	0.00
8.55	20.0	21.51	0.026	0.024	70.0	207.0	0.00
9.05	20.0	21.54	0.027	0.025	70.0	207.0	0.00
FRICTION COEFFICIENT ON BARREL SURFACE MUST BE HIGHER THAN ON SCREW SURFACE							
FRIS= 0.251617E-01 FRIB= 0.251022E-01							
9.55	20.0	21.54	0.026	0.025	70.0	207.0	0.00
10.05	20.0	21.54	0.026	0.025	70.0	207.0	0.00
10.10	20.0	21.54	0.026	0.025	329.8	207.0	0.00

L	TOUT	X/W	X/W	GRATIO	PRESSURE	POWER	HOUT	TBAR	TVISC	D.HEAT	FILM
IN	DEG F	SOLID			PSI	HP	IN	DEG F	LB.SEC	BTU/IN	TEMP
					REAL	FULL			/SQ.IN	.MIN	DEG F
12.60	342.5				0.	479.		0.437	349.0	0.0853	
14.60	355.5				0.	840.		0.437	368.0	0.0904	
16.10	354.1	.878	.878	.727	0.	934.	0.10	0.437	380.8	0.2088	-35.8
19.80	359.3	.790	.790	.652	0.	1042.	0.45	0.437	391.8	0.1956	-2.4
24.10	371.1	.747	.747	.633	0.	1168.	0.83	0.393	394.3	0.1447	2.6
29.10	384.3	.696	.696	.608	0.	1325.	1.3	0.340	397.3	0.1289	1.7
34.10	393.0	.640	.640	.575	0.	1503.	1.7	0.288	400.3	0.1193	1.0
39.10	398.4	.576	.576	.533	0.	1705.	2.1	0.236	403.2	0.1136	0.0
44.10	401.4	.500	.500	.474	0.	1909.	2.5	0.184	406.0	0.1106	-1.5
47.35	402.6	.439	.439	.425	0.	2004.	2.6	0.150	408.0	0.1095	-3.4
-----SECONDARY CHANNEL BEGINS-----											
52.35	397.8	.240	.485	.240	0.	2183.	3.1	0.150	410.5	0.1179	-10.8
57.35	400.4	.096	.235	.096	0.	2398.	3.4	0.150	413.3	0.1168	-3.0
62.35	407.2	.021	.064	.021	0.	2575.	3.8	0.150	416.2	0.1104	0.4
63.95	405.4	.009	.030	.009	0.	2619.	4.0	0.150	417.3	0.1085	1.7
-----SECONDARY CHANNEL ENDS-----											

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      FILM THICKNESS IS 0 - TBAR= 0.4175E+03
      FILM THICKNESS IS 0 - TBAR= 0.4175E+03
65.19 411.4 .004 .004 .004 0. 2666. 4.2 0.269 418.1 0.1014 3.7 418.
66.42 413.0 .002 .002 .002 0. 2700. 4.3 0.387 418.8 0.1069 0.7 419.
      FILM THICKNESS IS 0 - TBAR= 0.4192E+03
      FILM THICKNESS IS 0 - TBAR= 0.4192E+03
71.37 418.3 .000 .000 .000 0. 2805. 4.4 0.412 421.5 0.1049 1.1 419.
76.32 422.4 .000 .000 .000 0. 2897. 4.5 0.437 424.3 0.1028 1.0 419.
77.89 423.6 .000 .000 .000 0. 2930. 4.6 0.338 425.4 0.0973 1.2 419.
79.45 425.2 .000 .000 .000 0. 2975. 4.6 0.238 426.3 0.0924 1.4 419.
-----
      FLUTED SECTION WITH 1. PAIRS OF FLUTES
96.05 425.2 .000 .000 .000 0. 2974. 4.7 0.213 431.1 0.0924 1.4 419.
-----
101.00 433.7 .000 .000 .000 0. 3145. 4.8 0.213 438.2 0.0910 1.4 419.

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MINIMUM TEMPERATURE= 433.725 DEG F
TEMP FLUCTUATION= 0.000 DEG F
FLOW INDEX (N)= 0.789
GRATIO INJ.= 0.000
RESIDENCE TIME:
MELT POOL= 0.052126914 HRS

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TORQUE = 7634.1 INCH.POUNDS
POWER BREAK-DOWN:
SOLIDS CONV. = 0.002 HP
MELTING = 2.803 HP
MIXING = 0.932 HP
FLIGHT CLEAR = 0.946 HP
COMPRESSION = 0.131 HP
MIXING DEVICE= 0.041 HP

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PRESSURE FLUCTUATION= 119.39 PSI/CYCLE
TOTAL CONDUCTED HEAT THROUGH BARREL= -159.2 TO -86.5 BTU/MIN OR
-3.75 TO -2.04 HP

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MAXIMUM SCREW SPEED, RPM: 40.0 66.7 93.3 120.0 146.7 173.3 200.0
POWER CONSUMPTION, % OF AVAILABLE: 4.8 8.1 11.3 14.5 17.8 21.0 24.2

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STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

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MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.658 INCHES

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VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
686.10	374.1	0.0502803
4.95	380.8	0.1767041

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
33.41	438.2	0.0882818
343.05	329.0	0.0903600

SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

1MS50

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 67.00 DEG.F AND SCREW = 207.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	13.7	21.13	0.059	0.003	67.0	207.0	0.00	0.51
2.00	13.6	21.22	0.065	0.008	67.0	207.0	0.00	0.79
3.00	13.5	21.33	0.072	0.014	67.0	207.0	0.00	1.25
4.00	13.3	21.53	0.084	0.025	67.0	207.0	0.00	2.00
5.00	12.9	21.92	0.101	0.044	75.0	207.0	0.00	3.28
6.00	12.7	22.12	0.072	0.054	67.0	207.0	0.01	4.03
7.00	12.5	22.39	0.083	0.067	67.0	207.0	0.01	4.94
8.00	12.2	22.66	0.093	0.078	67.0	207.0	0.01	5.89
9.00	12.0	22.96	0.105	0.091	67.0	207.0	0.01	6.98
10.00	11.7	23.31	0.117	0.104	67.0	207.0	0.02	8.23
10.90	11.4	23.66	0.129	0.117	330.0	207.0	0.03	9.53

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
13.10	342.5			471. 471.		0.437	349.0	0.0811		
15.10	364.4			837. 837.		0.437	380.8	0.0839		
17.10	371.3			1071. 1071.		0.437	390.6	0.0903		
18.10	359.9	.879	.879	.732 1111. 1111.	0.2	0.437	390.6	0.1863	-32.5	391.
19.80	361.7	.830	.830	.691 1179. 1179.	0.4	0.437	390.6	0.1851	-2.2	391.
24.80	373.3	.763	.763	.655 1379. 1379.	1.1	0.385	394.7	0.1522	2.8	394.
26.10	378.0	.746	.746	.645 1431. 1431.	1.2	0.372	395.5	0.1232	3.5	395.
31.10	391.2	.674	.674	.601 1646. 1646.	1.9	0.320	398.6	0.1098	2.1	398.
36.10	398.9	.596	.596	.546 1899. 1899.	2.5	0.267	401.5	0.1027	1.0	401.
41.10	403.6	.508	.508	.478 2200. 2200.	3.1	0.215	404.4	0.0985	-0.5	404.
46.10	406.3	.402	.402	.390 2527. 2527.	3.7	0.163	407.2	0.0964	-2.6	407.
47.35	406.7	.373	.373	.363 2599. 2599.	3.8	0.150	408.1	0.0960	-4.0	408.
-----SECONDARY CHANNEL BEGINS-----										
52.35	404.0	.185	.374	.185 2953. 2953.	4.3	0.150	410.6	0.1020	-8.2	410.
57.35	408.0	.077	.188	.077 3282. 3282.	4.6	0.150	413.5	0.1001	-2.7	413.
62.35	413.1	.003	.010	.003 3520. 3520.	5.6	0.150	416.3	0.0959	3.4	416.
63.95	415.3	.000	.000	.000 3576. 3576.	5.6	0.150	417.4	0.0944	1.8	417.
-----SECONDARY CHANNEL ENDS-----										

65.19	417.6	.000	.000	.000	3644.	3644.	5.7	0.269	418.2	0.0876	2.2	417.
66.42	419.1	.000	.000	.000	3687.	3687.	5.8	0.387	418.9	0.0932	1.7	417.
71.37	422.9	.000	.000	.000	3820.	3820.	6.0	0.412	421.6	0.0925	1.6	417.
76.32	426.1	.000	.000	.000	3939.	3939.	6.1	0.437	424.4	0.0915	1.5	417.
77.89	427.2	.000	.000	.000	3981.	3981.	6.2	0.338	425.4	0.0862	1.7	417.
79.45	428.7	.000	.000	.000	4040.	4040.	6.3	0.238	426.3	0.0815	2.1	417.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
96.05	428.7	.000	.000	.000	4039.	4039.	6.3	0.213	431.1	0.0815	2.1	417.

101.00	437.9	.000	.000	.000	4288.	4288.	6.6	0.213	438.3	0.0803	2.1	417.

MINIMUM TEMPERATURE= 437.908 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.763
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.050008345 HRS

TORQUE = 8303.5 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.027 HP
 MELTING = 3.545 HP
 MIXING = 1.463 HP
 FLIGHT CLEAR = 1.313 HP
 COMPRESSION = 0.195 HP
 MIXING DEVICE= 0.060 HP
 PRESSURE FLUCTUATION= 170.41 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -89.1 TO -21.0 BTU/MIN OR
 -2.10 TO -0.49 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 6.6 9.9 13.2 16.5 19.8 23.1 26.3

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.641 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
770.55	342.5	0.0588104
8.18	390.6	0.1541261

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	441.3	0.1012381
230.69	329.0	0.1049526

AT 50.00 RPM & 100.00 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 4288. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

1MS60

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 60.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH. DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 63.50 DEG.F AND SCREW = 207.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	10.2	21.15	0.066	0.004	63.5	207.0	0.00	0.55
2.00	10.1	21.26	0.075	0.010	63.5	207.0	0.00	0.93
3.00	10.0	21.45	0.087	0.020	63.5	207.0	0.00	1.61
4.00	9.7	21.80	0.109	0.038	63.5	207.0	0.00	2.88
5.00	9.3	22.50	0.142	0.071	73.0	207.0	0.01	5.44
6.00	9.0	23.06	0.121	0.095	63.5	207.0	0.01	7.38
7.00	8.6	23.76	0.146	0.120	63.5	207.0	0.02	9.95
8.00	8.1	24.71	0.173	0.147	63.5	207.0	0.04	13.48
9.00	7.5	26.00	0.197	0.170	63.5	207.0	0.06	18.36
9.30	7.3	26.53	0.229	0.175	330.0	207.0	0.07	20.59

L IN	TOUT DEG F	X/W SOLID	X/W	GRATIO	PRESSURE PSI REAL	PRESSURE PSI FULL	POWER HP	HOUT IN	TBAR DEG F	TVISC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
11.68	342.5				546.	546.		0.437	349.0	0.0826		
13.60	342.5				920.	920.		0.437	349.0	0.0960		
16.10	356.2	.871	.871	.723	1183.	1183.	0.3	0.437	380.8	0.1806	-29.7	381.
19.80	362.8	.757	.757	.627	1351.	1351.	1.0	0.437	391.8	0.1583	-0.6	391.
24.10	377.4	.684	.684	.581	1546.	1546.	1.7	0.393	394.4	0.1138	4.4	394.
29.10	391.9	.595	.595	.522	1789.	1789.	2.6	0.340	397.5	0.1004	2.6	397.
34.10	400.1	.501	.501	.453	2075.	2075.	3.4	0.288	400.4	0.0934	1.3	400.
39.10	405.3	.400	.400	.372	2422.	2422.	4.2	0.236	403.3	0.0893	-0.1	403.
44.10	409.2	.290	.290	.277	2845.	2845.	4.9	0.184	406.1	0.0865	-1.6	406.
47.35	411.4	.215	.215	.209	3140.	3140.	5.3	0.150	408.2	0.0851	-3.1	408.
-----SECONDARY CHANNEL BEGINS-----												
52.35	412.8	.087	.175	.087	3645.	3645.	5.8	0.150	410.8	0.0878	-2.9	410.
TBAR WAS CHANGED AT AXIAL LOC= 54.35 IN. TO TBAR= 434.0 F												
IN ORDER TO CONVERGE.												
57.35	417.7	.000	.000	.000	4073.	4073.	7.3	0.150	413.7	0.0857	3.1	434.
62.35	422.9	.000	.000	.000	4358.	4358.	7.6	0.150	416.5	0.0823	2.5	434.
63.95	424.0	.000	.000	.000	4423.	4423.	7.7	0.150	417.6	0.0817	2.3	434.
-----SECONDARY CHANNEL ENDS-----												

65.19	425.8	.000	.000	.000	4507.	4507.	7.8	0.269	418.4	0.0758	2.9	434.
66.42	426.4	.000	.000	.000	4559.	4559.	7.8	0.387	419.1	0.0815	2.3	434.
71.37	428.1	.000	.000	.000	4717.	4717.	8.1	0.412	421.7	0.0821	2.2	434.
76.32	429.9	.000	.000	.000	4860.	4860.	8.4	0.437	424.4	0.0820	2.1	434.
77.89	430.8	.000	.000	.000	4910.	4910.	8.4	0.338	425.5	0.0771	2.3	434.
79.45	432.3	.000	.000	.000	4983.	4983.	8.5	0.238	426.4	0.0725	2.9	434.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
96.05	432.3	.000	.000	.000	4982.	4982.	8.6	0.213	431.2	0.0725	2.9	434.

101.00	442.1	.000	.000	.000	5297.	5297.	9.0	0.213	438.4	0.0717	3.0	434.

MINIMUM TEMPERATURE= 442.133 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.742
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.052399963 HRS

TORQUE = 9414.4 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.070 HP
 MELTING = 4.513 HP
 MIXING = 2.214 HP
 FLIGHT CLEAR = 1.822 HP
 COMPRESSION = 0.283 HP
 MIXING DEVICE= 0.081 HP
 PRESSURE FLUCTUATION= 210.67 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= 7.8 TO 85.2 BTU/MIN OR
 0.18 TO 2.01 HP

MAXIMUM SCREW SPEED,RPM: 60.0 83.3 106.7 130.0 153.3 176.7 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 9.0 12.4 15.9 19.4 22.9 26.4 29.9

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.616 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
1160.66	331.1	0.0529186
12.82	380.8	0.1544832

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
17.19	447.5	0.0948087
1160.66	319.0	0.0576891

AT 60.00 RPM & 100.00 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 5297. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

1MS70

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 70.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 60.50 DEG.F AND SCREW = 207.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	8.1	21.16	0.076	0.004	60.5	207.0	0.00	0.59
2.00	8.0	21.28	0.084	0.011	60.5	207.0	0.00	1.08
3.00	7.9	21.56	0.102	0.026	60.5	207.0	0.00	2.02
4.00	7.6	22.10	0.136	0.053	60.5	207.0	0.01	4.00
5.00	7.1	23.39	0.193	0.107	71.5	207.0	0.01	8.76
6.00	6.6	24.66	0.183	0.146	60.5	207.0	0.03	13.36
7.00	6.0	26.48	0.213	0.175	60.5	207.0	0.06	20.32
7.70	5.4	28.38	0.210	0.172	60.5	207.0	0.10	27.49
7.85	5.3	28.85	0.210	0.172	329.5	207.0	0.10	29.35

L IN	TOUT DEG F	X/W SOLID	X/W GRATIC SOLID	PRESSURE PSI REAL	PRESSURE PSI FULL	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
10.18	342.5			575.	575.		0.437	349.0	0.0826		
12.18	342.5			959.	959.		0.437	349.0	0.0971		
14.10	342.1	.872	.872	.727	1158.	1158.	0.4	0.437	349.0	0.1963	-22.6
19.10	358.6	.714	.714	.591	1412.	1412.	1.6	0.437	391.2	0.1482	0.5
19.80	361.6	.690	.690	.572	1447.	1447.	1.9	0.437	391.7	0.1409	0.1
22.10	373.1	.644	.644	.541	1564.	1564.	2.4	0.413	393.1	0.1094	5.7
27.10	391.1	.542	.542	.470	1831.	1831.	3.5	0.361	396.3	0.0936	3.4
32.10	400.7	.437	.437	.391	2139.	2139.	4.5	0.309	399.3	0.0861	1.9
37.10	406.9	.330	.330	.304	2513.	2513.	5.4	0.257	402.2	0.0816	0.7
42.10	412.0	.223	.223	.211	2981.	2981.	6.2	0.205	405.1	0.0784	-0.1
47.10	417.0	.123	.123	.119	3552.	3552.	7.0	0.153	408.0	0.0758	-0.1
47.35	417.3	.118	.118	.115	3582.	3582.	7.0	0.150	408.3	0.0755	-0.4

-----SECONDARY CHANNEL BEGINS-----
 TBAR WAS CHANGED AT AXIAL LOC= 50.35 IN. TO TBAR= 434.0 F
 IN ORDER TO CONVERGE.

52.35	420.9	.000	.000	.000	4229.	4229.	6.8	0.150	410.9	0.0769	4.7
57.35	426.6	.000	.000	.000	4732.	4732.	9.3	0.150	413.8	0.0746	3.9
62.35	429.0	.000	.000	.000	5058.	5058.	9.7	0.150	416.7	0.0730	3.2
63.95	429.5	.000	.000	.000	5133.	5133.	9.9	0.150	417.7	0.0728	3.0

-----SECONDARY CHANNEL ENDS-----

65.19	431.1	.000	.000	.000	5232.	5232.	10.0	0.269	418.5	0.0674	3.7	434.
66.42	431.5	.000	.000	.000	5291.	5291.	10.1	0.387	419.2	0.0730	3.0	434.
71.37	431.8	.000	.000	.000	5475.	5475.	10.4	0.412	421.7	0.0742	2.8	434.
76.32	433.0	.000	.000	.000	5639.	5639.	10.7	0.437	424.5	0.0745	2.6	434.
77.89	433.8	.000	.000	.000	5698.	5698.	10.8	0.338	425.6	0.0698	3.0	434.
79.45	435.4	.000	.000	.000	5783.	5783.	11.0	0.238	426.5	0.0654	3.7	434.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
96.05	435.4	.000	.000	.000	5782.	5782.	11.1	0.213	431.3	0.0654	3.7	434.

101.00	446.1	.000	.000	.000	6158.	6158.	11.5	0.213	438.5	0.0646	3.9	434.

MINIMUM TEMPERATURE= 446.076 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.724
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.054696292 HRS

TORQUE = 10365.2 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.104 HP
 MELTING = 5.474 HP
 MIXING = 3.061 HP
 FLIGHT CLEAR = 2.427 HP
 COMPRESSION = 0.369 HP
 MIXING DEVICE= 0.104 HP
 PRESSURE FLUCTUATION= 247.25 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= 112.4 TO 194.5 BTU/MIN OR
 2.65 TO 4.58 HP

MAXIMUM SCREW SPEED, RPM: 70.0 91.7 113.3 135.0 156.7 178.3 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 11.5 15.1 18.6 22.2 25.8 29.3 32.9

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.596 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
1369.03	323.7	0.0516086
17.62	349.0	0.1859733

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
20.05	453.9	0.0890560
1369.03	319.0	0.0533599

AT 70.00 RPM & 100.00 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 6158. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

OUTPUT OF SIMULATION

(II) Varying Flow Rate

1MF80

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 80.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 65.50 DEG.F AND SCREW = 197.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F		POWER HP	PRESSURE PSI
					BARREL	SCREW		
1.00	9.6	21.12	0.062	0.003	65.5	197.0	0.00	0.53
2.00	9.5	21.22	0.068	0.008	65.5	197.0	0.00	0.87
3.00	9.4	21.40	0.080	0.018	65.5	197.0	0.00	1.44
4.00	9.2	21.69	0.097	0.033	65.5	197.0	0.00	2.47
5.00	8.9	22.22	0.122	0.059	75.0	197.0	0.00	4.40
6.00	8.7	22.60	0.097	0.076	65.5	197.0	0.01	5.72
7.00	8.5	23.04	0.114	0.094	65.5	197.0	0.01	7.30
8.00	8.2	23.60	0.134	0.115	65.5	197.0	0.02	9.32
9.00	7.8	24.31	0.155	0.137	65.5	197.0	0.03	11.95
9.90	7.5	25.13	0.175	0.157	329.1	197.0	0.04	14.97

L IN	TOUT DEG F	X/W SOLID	X/W GRATIC	PRESSURE PSI		POWEP HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F	
				REAL	FULL							
12.25	342.5			506.	506.		0.437	349.0	0.0867			
14.10	346.7			838.	838.		0.437	355.2	0.0969			
16.60	360.4	.867	.867	.717	1063.	1063.	0.2	0.437	389.8	0.1760	-24.5	390.
19.80	365.9	.753	.753	.623	1189.	1189.	0.6	0.437	392.0	0.1565	-3.1	392.
24.60	380.8	.653	.653	.557	1379.	1379.	1.3	0.387	394.7	0.1147	1.8	394.
29.60	392.2	.545	.545	.479	1594.	1594.	1.9	0.335	397.7	0.1037	0.3	397.
34.60	398.5	.431	.431	.390	1850.	1850.	2.4	0.283	400.7	0.0979	-0.8	400.
39.60	403.0	.313	.313	.291	2167.	2167.	3.0	0.231	403.5	0.0941	-1.7	403.
44.60	407.0	.193	.193	.185	2556.	2556.	3.4	0.179	406.4	0.0913	-2.3	406.
47.35	409.3	.131	.131	.128	2787.	2787.	3.7	0.150	408.0	0.0899	-2.2	408.
-----SECONDARY CHANNEL BEGINS-----												
52.35	412.5	.002	.005	.002	3252.	3252.	4.7	0.150	410.8	0.0912	3.8	410.
TBAR WAS CHANGED AT AXIAL LOC= 52.35 IN. TO TBAR= 434.0 F												
IN ORDER TO CONVERGE.												
57.35	419.1	.000	.000	.000	3630.	3630.	5.0	0.150	413.7	0.0878	2.3	434.
62.35	422.6	.000	.000	.000	3879.	3879.	5.2	0.150	416.5	0.0854	1.9	434.
63.95	423.3	.000	.000	.000	3936.	3936.	5.3	0.150	417.5	0.0849	1.7	434.
-----SECONDARY CHANNEL ENDS-----												

65.19	424.8	.000	.000	.000	4010.	4010.	5.4	0.269	418.4	0.0791	2.1	434.
66.42	425.3	.000	.000	.000	4056.	4056.	5.4	0.387	419.1	0.0849	1.7	434.
71.37	426.6	.000	.000	.000	4195.	4195.	5.6	0.412	421.6	0.0857	1.6	434.
76.32	428.5	.000	.000	.000	4319.	4319.	5.8	0.437	424.4	0.0856	1.5	434.
77.89	429.3	.000	.000	.000	4363.	4363.	5.9	0.338	425.5	0.0806	1.7	434.
79.45	430.8	.000	.000	.000	4427.	4427.	5.9	0.238	426.4	0.0760	2.1	434.

 FLUTED SECTION WITH 1. PAIRS OF FLUTES

96.05	430.8	.000	.000	.000	4426.	4426.	6.0	0.213	431.2	0.0760	2.1	434.
101.00	440.8	.000	.000	.000	4707.	4707.	6.2	0.213	438.4	0.0748	2.2	434.

MINIMUM TEMPERATURE= 440.794 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.750
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.065096207 HRS

TORQUE = 7877.5 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.043 HP
 MELTING = 2.935 HP
 MIXING = 1.671 HP
 FLIGHT CLEAR = 1.345 HP
 COMPRESSION = 0.213 HP
 MIXING DEVICE= 0.059 HP
 PRESSURE FLUCTUATION= 187.10 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -31.8 TO 28.1 BTU/MIN OR
 -0.75 TO 0.66 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 6.2 9.4 12.5 15.6 18.7 21.9 25.0

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.652 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
969.99	337.7	0.0548940
11.73	389.8	0.1468164

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	442.2	0.1006939
969.99	319.0	0.0626749

AT 50.00 RPM & 80.00 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 4707. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

1MF90

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 90.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 66.00 DEG.F AND SCREW = 202.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F	POWER HP	PRESSURE PSI
					BARREL	SCREW	
1.00	11.5	21.12	0.060	0.002	66.0	202.0	0.52
2.00	11.5	21.22	0.066	0.008	66.0	202.0	0.83
3.00	11.3	21.36	0.075	0.015	66.0	202.0	1.35
4.00	11.1	21.62	0.092	0.029	66.0	202.0	2.23
5.00	10.8	22.06	0.112	0.051	75.0	202.0	3.82
6.00	10.6	22.34	0.084	0.064	66.0	202.0	4.85
7.00	10.3	22.68	0.097	0.079	66.0	202.0	6.00
8.00	10.0	23.08	0.112	0.096	66.0	202.0	7.42
9.00	9.7	23.55	0.129	0.113	66.0	202.0	9.13
10.00	9.4	24.12	0.147	0.131	66.0	202.0	11.24
10.30	9.3	24.32	0.152	0.137	330.0	202.0	11.96

L IN	TOUT DEG F	X/W SOLID	X/W	GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
					REAL FULL						
12.60	342.5				496. 496.		0.437	349.0	0.0844		
14.60	355.5				861. 861.		0.437	368.0	0.0901		
17.10	360.1	.870	.870	.721	1081. 1081.	0.2	0.437	390.0	0.1809	-29.1	390.
19.80	363.9	.784	.784	.649	1188. 1188.	0.5	0.437	391.9	0.1696	-2.1	390.
24.10	375.3	.712	.712	.605	1357. 1357.	1.1	0.393	394.6	0.1220	2.2	394.
25.10	378.9	.695	.695	.594	1397. 1397.	1.2	0.382	395.0	0.1197	2.6	395.
30.10	391.2	.606	.606	.534	1610. 1610.	1.9	0.330	398.0	0.1074	1.1	397.
35.10	398.2	.510	.510	.463	1863. 1863.	2.5	0.278	400.9	0.1008	0.0	400.
40.10	402.7	.405	.405	.378	2171. 2171.	3.0	0.226	403.8	0.0968	-1.4	403.
45.10	406.0	.289	.289	.277	2534. 2534.	3.6	0.173	406.6	0.0943	-2.8	406.
47.35	407.3	.233	.233	.226	2694. 2694.	3.8	0.150	408.1	0.0934	-4.0	408.
-----SECONDARY CHANNEL BEGINS-----											
52.35	408.5	.094	.190	.094	3102. 3102.	4.2	0.150	410.7	0.0963	-3.8	410.
57.35	412.9	.002	.004	.002	3462. 3462.	5.1	0.150	413.6	0.0942	0.4	413.
62.35	419.2	.000	.000	.000	3706. 3706.	5.3	0.150	416.5	0.0899	1.9	414.
63.95	420.5	.000	.000	.000	3761. 3761.	5.4	0.150	417.5	0.0890	1.7	414.
-----SECONDARY CHANNEL ENDS-----											

65.19	422.3	.000	.000	.000	3832.	3832.	5.5	0.269	418.3	0.0828	2.2	414.
66.42	423.1	.000	.000	.000	3876.	3876.	5.5	0.387	419.0	0.0886	1.7	414.
71.37	425.4	.000	.000	.000	4012.	4012.	5.7	0.412	421.6	0.0889	1.6	414.
76.32	427.6	.000	.000	.000	4133.	4133.	5.9	0.437	424.4	0.0885	1.5	414.
77.89	428.6	.000	.000	.000	4175.	4175.	5.9	0.338	425.5	0.0834	1.7	414.
79.45	430.0	.000	.000	.000	4237.	4237.	6.0	0.238	426.4	0.0788	2.1	414.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
96.05	430.0	.000	.000	.000	4236.	4236.	6.1	0.213	431.2	0.0788	2.1	414.

101.00	439.5	.000	.000	.000	4501.	4501.	6.3	0.213	438.3	0.0776	2.2	414.

MINIMUM TEMPERATURE= 439.452 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.757
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.056948207 HRS

TORQUE = 7984.1 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.034 HP
 MELTING = 3.137 HP
 MIXING = 1.577 HP
 FLIGHT CLEAR = 1.334 HP
 COMPRESSION = 0.209 HP
 MIXING DEVICE= 0.060 HP
 PRESSURE FLUCTUATION= 179.06 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -64.3 TO 1.4 BTU/MIN OR
 -1.51 TO 0.03 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 6.3 9.5 12.7 15.8 19.0 22.2 25.3

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.649 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
787.11	342.5	0.0582690
9.95	390.0	0.1504015

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	441.9	0.1008983
233.20	329.0	0.1045385

AT 50.00 RPM & 90.00 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 4501. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

1MF100

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH. DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 67.00 DEG.F AND SCREW = 207.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/ CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	13.7	21.13	0.059	0.003	67.0	207.0	0.00	0.51
2.00	13.6	21.22	0.065	0.008	67.0	207.0	0.00	0.79
3.00	13.5	21.33	0.072	0.014	67.0	207.0	0.00	1.25
4.00	13.3	21.53	0.084	0.025	67.0	207.0	0.00	2.00
5.00	12.9	21.92	0.101	0.044	75.0	207.0	0.00	3.28
6.00	12.7	22.12	0.072	0.054	67.0	207.0	0.01	4.03
7.00	12.5	22.39	0.083	0.067	67.0	207.0	0.01	4.94
8.00	12.2	22.66	0.093	0.078	67.0	207.0	0.01	5.89
9.00	12.0	22.96	0.105	0.091	67.0	207.0	0.01	6.98
10.00	11.7	23.31	0.117	0.104	67.0	207.0	0.02	8.23
10.90	11.4	23.66	0.129	0.117	330.0	207.0	0.03	9.53

L IN	TOUT DEG F	X/W SOLID	X/W GRATIC SOLID	REAL PRESSURE PSI	FULL PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB. SEC /SQ. IN	D. HEAT BTU/IN .MIN	FILM TEMP DEG F
13.10	342.5			471.	471.	0.437	349.0	0.0811			
15.10	364.4			837.	837.	0.437	380.8	0.0839			
17.10	371.3			1071.	1071.	0.437	390.6	0.0903			
18.10	355.9	.879	.879	.732	1111.	1111.	0.2	0.437	390.6	0.1863	-32.5 391.
19.80	361.7	.830	.830	.691	1179.	1179.	0.4	0.437	390.6	0.1851	-2.2 391.
24.80	373.3	.763	.763	.655	1379.	1379.	1.1	0.385	394.7	0.1522	2.8 394.
26.10	378.0	.746	.746	.645	1431.	1431.	1.2	0.372	395.5	0.1232	3.5 395.
31.10	391.2	.674	.674	.601	1646.	1646.	1.9	0.320	398.6	0.1098	2.1 398.
36.10	398.9	.596	.596	.546	1899.	1899.	2.5	0.267	401.5	0.1027	1.0 401.
41.10	403.6	.508	.508	.478	2200.	2200.	3.1	0.215	404.4	0.0985	-0.5 404.
46.10	406.3	.402	.402	.390	2527.	2527.	3.7	0.163	407.2	0.0964	-2.6 407.
47.35	406.7	.373	.373	.363	2599.	2599.	3.8	0.150	408.1	0.0960	-4.0 408.
-----SECONDARY CHANNEL BEGINS-----											
52.35	404.0	.185	.374	.185	2953.	2953.	4.3	0.150	410.6	0.1020	-6.2 410.
57.35	408.0	.077	.188	.077	3282.	3282.	4.6	0.150	413.5	0.1001	-2.7 413.
62.35	413.1	.003	.010	.003	3520.	3520.	5.6	0.150	416.3	0.0959	3.4 416.
63.95	415.3	.000	.000	.000	3576.	3576.	5.6	0.150	417.4	0.0944	1.8 417.
-----SECONDARY CHANNEL ENDS-----											

65.19	417.6	.000	.000	.000	3644.	3644.	5.7	0.269	418.2	0.0876	2.2	417.
66.42	419.1	.000	.000	.000	3687.	3687.	5.8	0.387	418.9	0.0932	1.7	417.
71.37	422.9	.000	.000	.000	3820.	3820.	6.0	0.412	421.6	0.0925	1.6	417.
76.32	426.1	.000	.000	.000	3939.	3939.	6.1	0.437	424.4	0.0915	1.5	417.
77.89	427.2	.000	.000	.000	3981.	3981.	6.2	0.338	425.4	0.0862	1.7	417.
79.45	428.7	.000	.000	.000	4040.	4040.	6.3	0.238	426.3	0.0815	2.1	417.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
96.05	428.7	.000	.000	.000	4039.	4039.	6.3	0.213	431.1	0.0815	2.1	417.

101.00	437.9	.000	.000	.000	4288.	4288.	6.6	0.213	438.3	0.0803	2.1	417.

MINIMUM TEMPERATURE= 437.908 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.763
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.050008345 HRS

TORQUE = 8303.5 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.027 HP
 MELTING = 3.545 HP
 MIXING = 1.463 HP
 FLIGHT CLEAR = 1.313 HP
 COMPRESSION = 0.195 HP
 MIXING DEVICE= 0.060 HP
 PRESSURE FLUCTUATION= 170.41 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -89.1 TO -21.0 BTU/MIN OR
 -2.10 TO -0.49 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 6.6 9.9 13.2 16.5 19.8 23.1 26.3

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.641 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
770.55	342.5	0.0588104
8.18	390.6	0.1541261

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	441.3	0.1012381
230.69	329.0	0.1049526

 AT 50.00 RPM & 100.00 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 4288. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

1MF110

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 110.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH. DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 67.50 DEG.F AND SCREW = 213.50 DEG.F

LOCATION IN	PHI DEG	ROBP LB/ CU. FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	16.3	21.12	0.057	0.003	67.5	213.5	0.00	0.50
2.00	16.2	21.19	0.061	0.006	67.5	213.5	0.00	0.75
3.00	16.0	21.32	0.070	0.013	67.5	213.5	0.00	1.15
4.00	15.7	21.50	0.081	0.023	67.5	213.5	0.00	1.79
5.00	15.4	21.79	0.093	0.038	75.3	213.5	0.00	2.82
6.00	15.2	21.95	0.063	0.046	67.5	213.5	0.00	3.38
7.00	15.0	22.11	0.066	0.053	67.5	213.5	0.01	3.92
8.00	14.8	22.26	0.074	0.060	67.5	213.5	0.01	4.52
9.00	14.6	22.44	0.080	0.068	67.5	213.5	0.01	5.15
10.00	14.4	22.63	0.087	0.077	67.5	213.5	0.01	5.83
11.00	14.2	22.83	0.095	0.085	67.5	213.5	0.02	6.55
11.10	14.1	22.87	0.097	0.087	330.0	213.5	0.02	6.63

L IN	TOUT DEG F	X/W SOLID	X/W GRATIC	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB. SEC /SQ. IN	D. HEAT BTU/IN .MIN	FILM TEMP DEG F
13.10	342.5			418. 418.		0.437	349.0	0.0775		
15.10	364.4			806. 806.		0.437	380.8	0.0816		
17.10	371.3			1051. 1051.		0.437	390.6	0.0885		
18.60	359.4	.892	.892	.752 1144. 1144.	0.2	0.437	390.9	0.1932	-34.6	391.
19.80	360.5	.860	.860	.724 1191. 1191.	0.3	0.437	390.9	0.1954	-3.0	391.
24.80	371.1	.809	.809	.702 1389. 1389.	1.0	0.385	394.7	0.1638	3.7	394.
26.60	378.0	.790	.790	.693 1460. 1460.	1.2	0.367	395.8	0.1258	4.4	395.
31.60	392.0	.737	.737	.665 1671. 1671.	1.9	0.314	398.9	0.1116	3.3	398.
36.60	400.6	.678	.678	.630 1916. 1916.	2.6	0.262	401.8	0.1036	2.3	401.
41.60	405.6	.611	.611	.584 2199. 2199.	3.2	0.210	404.7	0.0993	1.1	404.
46.60	408.2	.530	.530	.520 2477. 2477.	3.8	0.158	407.5	0.0971	-1.0	407.
47.35	408.4	.516	.516	.508 2511. 2511.	3.9	0.150	408.0	0.0970	-1.5	408.
-----SECONDARY CHANNEL BEGINS-----										
52.35	400.2	.296	.598	.296 2813. 2813.	4.4	0.150	410.6	0.1075	-12.5	410.
57.35	402.8	.145	.353	.145 3114. 3114.	4.8	0.150	413.4	0.1063	-5.9	413.
62.35	408.6	.067	.204	.067 3338. 3338.	5.1	0.150	416.3	0.1014	-2.1	416.
63.95	409.6	.028	.093	.028 3392. 3392.	5.6	0.150	417.3	0.1002	-6.3	417.
-----SECONDARY CHANNEL ENDS-----										

65.19	411.9	.020	.020	.020	3456.	3456.	5.8	0.269	418.1	0.0930	4.4	418.
FILM THICKNESS IS 0 - TBAR= 0.4184E+03												
FILM THICKNESS IS 0 - TBAR= 0.4184E+03												
66.42	413.4	.015	.015	.013	3499.	3499.	6.1	0.387	418.8	0.0988	3.6	419.
71.37	418.5	.001	.001	.001	3632.	3632.	6.6	0.412	421.5	0.0973	1.1	421.
FILM THICKNESS IS 0 - TBAR= 0.4220E+03												
FILM THICKNESS IS 0 - TBAR= 0.4220E+03												
76.32	423.3	.000	.000	.000	3749.	3749.	6.8	0.437	424.3	0.0951	1.5	422.
77.89	424.7	.000	.000	.000	3790.	3790.	6.8	0.338	425.4	0.0895	1.7	422.
79.45	426.5	.000	.000	.000	3848.	3848.	6.9	0.238	426.3	0.0845	2.1	422.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
96.05	426.5	.000	.000	.000	3847.	3847.	7.0	0.213	431.1	0.0845	2.1	422.

101.00	435.8	.000	.000	.000	4079.	4079.	7.2	0.213	438.3	0.0831	2.1	422.

MINIMUM TEMPERATURE= 435.849 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.768
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.045023140 HRS

TORQUE = 9111.0 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.017 HP
 MELTING = 4.325 HP
 MIXING = 1.361 HP
 FLIGHT CLEAR = 1.301 HP
 COMPRESSION = 0.178 HP
 MIXING DEVICE= 0.060 HP
 PRESSURE FLUCTUATION= 160.29 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -96.7 TO -28.2 BTU/MIN OR
 -2.28 TO -0.66 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 7.2 10.8 14.5 18.1 21.7 25.3 28.9

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.623 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
884.32	375.5	0.0447617
6.39	390.9	0.1588934

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	440.3	0.1018387
442.16	329.0	0.0816959

AT 50.00 RPM & 110.00 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 4079. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

1MF120

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 120.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH SOLID (IN)	MELT (IN)	WIDTH SOLID (IN)	MELT (IN)	LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 89.50 DEG.F AND SCREW = 226.50 DEG.F

LOCATION IN	PHI DEG	ROBF LB/CC.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	SCREW	POWER HP	PRESSURE PSI
1.00	19.1	21.13	0.052	0.002	93.7	226.5	0.00	0.48
2.00	19.0	21.19	0.056	0.006	94.7	226.5	0.00	0.69
3.00	18.9	21.28	0.061	0.011	96.1	226.5	0.00	0.99
4.00	16.7	21.39	0.068	0.017	95.8	226.5	0.00	1.44
5.00	16.4	21.57	0.077	0.026	87.9	226.5	0.00	2.12
6.00	16.2	21.68	0.046	0.032	70.0	226.5	0.00	2.47
7.00	18.1	21.78	0.049	0.037	70.0	226.5	0.00	2.76
8.00	18.0	21.85	0.050	0.040	70.0	226.5	0.00	3.04
9.00	17.8	21.94	0.053	0.045	70.0	226.5	0.01	3.31
10.00	17.7	22.00	0.055	0.048	70.0	226.5	0.01	3.57
10.70	17.6	22.06	0.057	0.050	329.0	226.5	0.01	3.75

L IN	TOUT DEG F	X/W SOLID	X/W SOLID	GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
13.10	342.5				0. 507.		0.437	349.0	0.0796		
15.10	364.4				0. 887.		0.437	380.8	0.0818		
17.10	371.3				0. 1132.		0.437	390.6	0.0881		
18.10	358.5	.907	.907	.776	0. 1170.	0.1	0.437	390.6	0.2009	-35.2	391.
19.80	359.8	.866	.866	.740	0. 1235.	0.4	0.437	390.6	0.2021	-2.2	391.
24.80	370.4	.829	.829	.730	0. 1424.	1.0	0.385	394.7	0.1700	4.5	394.
26.10	375.5	.819	.819	.727	0. 1474.	1.2	0.372	395.5	0.1311	5.2	395.
31.10	391.3	.780	.780	.713	0. 1675.	1.9	0.320	398.6	0.1147	4.5	398.
36.10	401.9	.741	.741	.696	0. 1903.	2.6	0.267	401.5	0.1050	3.9	401.
41.10	408.6	.697	.697	.674	0. 2157.	3.2	0.215	404.5	0.0995	3.2	404.
46.10	412.4	.647	.647	.642	0. 2398.	3.9	0.163	407.3	0.0964	1.9	407.
47.35	413.0	.633	.633	.631	0. 2443.	4.0	0.150	408.2	0.0958	1.2	408.
-----SECONDARY CHANNEL BEGINS-----											
52.35	397.3	.398	.806	.398	0. 2698.	4.6	0.150	410.5	0.1126	-15.9	410.
57.35	398.5	.218	.531	.218	0. 2970.	5.0	0.150	413.3	0.1122	-8.9	413.
62.35	404.1	.113	.345	.113	0. 3182.	5.3	0.150	416.2	0.1070	-4.3	416.
63.95	406.1	.091	.303	.091	0. 3233.	5.4	0.150	417.2	0.1053	-3.5	417.
-----SECONDARY CHANNEL ENDS-----											

65.19	408.4	.077	.077	.077	0.3293.	5.6	0.269	418.1	0.0971	5.3	418.
66.42	410.1	.080	.080	.070	0.3335.	5.8	0.387	418.8	0.1028	0.3	419.
FILM THICKNESS IS 0 - TBAR= 0.4188E+03											
FILM THICKNESS IS 0 - TBAR= 0.4188E+03											
71.37	414.2	.034	.034	.029	0.3466.	6.8	0.412	421.4	0.1019	2.8	421.
FILM THICKNESS IS 0 - TBAR= 0.4237E+03											
FILM THICKNESS IS 0 - TBAR= 0.4237E+03											
76.32	418.8	.008	.008	.007	0.3582.	7.7	0.437	424.2	0.0997	17.6	424.
77.89	420.5	.005	.005	.005	0.3622.	7.9	0.338	425.3	0.0938	4.7	425.
FILM THICKNESS IS 0 - TBAR= 0.4259E+03											
FILM THICKNESS IS 0 - TBAR= 0.4259E+03											
79.45	422.4	.001	.001	.001	0.3679.	8.0	0.238	426.2	0.0885	0.9	426.

FLUTED SECTION WITH 1. PAIRS OF FLUTES											
96.05	438.0	.001	.001	.001	0.3678.	8.1	0.213	431.0	0.0885	0.9	426.

101.00	441.9	.000	.000	.000	0.3882.	8.3	0.213	438.4	0.0817	2.0	431.

MINIMUM TEMPERATURE= 441.932 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.775
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.041631229 HRS

TORQUE = 10507.7 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.008 HP
 MELTING = 5.548 HP
 MIXING = 1.263 HP
 FLIGHT CLEAR = 1.310 HP
 COMPRESSION = 0.162 HP
 MIXING DEVICE= 0.061 HP
 PRESSURE FLUCTUATION= 143.29 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -93.0 TO -15.7 BTU/MIN OR
 -2.19 TO -0.37 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 8.3 12.5 16.7 20.8 25.0 29.2 33.3

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.593 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
870.15	380.0	0.0438751
4.84	390.6	0.1644468

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
43.90	441.7	0.0815906
435.08	329.0	0.0822313

SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

OUTPUT OF SIMULATION

(III) Varying the IPFC

1MBF05

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH (IN)	SOLID MELT (IN)	WIDTH (IN)	SOLID MELT (IN)	LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 270.00 DEG.F AND SCREW = 190.50 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F	POWER HP	PRESSURE PSI
FRICION COEFFICIENT ON BARREL SURFACE MUST BE HIGHER THAN ON SCREW SURFACE							
FRIS=		0.839140E-01		FRIB=		0.401214E-01	
1.00	13.8	21.10	0.086	0.084	315.0	190.5	0.30
2.00	13.8	21.10	0.113	0.084	329.5	190.5	0.36
2.00	13.8	21.10	0.113	0.084	329.5	190.5	0.36

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN	FILM TEMP DEG F	
4.45	342.5			0. 520.		0.437	349.0	0.0833			
6.45	342.5			0. 906.		0.437	349.0	0.0963			
8.95	337.8	.907	.907	.779	0. 1179.	0.2	0.437	339.0	0.2403	-23.9	343.
13.95	336.2	.756	.756	.633	0. 1343.	2.0	0.437	344.8	0.2075	33.0	343.
16.95	350.3	.688	.688	.586	0. 1441.	2.4	0.437	389.9	0.1809	-0.6	389.
19.80	361.8	.616	.616	.524	0. 1534.	2.8	0.437	391.8	0.1579	-1.9	391.
24.80	380.1	.550	.550	.483	0. 1713.	3.4	0.385	394.8	0.1219	1.9	394.
29.80	391.1	.481	.481	.435	0. 1915.	3.9	0.333	397.8	0.1106	1.1	397.
34.80	397.9	.407	.407	.379	0. 2153.	4.5	0.281	400.8	0.1040	0.1	400.
39.80	402.6	.327	.327	.314	0. 2438.	5.0	0.229	403.6	0.0997	-0.9	403.
44.80	406.2	.240	.240	.236	0. 2759.	5.4	0.177	406.5	0.0969	-2.0	406.
47.35	407.7	.192	.192	.192	0. 2909.	5.7	0.150	408.0	0.0958	-2.8	408.
-----SECONDARY CHANNEL BEGINS-----											
52.35	408.8	.082	.167	.082	0. 3251.	6.0	0.150	410.7	0.0985	-3.2	410.
57.35	412.9	.001	.003	.001	0. 3578.	7.0	0.150	413.6	0.0966	0.7	413.
62.35	418.6	.000	.000	.000	0. 3811.	7.2	0.150	416.5	0.0925	1.9	414.
63.95	419.9	.000	.000	.000	0. 3865.	7.3	0.150	417.5	0.0916	1.7	414.
-----SECONDARY CHANNEL ENDS-----											
65.19	421.5	.000	.000	.000	0. 3931.	7.4	0.269	418.3	0.0855	2.1	414.
66.42	422.4	.000	.000	.000	0. 3974.	7.4	0.387	419.0	0.0913	1.7	414.
71.37	424.8	.000	.000	.000	0. 4105.	7.6	0.412	421.6	0.0915	1.6	414.
76.32	427.1	.000	.000	.000	0. 4222.	7.8	0.437	424.4	0.0909	1.5	414.
77.89	428.0	.000	.000	.000	0. 4264.	7.9	0.338	425.5	0.0858	1.7	414.
75.45	429.4	.000	.000	.000	0. 4323.	7.9	0.238	426.4	0.0812	2.1	414.

FLUTED SECTION WITH 1. PAIRS OF FLUTES

96.05	429.4	.000	.000	.000	0.4322	8.0	0.213	431.1	0.0812	2.1	414.

101.00	438.3	.000	.000	.000	0.4571	8.3	0.213	438.3	0.0801	2.1	414.

MINIMUM TEMPERATURE= 438.261 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.763
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.059739724 HRS

TORQUE = 10404.7 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.000 HP
 MELTING = 4.736 HP
 MIXING = 1.670 HP
 FLIGHT CLEAR = 1.569 HP
 COMPRESSION = 0.234 HP
 MIXING DEVICE= 0.060 HP
 PRESSURE FLUCTUATION= 170.05 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -18.7 TO 58.6 BTU/MIN OR
 -0.44 TO 1.38 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 8.3 12.4 16.5 20.6 24.8 28.9 33.0

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.595 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
968.41	334.0	0.0563521
6.00	339.0	0.2426229

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	441.6	0.1010565
12.91	293.7	0.2909913

SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

1MBF10

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH SOLID (IN)	CH.DEPTH MELT (IN)	WIDTH SOLID (IN)	WIDTH MELT (IN)	LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.29 PSI
 INCREASE HEIGHT TO = 124.00 IN. MAXIMUM PRESSURE = 0.50 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 67.00 DEG.F AND SCREW = 229.00 DEG.F

LOCATION	PHI	ROBP	FRIB	FRIS	TEMPERATURE, DEG F	POWER	PRESSURE
IN	DEG	LB/CU.FT			BARREL	SCREW	PSI
1.00	13.7	21.11	0.135	0.076	67.0	229.0	0.47
2.00	13.6	21.22	0.142	0.082	67.0	229.0	0.77
3.00	13.5	21.35	0.151	0.089	67.0	229.0	1.26
4.00	13.2	21.59	0.165	0.101	67.0	229.0	2.11
5.00	12.8	22.00	0.183	0.121	74.9	229.0	3.58
6.00	12.6	22.26	0.157	0.134	67.0	229.0	4.57
7.00	12.3	22.59	0.170	0.148	67.0	229.0	5.67
8.00	12.0	22.95	0.184	0.163	67.0	229.0	6.95
9.00	11.6	23.36	0.198	0.178	67.0	229.0	8.42
10.00	11.3	23.81	0.213	0.194	67.0	229.0	10.09
10.70	11.0	24.17	0.224	0.205	329.4	229.0	11.37

L	TOUT	X/W	X/W	GRATIO	PRESSURE	POWER	HOUT	TBAR	TVISC	D.HEAT	FILM
IN	DEG F		SOLID		PSI	HP	IN	DEG F	LB.SEC	BTU/IN	TEMP
					REAL	FULL			/SQ.IN	.MIN	DEG F
13.10	342.5				490.	490.	0.437	349.0	0.0830		
15.10	364.4				847.	847.	0.437	380.8	0.0847		
17.10	371.3				1077.	1077.	0.437	390.6	0.0907		
18.10	359.9	.878	.878	.730	1117.	1117.	0.2	0.437	390.6	0.1860	-32.8
19.80	361.7	.828	.828	.688	1185.	1185.	0.4	0.437	390.6	0.1848	-2.2
24.80	373.3	.762	.762	.653	1386.	1386.	1.1	0.385	394.7	0.1521	2.8
26.10	378.0	.744	.744	.643	1438.	1438.	1.3	0.372	395.5	0.1232	3.5
31.10	391.2	.673	.673	.598	1653.	1653.	1.9	0.320	398.6	0.1099	2.1
36.10	398.9	.595	.595	.544	1905.	1905.	2.6	0.267	401.5	0.1027	0.9
41.10	403.5	.506	.506	.476	2207.	2207.	3.2	0.215	404.4	0.0986	-0.5
46.10	406.3	.401	.401	.388	2533.	2533.	3.7	0.163	407.2	0.0964	-2.6
47.35	406.7	.371	.371	.361	2606.	2606.	3.9	0.150	408.1	0.0960	-4.0
-----SECONDARY CHANNEL BEGINS-----											
52.35	404.1	.184	.372	.184	2959.	2959.	4.3	0.150	410.6	0.1020	-8.2
57.35	408.1	.076	.186	.076	3288.	3288.	4.7	0.150	413.5	0.1000	-2.7
62.35	413.2	.003	.010	.003	3526.	3526.	5.6	0.150	416.3	0.0959	3.4
63.95	415.3	.000	.000	.000	3582.	3582.	5.7	0.150	417.4	0.0943	1.8
-----SECONDARY CHANNEL ENDS-----											

65.19	417.7	.000	.000	.000	3650.	3650.	5.7	0.269	418.2	0.0876	2.2	417.
66.42	419.1	.000	.000	.000	3693.	3693.	5.8	0.387	418.9	0.0932	1.7	417.
71.37	423.0	.000	.000	.000	3826.	3826.	6.0	0.412	421.6	0.0925	1.6	417.
76.32	426.1	.000	.000	.000	3945.	3945.	6.2	0.437	424.4	0.0915	1.5	417.
77.89	427.2	.000	.000	.000	3987.	3987.	6.2	0.338	425.4	0.0862	1.7	417.
79.45	428.7	.000	.000	.000	4046.	4046.	6.3	0.238	426.3	0.0815	2.1	417.

 FLUTED SECTION WITH 1. PAIRS OF FLUTES

96.05	428.7	.000	.000	.000	4045.	4045.	6.4	0.213	431.1	0.0815	2.1	417.
101.00	437.9	.000	.000	.000	4294.	4294.	6.6	0.213	438.3	0.0803	2.1	417.

MINIMUM TEMPERATURE= 437.910 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.763
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.050001115 HRS

TORQUE = 8334.4 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.057 HP
 MELTING = 3.538 HP
 MIXING = 1.464 HP
 FLIGHT CLEAR = 1.313 HP
 COMPRESSION = 0.195 HP
 MIXING DEVICE= 0.060 HP
 PRESSURE FLUCTUATION= 170.40 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -88.1 TO -20.8 BTU/MIN OR
 -2.08 TO -0.49 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 6.6 9.9 13.2 16.5 19.8 23.1 26.4

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.641 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
779.85	342.5	0.0585047
8.28	390.6	0.1538658

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	441.3	0.1012367
230.72	329.0	0.1049472

AT 50.00 RPM & 100.00 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 4294. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

1MBF15

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.21 PSI
 INCREASE HEIGHT TO = 64.55 IN. MAXIMUM PRESSURE = 0.26 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 67.00 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	13.7	21.13	0.186	0.077	67.0	229.0	0.00	0.50
2.00	13.5	21.32	0.199	0.087	67.0	229.0	0.00	1.17
3.00	13.1	21.77	0.227	0.111	67.0	229.0	0.00	2.83
4.00	12.0	22.93	0.289	0.162	67.0	229.0	0.01	7.14
4.75	10.4	25.07	0.370	0.227	117.3	229.0	0.03	14.98
5.25	9.4	26.71	0.337	0.248	275.7	229.0	0.05	21.11
5.75	8.5	28.78	0.332	0.244	284.8	229.0	0.08	29.28
6.25	7.4	31.72	0.331	0.243	291.4	229.0	0.11	41.36
6.75	6.2	35.88	0.330	0.241	297.6	229.0	0.17	59.72
7.25	5.1	41.75	0.330	0.239	303.8	229.0	0.25	88.21
7.75	4.1	49.65	0.329	0.238	311.4	229.0	0.37	133.21
8.25	3.3	59.52	0.329	0.236	320.0	229.0	0.55	204.78
8.75	2.7	70.15	0.327	0.235	330.0	229.0	0.83	318.14
8.75	2.7	70.15	0.327	0.235	330.0	229.0	0.83	318.14

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
11.20	342.5			938. 938.	0.437	349.0	0.0829			
13.10	342.5			1303. 1303.	0.437	349.0	0.0957			
15.10	364.4			1591. 1591.	0.437	380.8	0.0908			
16.10	354.7	.891	.891	.752 1629. 1629.	1.0	0.437 380.8	0.1985	-29.3	381.	
19.80	360.4	.789	.789	.665 1768. 1768.	1.5	0.437 391.8	0.1781	-1.6	391.	
24.10	374.1	.732	.732	.633 1931. 1931.	2.1	0.393 394.3	0.1278	3.5	394.	
29.10	388.5	.663	.663	.591 2133. 2133.	2.7	0.340 397.4	0.1127	2.2	397.	
34.10	397.0	.588	.588	.539 2367. 2367.	3.4	0.288 400.3	0.1046	1.2	400.	
39.10	402.2	.504	.504	.476 2647. 2647.	3.9	0.236 403.2	0.0998	-0.1	403.	
44.10	405.4	.408	.408	.396 2971. 2971.	4.5	0.184 406.1	0.0971	-1.8	406.	
47.35	406.8	.335	.335	.331 3170. 3170.	4.8	0.150 406.1	0.0960	-4.0	408.	
-----SECONDARY CHANNEL BEGINS-----										
52.35	404.9	.162	.328	.162 3521. 3521.	5.3	0.150 410.6	0.1014	-7.2	410.	
57.35	409.0	.066	.161	.066 3850. 3850.	5.6	0.150 413.5	0.0993	-2.1	413.	
62.35	414.2	.001	.002	.001 4088. 4088.	6.5	0.150 416.4	0.0952	0.8	416.	
63.95	416.3	.000	.000	.000 4143. 4143.	6.6	0.150 417.4	0.0937	1.8	416.	
-----SECONDARY CHANNEL ENDS-----										

65.19	418.5	.000	.000	.000	4211.	4211.	6.7	0.269	418.2	0.0871	2.2	416.
66.42	419.8	.000	.000	.000	4254.	4254.	6.7	0.387	419.0	0.0927	1.7	416.
71.37	423.4	.000	.000	.000	4387.	4387.	6.9	0.412	421.6	0.0923	1.6	416.
76.32	426.3	.000	.000	.000	4505.	4505.	7.1	0.437	424.4	0.0914	1.5	416.
77.89	427.4	.000	.000	.000	4547.	4547.	7.2	0.338	425.5	0.0861	1.7	416.
79.45	428.9	.000	.000	.000	4606.	4606.	7.2	0.238	426.3	0.0814	2.1	416.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
96.05	428.9	.000	.000	.000	4605.	4605.	7.3	0.213	431.1	0.0814	2.1	416.

101.00	438.0	.000	.000	.000	4854.	4854.	7.6	0.213	438.3	0.0802	2.1	416.

MINIMUM TEMPERATURE= 437.987 DEG F
TEMP FLUCTUATION= 0.000 DEG F
FLOW INDEX (N)= 0.763
GRATIO INJ.= 0.000
RESIDENCE TIME:
MELT POOL= 0.052353885 HRS

TORQUE = 9534.4 INCH.POUNDS
POWER BREAK-DOWN:
SOLIDS CONV. = 0.829 HP
MELTING = 3.618 HP
MIXING = 1.511 HP
FLIGHT CLEAR = 1.358 HP
COMPRESSION = 0.202 HP
MIXING DEVICE= 0.060 HP
PRESSURE FLUCTUATION= 170.33 PSI/CYCLE
TOTAL CONDUCTED HEAT THROUGH BARREL= -47.7 TO -14.9 BTU/MIN OR
-1.13 TO -0.35 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
POWER CONSUMPTION, % OF AVAILABLE: 7.6 11.3 15.1 18.9 22.7 26.5 30.3

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.613 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
1077.25	342.5	0.0506723
7.29	380.8	0.1684484

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	441.4	0.1011971
230.45	329.0	0.1049915

AT 50.00 RPM & 100.00 LB/HR PRODUCTION RATE
HEAD PRESSURE IS 4854. PSI.

FOR MORE DETAIL
SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

1MBF20

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH (IN)		WIDTH (IN)		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID	MELT	SOLID	MELT					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.14 PSI
 INCREASE HEIGHT TO = 37.27 IN. MAXIMUM PRESSURE = 0.15 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 67.00 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBF LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F	POWER HP	PRESSURE PSI
					BARREL	SCREW	
1.00	13.7	21.13	0.236	0.077	67.0	229.0	0.00
2.00	13.4	21.44	0.256	0.094	67.0	229.0	0.00
3.00	12.3	22.56	0.321	0.147	67.0	229.0	0.01
3.65	10.6	24.75	0.411	0.220	67.8	229.0	0.02
4.15	8.7	28.33	0.445	0.245	70.2	229.0	0.05
4.65	6.2	35.79	0.447	0.241	106.6	229.0	0.11
5.13	4.6	45.47	0.386	0.238	285.3	229.0	0.22
5.63	3.3	59.63	0.406	0.236	300.4	229.0	0.41
6.13	2.5	75.00	0.380	0.234	317.1	229.0	0.78
6.43	2.3	81.83	0.378	0.234	330.0	229.0	1.15

L IN	TOUT DEG F	X/W SOLID	X/W GRATIC SOLID	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
				REAL FULL						
6.87	342.5			1211. 1211.		0.437	349.0	0.0828		
10.87	342.5			1590. 1590.		0.437	349.0	0.0962		
13.37	336.3	.909	.909	.782 1860. 1860.	1.4	0.437	330.2	0.2425	-23.4	339.
18.37	354.1	.775	.775	.658 2037. 2037.	2.1	0.437	390.8	0.1860	-1.8	390.
19.80	359.0	.736	.736	.625 2088. 2088.	2.3	0.437	391.8	0.1707	-2.3	391.
21.37	366.5	.715	.715	.614 2144. 2144.	2.5	0.421	392.7	0.1372	3.6	392.
26.37	383.6	.648	.648	.573 2331. 2331.	3.1	0.369	395.8	0.1179	2.3	395.
31.37	393.7	.576	.576	.525 2544. 2544.	3.7	0.317	398.8	0.1079	1.4	398.
36.37	399.8	.498	.498	.467 2797. 2797.	4.3	0.265	401.7	0.1020	0.3	401.
41.37	403.9	.410	.410	.396 3099. 3099.	4.9	0.212	404.5	0.0985	-1.1	404.
46.37	406.6	.309	.309	.307 3420. 3420.	5.4	0.160	407.4	0.0963	-2.8	407.
47.35	407.0	.288	.288	.287 3475. 3475.	5.5	0.150	407.9	0.0961	-3.3	407.
-----SECONDARY CHANNEL BEGINS-----										
52.35	406.0	.134	.272	.134 3823. 3823.	5.9	0.150	410.7	0.1005	-5.9	410.
57.35	409.3	.023	.056	.023 4151. 4151.	6.7	0.150	413.5	0.0988	-3.3	413.
62.35	415.9	.000	.000	.000 4389. 4389.	7.1	0.150	416.4	0.0941	1.9	415.
63.95	417.7	.000	.000	.000 4443. 4443.	7.2	0.150	417.4	0.0929	1.8	415.
-----SECONDARY CHANNEL ENDS-----										

65.19	419.7	.000	.000	.000	4511.	4511.	7.3	0.269	418.3	0.0865	2.2	415.
66.42	420.8	.000	.000	.000	4554.	4554.	7.3	0.387	419.0	0.0922	1.7	415.
71.37	423.9	.000	.000	.000	4686.	4686.	7.5	0.412	421.6	0.0920	1.6	415.
76.32	426.6	.000	.000	.000	4804.	4804.	7.7	0.437	424.4	0.0912	1.5	415.
77.89	427.6	.000	.000	.000	4845.	4845.	7.8	0.338	425.5	0.0860	1.7	415.
79.45	429.1	.000	.000	.000	4905.	4905.	7.8	0.238	426.4	0.0813	2.1	415.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
96.05	429.1	.000	.000	.000	4904.	4904.	7.9	0.213	431.1	0.0813	2.1	415.

101.00	438.1	.000	.000	.000	5152.	5152.	8.2	0.213	438.3	0.0802	2.1	415.

MINIMUM TEMPERATURE= 438.093 DEG F
TEMP FLUCTUATION= 0.000 DEG F
FLOW INDEX (N)= 0.763
GRATIO INJ.= 0.000
RESIDENCE TIME:
MELT POOL= 0.055453643 HRS

TORQUE = 10282.6 INCH.POUNDS
POWER BREAK-DOWN:
SOLIDS CONV. = 1.148 HP
MELTING = 3.745 HP
MIXING = 1.580 HP
FLIGHT CLEAR = 1.428 HP
COMPRESSION = 0.212 HP
MIXING DEVICE= 0.060 HP
PRESSURE FLUCTUATION= 170.22 PSI/CYCLE
TOTAL CONDUCTED HEAT THROUGH BARREL= -22.7 TO -0.7 BTU/MIN OR
-0.53 TO -0.02 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
POWER CONSUMPTION, % OF AVAILABLE: 8.2 12.2 16.3 20.4 24.5 28.6 32.6

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.597 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
1099.72	342.5	0.0501981
5.71	355.9	0.2118465

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	441.5	0.1011423
230.26	329.0	0.1050236

AT 50.00 RPM & 100.00 LB/HR PRODUCTION RATE
HEAD PRESSURE IS 5152. PSI.

FOR MORE DETAIL
SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

1MBF25

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 100.00 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH. DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
2	27.550	0.150	0.000	2.061	0.000	2.475	2.500	0.300		
3	16.600	0.150	0.450	1.354	1.354	3.450	2.500	0.300		
4	2.475	0.387	0.000	2.061	0.000	2.475	2.500	0.300		
5	9.900	0.437	0.000	2.061	0.000	2.475	2.500	0.300		
6	3.125	0.237	0.000	2.604	0.000	3.125	2.500	0.300		
7	16.600	0.213	0.000	2.859	0.000	3.450	2.500	0.300	1.000	0.914
8	4.950	0.213	0.000	2.061	0.000	2.475	2.500	0.300		

HOPPER ANALYSIS

ATTENTION - KEEP SOLIDS LEVEL IN HOPPER ABOVE 24.47 IN.
 BASE PRESSURE = 0.10 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 67.50 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	13.7	21.13	0.286	0.077	67.5	229.0	0.00	0.48
2.00	13.2	21.63	0.318	0.104	67.5	229.0	0.00	2.40
2.85	11.4	23.63	0.421	0.188	67.5	229.0	0.01	9.73
3.35	9.3	27.03	0.498	0.249	70.5	229.0	0.04	22.98
3.85	6.4	35.26	0.496	0.241	77.7	229.0	0.10	58.60
4.35	3.8	53.32	0.491	0.237	99.9	229.0	0.26	162.05
4.85	2.5	77.06	0.481	0.234	114.2	229.0	0.70	451.66
5.00	2.3	82.03	0.428	0.234	330.0	229.0	0.93	605.03

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO SOLID	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F		
				REAL	FULL							
7.45	342.5			1225.	1225.	0.437	349.0	0.0828				
9.45	342.5			1603.	1603.	0.437	349.0	0.0962				
11.95	337.8	.907	.907	.779	1868.	1868.	1.1	0.437	339.0	0.2403	-23.9	343.
16.95	350.2	.773	.773	.657	2020.	2020.	2.1	0.437	389.9	0.1925	-1.0	389.
19.80	360.7	.696	.696	.592	2107.	2107.	2.4	0.437	391.7	0.1654	-1.6	391.
24.80	379.8	.630	.630	.552	2288.	2288.	3.1	0.385	394.8	0.1220	2.4	394.
29.80	391.2	.560	.560	.506	2490.	2490.	3.7	0.333	397.8	0.1104	1.5	397.
34.80	398.1	.484	.484	.450	2729.	2729.	4.3	0.281	400.8	0.1037	0.5	400.
39.80	402.7	.401	.401	.384	3015.	3015.	4.8	0.229	403.6	0.0995	-0.7	403.
44.80	405.9	.307	.307	.302	3338.	3338.	5.3	0.177	406.5	0.0969	-2.2	406.
47.35	407.2	.254	.254	.253	3490.	3490.	5.5	0.150	408.0	0.0960	-3.3	408.
-----SECONDARY CHANNEL BEGINS-----												
52.35	407.0	.115	.233	.115	3836.	3836.	5.9	0.150	410.7	0.0999	-5.0	410.
57.35	410.5	.013	.031	.013	4163.	4163.	6.8	0.150	413.5	0.0982	1.9	413.
62.35	416.9	.000	.000	.000	4399.	4399.	7.2	0.150	416.4	0.0935	1.9	415.
63.95	418.6	.000	.000	.000	4454.	4454.	7.2	0.150	417.5	0.0924	1.8	415.
-----SECONDARY CHANNEL ENDS-----												
65.19	420.4	.000	.000	.000	4521.	4521.	7.3	0.269	418.3	0.0861	2.2	415.
66.42	421.4	.000	.000	.000	4563.	4563.	7.4	0.387	419.0	0.0918	1.7	415.
71.37	424.2	.000	.000	.000	4695.	4695.	7.6	0.412	421.6	0.0918	1.6	415.
76.32	426.8	.000	.000	.000	4813.	4813.	7.7	0.437	424.4	0.0911	1.5	415.
77.89	427.8	.000	.000	.000	4854.	4854.	7.8	0.338	425.5	0.0859	1.7	415.
79.45	429.2	.000	.000	.000	4914.	4914.	7.9	0.238	426.4	0.0813	2.1	415.

FLUTED SECTION WITH 1. PAIRS OF FLUTES
 96.05 429.2 .000 .000 .000 4913. 4913. 7.9 0.213 431.1 0.0813 2.1 415.

 101.00 438.2 .000 .000 .000 5162. 5162. 8.2 0.213 438.3 0.0802 2.1 415.

MINIMUM TEMPERATURE= 438.157 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.763
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.056831159 HRS

TORQUE = 10317.5 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.932 HP
 MELTING = 3.916 HP
 MIXING = 1.606 HP
 FLIGHT CLEAR = 1.468 HP
 COMPRESSION = 0.219 HP
 MIXING DEVICE= 0.060 HP
 PRESSURE FLUCTUATION= 170.16 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -21.5 TO 11.5 BTU/MIN OR
 -0.51 TO 0.27 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 8.2 12.3 16.4 20.5 24.6 28.6 32.7

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 1.100 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.597 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
1100.22	342.5	0.0501876
6.00	339.0	0.2426229

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
14.32	441.5	0.1011094
230.27	329.0	0.1050221

 AT 50.00 RPM & 100.00 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 5162. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

2MBF05

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 87.80 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH. DEPTH (IN)		WIDTH (IN)		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID	MELT	SOLID	MELT					
1	19.800	0.437	0.000	1.822	0.000	2.225	2.250	0.300		
2	27.550	0.150	0.000	1.822	0.000	2.225	2.250	0.300		
3	16.600	0.150	0.450	1.324	1.324	3.450	2.250	0.300		
4	2.225	0.387	0.000	1.822	0.000	2.225	2.250	0.300		
5	9.900	0.437	0.000	1.822	0.000	2.225	2.250	0.300		
6	3.125	0.237	0.000	2.558	0.000	3.125	2.250	0.300		
7	16.600	0.213	0.000	2.800	0.000	3.450	2.250	0.300	1.000	0.914
8	4.950	0.213	0.000	1.822	0.000	2.225	2.250	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 272.50 DEG.F AND SCREW = 204.50 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
FRICTION COEFFICIENT ON BARREL SURFACE MUST BE HIGHER THAN ON SCREW SURFACE								
FRIS= 0.794804E-01 FRIB= 0.378638E-01								
1.00	17.2	21.10	0.086	0.079	317.7	204.5	0.00	0.30
1.80	17.2	21.10	0.110	0.079	330.0	204.5	0.00	0.36

L IN	TOUT DEG F	X/W	X/W GRATIO SOLID	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
				REAL	FULL					
4.28	342.5			0.	507.	0.437	349.0	0.0843		
6.78	335.3	.867	.867 .740	0.	810.	0.3	0.437 339.0	0.2385	-15.9	340.
11.78	322.7	.749	.749 .621	0.	620.	1.2	0.437 290.1	0.2743	-4.2	342.
13.98	326.1	.692	.692 .568	0.	624.	2.0	0.437 345.6	0.2647	4.9	337.
18.98	352.5	.578	.578 .475	0.	941.	2.5	0.437 391.1	0.1828	-1.7	390.
19.80	355.9	.559	.559 .460	0.	964.	2.6	0.437 391.7	0.1757	-1.8	391.
24.80	375.3	.491	.491 .419	0.	1124.	3.0	0.385 394.7	0.1352	1.0	394.
29.80	367.0	.423	.423 .373	0.	1303.	3.4	0.333 397.8	0.1214	0.4	397.
34.80	394.4	.351	.351 .320	0.	1512.	3.8	0.281 400.7	0.1133	-0.3	400.
39.80	399.1	.270	.270 .255	0.	1756.	4.1	0.229 403.6	0.1083	-1.4	403.
44.80	401.8	.174	.174 .171	0.	2015.	4.5	0.177 406.4	0.1055	-3.0	406.
47.35	402.9	.119	.119 .115	0.	2123.	4.7	0.150 408.0	0.1046	-2.1	408.
-----SECONDARY CHANNEL BEGINS-----										
52.35	407.1	.019	.038 .019	0.	2382.	5.3	0.150 410.7	0.1042	0.9	410.
57.35	413.3	.000	.000 .000	0.	2648.	5.6	0.150 413.6	0.1002	1.7	412.
62.35	418.1	.000	.000 .000	0.	2842.	5.8	0.150 416.4	0.0965	1.4	412.
63.95	419.2	.000	.000 .000	0.	2887.	5.8	0.150 417.5	0.0957	1.3	412.
-----SECONDARY CHANNEL ENDS-----										
65.06	420.5	.000	.000 .000	0.	2937.	5.9	0.269 418.2	0.0899	1.6	412.
66.17	421.2	.000	.000 .000	0.	2970.	5.9	0.387 418.9	0.0975	1.3	412.
71.12	423.3	.000	.000 .000	0.	3084.	6.1	0.412 421.4	0.0981	1.2	412.
76.07	425.5	.000	.000 .000	0.	3186.	6.2	0.437 424.2	0.0977	1.1	412.
77.64	426.5	.000	.000 .000	0.	3222.	6.3	0.338 425.3	0.0908	1.3	412.
79.20	427.6	.000	.000 .000	0.	3272.	6.3	0.238 426.2	0.0850	1.6	412.

FLUTED SECTION WITH 1. PAIRS OF FLUTES
 95.80 427.8 .000 .000 .000 0. 3271. 6.4 0.213 431.0 0.0850 1.6 412.

 100.75 436.5 .000 .000 .000 0. 3480. 6.5 0.213 438.1 0.0851 1.6 412.

MINIMUM TEMPERATURE= 436.472 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.776
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.060664140 HRS

TORQUE = 8252.5 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.000 HP
 MELTING = 3.789 HP
 MIXING = 1.213 HP
 FLIGHT CLEAR = 1.340 HP
 COMPRESSION = 0.174 HP
 MIXING DEVICE= 0.042 HP
 PRESSURE FLUCTUATION= 134.22 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -44.7 TO 35.9 BTU/MIN OR
 -1.05 TO 0.85 HP

MAXIMUM SCREW SPEED, RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 6.5 9.8 13.1 16.4 19.6 22.9 26.2

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.900 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.518 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
991.08	334.0	0.0557660
5.78	265.0	0.3343562

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
12.89	438.8	0.1044811
9.11	238.1	0.3105899

SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

:

2MBF10

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 87.80 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH. DEPTH (IN)	SOLID (IN)	MELT (IN)	WIDTH (IN)	SOLID (IN)	MELT (IN)	LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
1	19.800	0.437	0.000	1.822	0.000	2.225	2.250	0.300				
2	27.550	0.150	0.000	1.822	0.000	2.225	2.250	0.300				
3	16.600	0.150	0.450	1.324	1.324	3.450	2.250	0.300				
4	2.225	0.387	0.000	1.822	0.000	2.225	2.250	0.300				
5	9.900	0.437	0.000	1.822	0.000	2.225	2.250	0.300				
6	3.125	0.237	0.000	2.558	0.000	3.125	2.250	0.300				
7	16.600	0.213	0.000	2.800	0.000	3.450	2.250	0.300	1.000		0.914	
8	4.950	0.213	0.000	1.822	0.000	2.225	2.250	0.300				

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.29 PSI
 INCREASE HEIGHT TO = 124.00 IN. MAXIMUM PRESSURE = 0.50 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 68.50 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	FHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	17.1	21.11	0.131	0.076	68.5	229.0	0.00	0.45
2.00	17.0	21.18	0.135	0.080	68.5	229.0	0.00	0.70
3.00	16.9	21.28	0.141	0.085	68.5	229.0	0.00	1.08
4.00	16.6	21.46	0.152	0.095	68.5	229.0	0.00	1.71
5.00	16.2	21.76	0.165	0.110	76.0	229.0	0.00	2.72
6.00	16.0	21.93	0.138	0.118	68.5	229.0	0.01	3.33
7.00	15.7	22.11	0.145	0.127	68.5	229.0	0.01	3.97
8.00	15.5	22.31	0.152	0.136	68.5	229.0	0.01	4.66
9.00	15.2	22.52	0.160	0.145	68.5	229.0	0.02	5.41
10.00	15.0	22.73	0.167	0.154	68.5	229.0	0.02	6.21
11.00	14.7	22.96	0.176	0.164	68.5	229.0	0.03	7.04
11.50	14.6	23.11	0.181	0.169	329.5	229.0	0.03	7.47

L IN	TOUT DEG F	X/W SOLID	X/W GRATIC SOLID	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F		
				REAL	FULL							
13.78	342.5			485.	485.	0.437	349.0	0.0825				
16.28	356.1	.875	.875	.720	778.	778.	0.14	0.437	385.5	0.2028	-32.6	385.
19.80	361.5	.779	.779	.639	891.	891.	0.50	0.437	391.9	0.1880	-2.1	391.
23.48	372.5	.730	.730	.615	1010.	1010.	0.87	0.399	394.0	0.1384	2.5	393.
28.48	385.7	.662	.662	.577	1182.	1182.	1.4	0.347	397.0	0.1227	1.6	396.
33.48	394.0	.589	.589	.532	1383.	1383.	1.8	0.295	399.9	0.1136	0.8	399.
38.48	399.3	.511	.511	.476	1619.	1619.	2.3	0.243	402.8	0.1081	-0.2	402.
43.48	402.7	.421	.421	.405	1884.	1884.	2.7	0.190	405.7	0.1046	-1.5	405.
47.35	404.5	.341	.341	.336	2066.	2066.	3.0	0.150	407.9	0.1030	-2.9	407.
-----SECONDARY CHANNEL BEGINS-----												
52.35	402.5	.168	.334	.168	2338.	2338.	3.3	0.150	410.6	0.1078	-6.8	410.
57.35	407.0	.071	.173	.071	2610.	2610.	3.6	0.150	413.5	0.1049	-2.1	413.
62.35	412.4	.003	.008	.003	2809.	2809.	4.4	0.150	416.3	0.1003	3.2	416.
63.95	414.5	.000	.000	.000	2855.	2855.	4.5	0.150	417.4	0.0988	1.3	417.
-----SECONDARY CHANNEL ENDS-----												
65.06	416.5	.000	.000	.000	2907.	2907.	4.5	0.269	418.1	0.0921	1.6	417.
66.17	417.7	.000	.000	.000	2940.	2940.	4.6	0.387	418.8	0.0997	1.3	417.
71.12	421.4	.000	.000	.000	3056.	3056.	4.7	0.412	421.4	0.0993	1.2	417.

76.07	424.5	.000	.000	.000	3160.	3160.	4.9	0.437	424.2	0.0983	1.2	417.
77.64	425.6	.000	.000	.000	3195.	3195.	4.9	0.338	425.3	0.0913	1.3	417.
79.20	427.1	.000	.000	.000	3246.	3246.	5.0	0.238	426.2	0.0853	1.6	417.

 FLUTED SECTION WITH 1. PAIRS OF FLUTES

95.80	427.1	.000	.000	.000	3244.	3244.	5.0	0.213	431.0	0.0853	1.6	417.
100.75	436.1	.000	.000	.000	3454.	3454.	5.2	0.213	438.1	0.0853	1.6	417.

MINIMUM TEMPERATURE= 436.120 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.775
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.051764593 HRS

TORQUE = 6544.8 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.031 HP
 MELTING = 2.812 HP
 MIXING = 1.075 HP
 FLIGHT CLEAR = 1.096 HP
 COMPRESSION = 0.148 HP
 MIXING DEVICE= 0.042 HP
 PRESSURE FLUCTUATION= 134.51 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -101.9 TO -38.5 BTU/MIN OR
 -2.40 TO -0.91 HP

MAXIMUM SCREW SPEED, RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 5.2 7.8 10.4 13.0 15.6 18.2 20.8

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.900 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.562 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
813.70	342.5	0.0574303
5.41	385.5	0.1687969

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
12.89	436.4	0.1046804
205.68	329.0	0.1093994

AT 50.00 RPM & 87.80 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 3454. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :

2MBF15

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 87.80 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH. DEPTH (IN)		WIDTH (IN)		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID	MELT	SOLID	MELT					
1	19.800	0.437	0.000	1.822	0.000	2.225	2.250	0.300		
2	27.550	0.150	0.000	1.822	0.000	2.225	2.250	0.300		
3	16.600	0.150	0.450	1.324	1.324	3.450	2.250	0.300		
4	2.225	0.387	0.000	1.822	0.000	2.225	2.250	0.300		
5	9.900	0.437	0.000	1.822	0.000	2.225	2.250	0.300		
6	3.125	0.237	0.000	2.558	0.000	3.125	2.250	0.300		
7	16.600	0.213	0.000	2.800	0.000	3.450	2.250	0.300	1.000	0.914
8	4.950	0.213	0.000	1.822	0.000	2.225	2.250	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.21 PSI
 INCREASE HEIGHT TO = 64.55 IN. MAXIMUM PRESSURE = 0.26 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 69.00 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBF LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	17.1	21.12	0.181	0.077	69.0	229.0	0.00	0.47
2.00	16.9	21.27	0.191	0.085	69.0	229.0	0.00	1.05
3.00	16.4	21.65	0.214	0.105	69.0	229.0	0.00	2.37
4.00	15.2	22.51	0.263	0.145	69.1	229.0	0.01	5.55
4.90	13.3	24.40	0.308	0.211	203.5	229.0	0.02	12.35
5.40	12.3	25.56	0.319	0.236	270.7	229.0	0.03	16.65
5.90	11.2	27.05	0.331	0.249	278.0	229.0	0.05	22.38
6.40	10.0	29.10	0.327	0.244	284.5	229.0	0.07	30.54
6.90	8.7	32.04	0.327	0.243	289.8	229.0	0.10	42.76
7.40	7.2	36.29	0.326	0.241	295.5	229.0	0.14	61.56
7.90	5.9	42.29	0.325	0.239	302.2	229.0	0.21	91.09
8.40	4.7	50.49	0.326	0.238	308.8	229.0	0.31	138.54
8.90	3.7	60.73	0.325	0.236	317.2	229.0	0.46	215.37
9.40	3.1	71.58	0.324	0.235	326.5	229.0	0.69	336.78
9.50	3.0	73.61	0.324	0.235	329.4	229.0	0.75	371.30

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	REAL PRESSURE PSI	FULL PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
11.80	342.5			950.	950.		0.437	349.0	0.0329		
14.30	336.0	.863	.863	.734	1288.	1288.	1.0	0.437	349.0	0.2366	-17.0
19.30	350.3	.750	.750	.616	1448.	1448.	1.6	0.437	391.2	0.2045	-1.9
19.80	352.3	.737	.737	.605	1465.	1465.	1.6	0.437	391.7	0.1966	-2.2
21.50	360.5	.714	.714	.594	1519.	1519.	1.8	0.420	392.6	0.1540	2.6
26.50	378.6	.647	.647	.557	1687.	1687.	2.3	0.368	395.8	0.1306	1.7
31.50	389.7	.576	.576	.514	1877.	1877.	2.7	0.315	398.8	0.1180	0.9
36.50	396.7	.501	.501	.461	2099.	2099.	3.2	0.263	401.7	0.1107	0.1
41.50	401.2	.417	.417	.396	2356.	2356.	3.6	0.211	404.5	0.1061	-1.0
46.50	404.1	.320	.320	.313	2608.	2608.	4.0	0.159	407.4	0.1035	-2.5
47.35	404.5	.302	.302	.297	2642.	2642.	4.0	0.150	407.9	0.1031	-2.9
-----SECONDARY CHANNEL BEGINS-----											
52.35	403.5	.144	.288	.144	2911.	2911.	4.3	0.150	410.6	0.1070	-5.8
57.35	407.6	.035	.085	.035	3183.	3183.	5.0	0.150	413.5	0.1042	11.1
62.35	413.5	.000	.001	.000	3382.	3382.	5.5	0.150	416.4	0.0995	0.8
63.95	415.5	.000	.000	.000	3427.	3427.	5.5	0.150	417.4	0.0980	1.3
-----SECONDARY CHANNEL ENDS-----											

65.06	417.4	.000	.000	.000	3479.	3479.	5.6	0.269	418.2	0.0916	1.6	416.
66.17	418.4	.000	.000	.000	3512.	3512.	5.6	0.387	418.8	0.0992	1.3	416.
71.12	421.8	.000	.000	.000	3628.	3628.	5.7	0.412	421.4	0.0990	1.2	416.
76.07	424.8	.000	.000	.000	3731.	3731.	5.9	0.437	424.2	0.0982	1.1	416.
77.64	425.8	.000	.000	.000	3767.	3767.	5.9	0.338	425.3	0.0912	1.3	416.
79.20	427.3	.000	.000	.000	3817.	3817.	6.0	0.238	426.2	0.0852	1.6	416.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
95.80	427.3	.000	.000	.000	3815.	3815.	6.0	0.213	431.0	0.0852	1.6	416.

100.75	436.2	.000	.000	.000	4025.	4025.	6.2	0.213	438.1	0.0852	1.6	416.

MINIMUM TEMPERATURE= 436.196 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.775
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.054166913 HRS

TORQUE = 7828.4 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.750 HP
 MELTING = 3.017 HP
 MIXING = 1.114 HP
 FLIGHT CLEAR = 1.144 HP
 COMPRESSION = 0.155 HP
 MIXING DEVICE= 0.042 HP
 PRESSURE FLUCTUATION= 134.44 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -58.7 TO -20.5 BTU/MIN OR
 -1.38 TO -0.48 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 6.2 9.3 12.4 15.5 18.6 21.7 24.8

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.900 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.528 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
1022.47	342.5	0.0518853
6.51	349.0	0.2203923

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
12.89	438.5	0.1046373
205.66	329.0	0.1094019

 AT 50.00 RPM & 87.80 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 4025. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

1 - Data Analysis
 2 - Run New Simulation
 3 - EXIT
 :

2MBF20

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 87.80 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	1.822	0.000	2.225	2.250	0.300		
2	27.550	0.150	0.000	1.822	0.000	2.225	2.250	0.300		
3	16.600	0.150	0.450	1.324	1.324	3.450	2.250	0.300		
4	2.225	0.387	0.000	1.822	0.000	2.225	2.250	0.300		
5	9.900	0.437	0.000	1.822	0.000	2.225	2.250	0.300		
6	3.125	0.237	0.000	2.558	0.000	3.125	2.250	0.300		
7	16.600	0.213	0.000	2.800	0.000	3.450	2.250	0.300	1.000	0.914
8	4.950	0.213	0.000	1.822	0.000	2.225	2.250	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.14 PSI
 INCREASE HEIGHT TO = 37.27 IN. MAXIMUM PRESSURE = 0.15 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 69.00 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F		POWER HP	PRESSURE PSI
					BARREL	SCREW		
1.00	17.2	21.10	0.230	0.076	69.0	229.0	0.00	0.45
2.00	16.7	21.39	0.249	0.091	69.0	229.0	0.00	1.45
3.00	15.5	22.28	0.301	0.135	69.2	229.0	0.01	4.79
3.75	13.3	24.32	0.391	0.209	69.6	229.0	0.02	12.21
4.25	11.1	27.26	0.442	0.249	71.3	229.0	0.03	23.65
4.75	6.2	33.33	0.440	0.242	117.3	229.0	0.07	49.31
5.25	5.9	42.31	0.383	0.239	276.7	229.0	0.14	92.19
5.75	4.2	55.55	0.381	0.237	288.8	229.0	0.27	175.22
6.25	3.1	71.57	0.388	0.235	303.6	229.0	0.52	342.83
6.75	2.6	83.41	0.375	0.234	325.7	229.0	1.00	671.39
6.85	2.5	84.73	0.373	0.234	330.0	229.0	1.14	766.92

L IN	TOUT DEG F	X/W SOLID	X/W GRATIC	PRESSURE PSI		POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN MIN	FILM TEMP DEG F	
				REAL	FULL							
9.33	342.5			1386.	1386.		0.437	349.0	0.0836			
11.83	336.0	.863	.863	.734	1704.	1704.	1.4	0.437	349.0	0.2366	-17.0	349.
16.83	346.5	.754	.754	.620	1818.	1818.	2.0	0.437	389.8	0.2087	-1.2	389.
19.03	356.6	.697	.697	.572	1868.	1868.	2.2	0.437	391.2	0.1862	-1.6	391.
19.80	359.1	.677	.677	.556	1867.	1867.	2.3	0.437	391.7	0.1794	-2.1	391.
24.80	377.1	.610	.610	.520	2045.	2045.	2.7	0.385	394.8	0.1330	1.6	394.
29.80	388.3	.541	.541	.477	2223.	2223.	3.2	0.333	397.8	0.1200	0.9	397.
34.80	395.4	.468	.468	.427	2431.	2431.	3.6	0.281	400.7	0.1122	0.1	400.
39.80	400.2	.389	.389	.366	2676.	2676.	4.0	0.229	403.6	0.1073	-0.8	403.
44.80	403.5	.300	.300	.291	2936.	2936.	4.4	0.177	406.4	0.1041	-2.0	406.
47.35	404.9	.250	.250	.247	3048.	3048.	4.5	0.150	408.0	0.1029	-2.8	408.
-----SECONDARY CHANNEL BEGINS-----												
52.35	405.0	.115	.229	.115	3314.	3314.	4.8	0.150	410.6	0.1059	-4.6	410.
57.35	408.6	.020	.047	.020	3584.	3584.	5.5	0.150	413.5	0.1033	-1.9	413.
62.35	415.0	.000	.000	.000	3782.	3782.	5.9	0.150	416.4	0.0984	1.4	415.
63.95	416.7	.000	.000	.000	3828.	3828.	5.9	0.150	417.4	0.0973	1.3	415.
-----SECONDARY CHANNEL ENDS-----												
65.00	416.4	.000	.000	.000	3878.	3878.	6.0	0.269	418.2	0.0911	1.6	415.
66.17	419.3	.000	.000	.000	3912.	3912.	6.0	0.387	418.8	0.0986	1.3	415.
71.12	422.3	.000	.000	.000	4027.	4027.	6.1	0.412	421.4	0.0987	1.2	415.

76.07	425.0	.000	.000	.000	4130.	4130.	6.3	0.437	424.2	0.0980	1.1	415.
77.64	426.0	.000	.000	.000	4166.	4166.	6.3	0.338	425.3	0.0911	1.3	415.
79.20	427.4	.000	.000	.000	4215.	4215.	6.4	0.238	426.2	0.0852	1.6	415.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
95.80	427.4	.000	.000	.000	4214.	4214.	6.4	0.213	431.0	0.0852	1.6	415.

100.75	436.3	.000	.000	.000	4423.	4423.	6.6	0.213	438.1	0.0852	1.6	415.

MINIMUM TEMPERATURE= 436.286 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.776
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.056131452 HRS

TORQUE = 8331.7 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 1.142 HP
 MELTING = 2.950 HP
 MIXING = 1.137 HP
 FLIGHT CLEAR = 1.189 HP
 COMPRESSION = 0.161 HP
 MIXING DEVICE= 0.042 HP
 PRESSURE FLUCTUATION= 134.37 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -41.9 TO -18.2 BTU/MIN OR
 -0.99 TO -0.43 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 6.6 9.9 13.2 16.5 19.8 23.1 26.4

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.900 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.516 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
1043.61	342.5	0.0514072
6.51	349.0	0.2203923

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
12.89	438.6	0.1045863
205.60	329.0	0.1094141

 AT 50.00 RPM & 87.80 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 4423. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

2MBF25

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 87.80 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	1.822	0.000	2.225	2.250	0.300		
2	27.550	0.150	0.000	1.822	0.000	2.225	2.250	0.300		
3	16.600	0.150	0.450	1.324	1.324	3.450	2.250	0.300		
4	2.225	0.387	0.000	1.822	0.000	2.225	2.250	0.300		
5	9.900	0.437	0.000	1.822	0.000	2.225	2.250	0.300		
6	3.125	0.237	0.000	2.558	0.000	3.125	2.250	0.300		
7	16.600	0.213	0.000	2.800	0.000	3.450	2.250	0.300	1.000	0.914
8	4.950	0.213	0.000	1.822	0.000	2.225	2.250	0.300		

HOPPER ANALYSIS

ATTENTION - KEEP SOLIDS LEVEL IN HOPPER ABOVE 24.47 IN.
BASE PRESSURE = 0.10 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
BARREL = 69.00 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F		POWER HP	PRESSURE PSI
					BARREL	SCREW		
1.00	17.1	21.12	0.281	0.077	69.0	229.0	0.00	0.45
2.00	16.5	21.55	0.308	0.100	69.0	229.0	0.00	2.08
2.90	14.3	23.32	0.402	0.177	69.2	229.0	0.01	8.55
3.40	11.8	26.14	0.484	0.244	71.5	229.0	0.02	19.38
3.90	8.4	32.83	0.489	0.243	76.0	229.0	0.06	47.50
4.40	4.9	48.54	0.488	0.238	91.3	229.0	0.16	130.09
4.90	3.0	73.06	0.481	0.235	69.0	229.0	0.45	372.94
5.25	2.6	83.54	0.425	0.234	330.0	229.0	0.85	685.23

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	PRESSURE PSI		POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ. IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F	
				REAL	FULL							
7.73	342.5			1305.	1305.		0.437	349.0	0.0836			
10.23	335.3	.867	.867	.740	1625.	1625.	1.1	0.437	339.0	0.2385	-15.9	340.
15.23	340.7	.746	.746	.617	1745.	1745.	2.0	0.437	377.3	0.2188	-5.8	352.
17.43	350.7	.691	.691	.568	1798.	1798.	2.2	0.437	390.2	0.1955	-1.4	390.
19.80	355.6	.631	.631	.519	1858.	1858.	2.4	0.437	391.9	0.1736	-2.2	391.
24.80	377.4	.565	.565	.481	2015.	2015.	2.9	0.385	394.8	0.1328	1.4	394.
29.80	388.4	.496	.496	.438	2193.	2193.	3.3	0.333	397.8	0.1200	0.7	397.
34.80	395.5	.424	.424	.387	2401.	2401.	3.7	0.281	400.7	0.1123	0.0	400.
39.80	400.2	.346	.346	.326	2645.	2645.	4.1	0.229	403.6	0.1073	-0.9	403.
44.80	403.7	.261	.261	.254	2904.	2904.	4.4	0.177	406.4	0.1041	-1.9	406.
47.35	405.2	.214	.214	.212	3015.	3015.	4.6	0.150	408.0	0.1027	-2.6	408.
-----SECONDARY CHANNEL BEGINS-----												
52.35	406.0	.096	.191	.096	3279.	3279.	4.9	0.150	410.7	0.1051	-3.7	410.
57.35	409.8	.010	.024	.010	3548.	3548.	5.7	0.150	413.5	0.1026	2.1	413.
62.35	416.0	.000	.000	.000	3745.	3745.	5.9	0.150	416.4	0.0978	1.4	415.
63.95	417.5	.000	.000	.000	3791.	3791.	6.0	0.150	417.4	0.0968	1.3	415.
-----SECONDARY CHANNEL ENDS-----												
65.06	419.1	.000	.000	.000	3841.	3841.	6.0	0.269	418.2	0.0907	1.6	415.
66.17	419.9	.000	.000	.000	3874.	3874.	6.0	0.387	418.8	0.0983	1.3	415.
71.12	422.6	.000	.000	.000	3990.	3990.	6.2	0.412	421.4	0.0985	1.2	415.
76.07	425.2	.000	.000	.000	4092.	4092.	6.3	0.437	424.2	0.0979	1.1	415.
77.64	426.2	.000	.000	.000	4128.	4128.	6.4	0.338	425.3	0.0910	1.3	415.
79.20	427.5	.000	.000	.000	4178.	4178.	6.4	0.238	426.2	0.0851	1.6	415.

FLUTED SECTION WITH 1. PAIRS OF FLUTES
 95.80 427.5 .000 .000 .000 4177. 4177. 6.5 0.213 431.0 0.0851 1.6 415.

 100.75 436.3 .000 .000 .000 4386. 4386. 6.7 0.213 438.1 0.0852 1.6 415.

MINIMUM TEMPERATURE= 436.345 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.776
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.057620168 HRS

TORQUE = 8388.6 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.846 HP
 MELTING = 3.217 HP
 MIXING = 1.161 HP
 FLIGHT CLEAR = 1.233 HP
 COMPRESSION = 0.167 HP
 MIXING DEVICE= 0.042 HP
 PRESSURE FLUCTUATION= 134.32 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -40.0 TO -1.5 BTU/MIN OR
 -0.94 TO -0.03 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 6.7 10.0 13.3 16.6 20.0 23.3 26.6

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.900 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.514 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE 1/SEC	TEMP. DEG.F	VISCOSITY LB.SEC/SQ.IN
1041.87	342.5	0.0514462
6.04	339.0	0.2424222

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE 1/SEC	TEMP. DEG.F	VISCOSITY LB.SEC/SQ.IN
12.89	438.6	0.1045531
9.11	326.7	0.2533081

 AT 50.00 RPM & 87.80 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 4386. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

JMBF05

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 75.60 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
2	27.550	0.150	0.000	1.584	0.000	1.975	2.000	0.300		
3	16.600	0.150	0.450	1.286	1.286	3.450	2.000	0.300		
4	1.975	0.387	0.000	1.584	0.000	1.975	2.000	0.300		
5	9.900	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
6	3.125	0.237	0.000	2.498	0.000	3.125	2.000	0.300		
7	16.600	0.213	0.000	2.724	0.000	3.450	2.000	0.300	1.000	0.914
8	4.950	0.213	0.000	1.584	0.000	1.975	2.000	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 73.00 DEG.F AND SCREW = 231.50 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
FRIS=	0.757367E-01		FRIB=	0.748980E-01				
1.00	22.7	21.10	0.075	0.076	73.7	231.5	0.00	0.34
2.00	22.7	21.10	0.075	0.076	73.8	231.5	0.00	0.34
3.00	22.7	21.10	0.075	0.076	73.8	231.5	0.00	0.34
4.00	22.7	21.10	0.075	0.076	74.3	231.5	0.00	0.34
5.00	22.7	21.10	0.072	0.076	77.6	231.5	0.00	0.35
6.00	22.7	21.10	0.039	0.076	70.0	231.5	0.00	0.28
7.00	22.7	21.07	0.035	0.074	70.0	231.5	0.00	0.22
8.00	22.7	21.07	0.033	0.074	70.0	231.5	0.00	0.17
9.00	22.8	21.04	0.029	0.073	70.0	231.5	0.00	0.13
10.00	22.8	21.04	0.027	0.073	70.0	231.5	0.00	0.09
11.00	22.8	21.04	0.026	0.073	70.0	231.5	0.00	0.07
12.00	22.8	21.04	0.025	0.073	70.0	231.5	0.00	0.05
12.10	22.8	21.04	0.025	0.073	330.0	231.5	0.00	0.05

ATTENTION - SOLIDS CONVEYING CONTROLS OPERATION REQUESTED OUTPUT IS UNATTAINABLE

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB./SQ.IN	D.HEAT BTU/IN	FILM TEMP DEG F
14.63	356.0			0.	460.	0.437	368.7	0.0815		
16.63	356.9	.875	.875	.711	0.	636.	0.08	0.437	389.8	0.2108
19.80	361.5	.787	.787	.639	0.	721.	0.31	0.437	392.0	0.2026
23.03	370.2	.743	.743	.620	0.	808.	0.54	0.404	393.7	0.1517
28.03	383.0	.675	.675	.588	0.	952.	0.89	0.352	396.7	0.1343
33.03	390.9	.603	.603	.546	0.	1119.	1.2	0.299	399.6	0.1241
38.03	396.2	.527	.527	.495	0.	1313.	1.6	0.247	402.5	0.1176
43.03	399.7	.441	.441	.430	0.	1520.	1.9	0.195	405.4	0.1134
47.35	401.4	.355	.355	.355	0.	1661.	2.1	0.150	408.0	0.1112
-----SECONDARY CHANNEL BEGINS-----										
52.35	397.1	.159	.311	.159	0.	1856.	2.3	0.150	410.5	0.1172
57.35	404.2	.043	.105	.043	0.	2077.	2.8	0.150	413.4	0.1116
FILM THICKNESS IS 0 - TBAP= 0.4157E+03										
FILM THICKNESS IS 0 - TBAR= 0.4157E+03										

62.35	411.3	.000	.001	.000	0.2240	3.2	0.150	416.3	0.1056	-0.4	416.
63.95	413.6	.000	.000	.000	0.2277	3.3	0.150	417.4	0.1041	1.0	416.
-----SECONDARY CHANNEL ENDS-----											
64.94	415.2	.000	.000	.000	0.2314	3.3	0.269	418.1	0.0974	1.2	416.
65.92	416.3	.000	.000	.000	0.2339	3.3	0.387	418.6	0.1072	0.9	416.
70.87	420.0	.000	.000	.000	0.2437	3.4	0.412	421.2	0.1071	0.9	416.
75.82	423.1	.000	.000	.000	0.2524	3.5	0.437	424.0	0.1062	0.8	416.
77.39	424.2	.000	.000	.000	0.2554	3.5	0.338	425.1	0.0971	0.9	416.
78.95	425.7	.000	.000	.000	0.2595	3.6	0.238	426.0	0.0897	1.1	416.

FLUTED SECTION WITH 1. PAIRS OF FLUTES											
95.55	425.7	.000	.000	.000	0.2594	3.6	0.213	430.8	0.0897	1.1	416.

100.50	434.6	.000	.000	.000	0.2763	3.7	0.213	438.0	0.0908	1.1	416.

MINIMUM TEMPERATURE= 434.567 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.790
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.050763860 HRS

TORQUE = 4725.6 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.001 HP
 MELTING = 2.050 HP
 MIXING = 0.719 HP
 FLIGHT CLEAR = 0.858 HP
 COMPRESSION = 0.101 HP
 MIXING DEVICE= 0.028 HP
 PRESSURE FLUCTUATION= 100.09 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -117.3 TO -60.8 BTU/MIN OR
 -2.76 TO -1.43 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 3.7 5.6 7.5 9.4 11.2 13.1 15.0

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.700 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.494 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
659.91	372.4	0.0516510
3.22	389.8	0.1719828

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
32.84	438.0	0.0887321
180.47	329.0	0.1145837

SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

:

JMBF10

EXPERIMENT NUMBER 1.01 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 75.60 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH (IN)		WIDTH (IN)		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID	MELT	SOLID	MELT					
1	19.800	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
2	27.550	0.150	0.000	1.584	0.000	1.975	2.000	0.300		
3	16.600	0.150	0.450	1.286	1.286	3.450	2.000	0.300		
4	1.975	0.387	0.000	1.584	0.000	1.975	2.000	0.300		
5	9.900	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
6	3.125	0.237	0.000	2.498	0.000	3.125	2.000	0.300		
7	16.600	0.213	0.000	2.724	0.000	3.450	2.000	0.300	1.000	0.914
8	4.950	0.213	0.000	1.584	0.000	1.975	2.000	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.29 PSI
 INCREASE HEIGHT TO = 124.00 IN. MAXIMUM PRESSURE = 0.50 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 101.50 DEG.F AND SCREW = 114.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
FRICION COEFFICIENT ON BARREL SURFACE MUST BE HIGHER THAN ON SCREW SURFACE								
FRIS=	0.119470E+00		FRIB=	0.119404E+00				
1.00	22.7	21.08	0.118	0.119	108.5	114.0	0.00	0.29
2.00	22.7	21.08	0.117	0.119	111.0	114.0	0.00	0.28
3.00	22.7	21.08	0.116	0.119	111.7	114.0	0.00	0.27
4.00	22.7	21.08	0.116	0.119	112.2	114.0	0.00	0.26
5.00	22.7	21.08	0.118	0.119	95.5	114.0	0.00	0.25
6.00	22.7	21.08	0.084	0.119	70.0	114.0	0.00	0.20
6.67	22.8	21.06	0.081	0.118	70.0	114.0	0.00	0.18
6.92	22.8	21.06	0.080	0.118	70.0	114.0	0.00	0.17
7.17	22.8	21.06	0.080	0.118	70.0	114.0	0.00	0.16
7.42	22.8	21.06	0.079	0.118	70.0	114.0	0.00	0.15
7.68	22.8	21.06	0.079	0.118	70.0	114.0	0.00	0.14
7.93	22.8	21.06	0.078	0.118	70.0	114.0	0.00	0.13
8.17	22.8	21.06	0.078	0.118	70.0	114.0	0.00	0.12
8.42	22.8	21.06	0.077	0.118	70.0	114.0	0.00	0.11
8.67	22.8	21.06	0.077	0.118	70.0	114.0	0.00	0.10
8.92	22.8	21.06	0.077	0.118	70.0	114.0	0.00	0.10
9.17	22.8	21.06	0.076	0.118	70.0	114.0	0.00	0.09
9.42	22.8	21.03	0.074	0.116	70.0	114.0	0.00	0.08
9.67	22.8	21.03	0.074	0.116	70.0	114.0	0.00	0.08
9.75	22.8	21.03	0.074	0.116	329.3	114.0	0.00	0.08

ATTENTION - SOLIDS CONVEYING CONTROLS OPERATION
 REQUESTED OUTPUT IS UNATTAINABLE

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
12.00	342.5			0. 410.		0.437	349.0	0.0838		
14.50	335.6	.864	.864	.728	0. 752.	0.18	0.437	349.0	0.2544	-18.9 349.
19.50	348.4	.752	.752	.611	0. 887.	0.61	0.437	391.3	0.2242	-2.0 391.
19.80	349.6	.744	.744	.604	0. 895.	0.63	0.437	391.7	0.2171	-2.4 391.
20.90	354.8	.729	.729	.597	0. 925.	0.71	0.426	392.2	0.1744	1.8 392.

25.90	373.6	.659	.659	.564	0.1067.	1.1	0.374	395.3	0.1460	1.1	395.
30.90	385.5	.588	.588	.524	0.1226.	1.4	0.322	398.3	0.1303	0.5	398.
35.90	393.0	.514	.514	.476	0.1410.	1.7	0.269	401.3	0.1212	-0.1	401.
40.90	397.8	.433	.433	.416	0.1614.	2.0	0.217	404.1	0.1155	-1.0	404.
45.90	400.8	.339	.339	.338	0.1804.	2.3	0.165	407.0	0.1121	-2.4	406.
47.35	401.0	.307	.307	.307	0.1839.	2.4	0.150	407.9	0.1116	-3.9	408.
-----SECONDARY CHANNEL BEGINS-----											
52.35	399.0	.127	.248	.127	0.2032.	2.7	0.150	410.5	0.1160	-3.5	410.
57.35	405.7	.028	.068	.028	0.2251.	3.1	0.150	413.4	0.1104	0.5	413.
FILM THICKNESS IS 0 - TBAR= 0.4152E+03											
FILM THICKNESS IS 0 - TBAR= 0.4152E+03											
62.35	412.8	.000	.000	.000	0.2414.	3.5	0.150	416.3	0.1046	1.0	415.
63.95	414.7	.000	.000	.000	0.2450.	3.5	0.150	417.4	0.1033	1.0	415.
-----SECONDARY CHANNEL ENDS-----											
64.94	416.3	.000	.000	.000	0.2488.	3.5	0.269	418.1	0.0968	1.2	415.
65.92	417.2	.000	.000	.000	0.2512.	3.6	0.387	418.6	0.1065	0.9	415.
70.87	420.4	.000	.000	.000	0.2610.	3.7	0.412	421.2	0.1068	0.9	415.
75.82	423.3	.000	.000	.000	0.2697.	3.8	0.437	424.0	0.1060	0.8	415.
77.39	424.4	.000	.000	.000	0.2727.	3.8	0.338	425.1	0.0969	0.9	415.
78.95	425.8	.000	.000	.000	0.2768.	3.8	0.238	426.0	0.0896	1.1	415.

FLUTED SECTION WITH 1. PAIRS OF FLUTES											
95.55	425.8	.000	.000	.000	0.2767.	3.9	0.213	430.8	0.0896	1.1	415.

100.50	434.7	.000	.000	.000	0.2936.	4.0	0.213	438.0	0.0908	1.1	415.

MINIMUM TEMPERATURE= 434.652 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.790
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.053197451 HRS

TORQUE = 5054.3 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.001 HP
 MELTING = 2.236 HP
 MIXING = 0.748 HP
 FLIGHT CLEAR = 0.899 HP
 COMPRESSION = 0.106 HP
 MIXING DEVICE= 0.028 HP
 PRESSURE FLUCTUATION= 100.05 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -106.3 TO -43.5 BTU/MIN OR
 -2.50 TO -1.02 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 4.0 6.0 8.0 10.0 12.0 14.0 16.0

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.700 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.482 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
843.97	339.0	0.0578758
3.72	349.0	0.2361072

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
32.85	438.0	0.0887296
334.90	329.0	0.0912090

SELECT ONE OF THE FOLLOWING:

1 - Data Analysis
 2 - Run New Simulation
 3 - EXIT
 :

3MBF15

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 75.60 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH SOLID (IN)	MELT (IN)	WIDTH SOLID (IN)	MELT (IN)	LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
1	19.800	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
2	27.550	0.150	0.000	1.584	0.000	1.975	2.000	0.300		
3	16.600	0.150	0.450	1.286	1.286	3.450	2.000	0.300		
4	1.975	0.387	0.000	1.584	0.000	1.975	2.000	0.300		
5	9.900	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
6	3.125	0.237	0.000	2.498	0.000	3.125	2.000	0.300		
7	16.600	0.213	0.000	2.724	0.000	3.450	2.000	0.300	1.000	0.914
8	4.950	0.213	0.000	1.584	0.000	1.975	2.000	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.21 PSI
 INCREASE HEIGHT TO = 64.55 IN. MAXIMUM PRESSURE = 0.26 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 70.50 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	SCREW	POWER HP	PRESSURE PSI
1.00	22.6	21.12	0.176	0.077	70.5	229.0	0.00	0.43
2.00	22.4	21.22	0.183	0.083	70.8	229.0	0.00	0.86
3.00	21.8	21.49	0.195	0.097	70.6	229.0	0.00	1.75
4.00	20.8	22.00	0.230	0.122	71.0	229.0	0.00	3.65
5.00	16.8	23.13	0.281	0.171	76.5	229.0	0.01	7.81
6.00	16.9	24.50	0.288	0.215	70.0	229.0	0.02	12.81
7.00	14.6	26.58	0.322	0.248	70.0	229.0	0.04	20.80
7.50	13.1	28.24	0.319	0.245	70.0	229.0	0.06	27.04
8.00	11.6	30.51	0.318	0.244	70.0	229.0	0.08	36.24
8.50	9.9	33.81	0.319	0.242	70.0	229.0	0.10	50.34
9.00	8.1	38.57	0.318	0.241	70.0	229.0	0.14	72.33
9.50	6.5	45.34	0.315	0.239	70.0	229.0	0.20	107.62
10.00	5.1	54.42	0.318	0.237	70.0	229.0	0.29	165.13
10.50	4.1	65.26	0.318	0.236	70.0	229.0	0.42	259.49
10.65	3.8	68.59	0.318	0.235	330.0	229.0	0.48	298.05

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F		
				REAL	FULL							
13.03	342.5			874.	874.	0.437	349.0	0.0838				
15.03	337.1	.862	.862	.726	1110.	1110.	0.6	0.437	353.4	0.2491	-19.4	353.
19.80	346.9	.754	.754	.612	1241.	1241.	1.0	0.437	391.5	0.2223	-2.1	391.
21.43	356.6	.731	.731	.602	1285.	1285.	1.2	0.421	392.5	0.1713	1.8	392.
26.43	374.6	.662	.662	.568	1429.	1429.	1.5	0.368	395.6	0.1443	1.1	395.
31.43	386.3	.591	.591	.528	1591.	1591.	1.9	0.316	398.7	0.1293	0.5	398.
36.43	393.6	.516	.516	.479	1777.	1777.	2.2	0.264	401.6	0.1205	-0.2	401.
41.43	398.2	.434	.434	.418	1983.	1983.	2.5	0.212	404.4	0.1151	-1.1	404.
46.43	401.0	.338	.338	.338	2167.	2167.	2.8	0.160	407.3	0.1119	-2.6	407.
47.35	401.1	.317	.317	.317	2188.	2188.	2.8	0.150	407.8	0.1116	-3.6	407.
-----SECONDARY CHANNEL BEGINS-----												
52.35	398.8	.134	.262	.134	2381.	2381.	3.1	0.150	410.5	0.1162	-3.7	410.
57.35	405.4	.031	.075	.031	2600.	2600.	3.6	0.150	413.4	0.1106	0.4	413.
FILM THICKNESS IS 0 - TBAR= 0.4152E+03												
FILM THICKNESS IS 0 - TBAR= 0.4152E+03												

62.35	412.4	.000	.000	.000	2763.	2763.	3.9	0.150	416.3	0.1049	1.0	416.
63.95	414.4	.000	.000	.000	2800.	2800.	3.9	0.150	417.4	0.1035	1.0	416.
-----SECONDARY CHANNEL ENDS-----												
64.94	416.0	.000	.000	.000	2837.	2837.	4.0	0.269	418.1	0.0969	1.2	416.
65.92	416.9	.000	.000	.000	2862.	2862.	4.0	0.387	418.6	0.1067	0.9	416.
70.87	420.3	.000	.000	.000	2960.	2960.	4.1	0.412	421.2	0.1069	0.9	416.
75.82	423.3	.000	.000	.000	3047.	3047.	4.2	0.437	424.0	0.1060	0.8	416.
77.39	424.3	.000	.000	.000	3076.	3076.	4.2	0.338	425.1	0.0970	0.9	416.
78.95	425.8	.000	.000	.000	3117.	3117.	4.3	0.238	426.0	0.0897	1.1	416.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
95.55	425.8	.000	.000	.000	3116.	3116.	4.3	0.213	430.8	0.0897	1.1	416.

100.50	434.6	.000	.000	.000	3285.	3285.	4.4	0.213	438.0	0.0908	1.1	416.

MINIMUM TEMPERATURE= 434.629 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.790
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.052846901 HRS

TORQUE = 5600.6 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.477 HP
 MELTING = 2.206 HP
 MIXING = 0.745 HP
 FLIGHT CLEAR = 0.890 HP
 COMPRESSION = 0.105 HP
 MIXING DEVICE= 0.028 HP
 PRESSURE FLUCTUATION= 100.06 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -87.9 TO -46.9 BTU/MIN OR
 -2.07 TO -1.11 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 4.4 6.7 8.9 11.1 13.3 15.6 17.8

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.700 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.465 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
1056.67	342.5	0.0511142
3.80	353.4	0.2269123

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
32.85	438.0	0.0887302
180.38	329.0	0.1146036

AT 50.00 RPM & 75.60 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 3285. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

JMBF20

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 75.60 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH SOLID (IN)	CH.DEPTH MELT (IN)	WIDTH SOLID (IN)	WIDTH MELT (IN)	LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
1	19.800	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
2	27.550	0.150	0.000	1.584	0.000	1.975	2.000	0.300		
3	16.600	0.150	0.450	1.286	1.286	3.450	2.000	0.300		
4	1.975	0.387	0.000	1.584	0.000	1.975	2.000	0.300		
5	9.900	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
6	3.125	0.237	0.000	2.498	0.000	3.125	2.000	0.300		
7	16.600	0.213	0.000	2.724	0.000	3.450	2.000	0.300	1.000	0.914
8	4.950	0.213	0.000	1.584	0.000	1.975	2.000	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.14 PSI
 INCREASE HEIGHT TO = 37.27 IN. MAXIMUM PRESSURE = 0.15 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 70.50 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	22.6	21.11	0.226	0.077	70.5	229.0	0.00	0.40
2.00	22.2	21.31	0.239	0.088	70.9	229.0	0.00	1.15
3.00	21.0	21.91	0.274	0.118	70.8	229.0	0.00	3.35
4.00	18.0	23.71	0.362	0.191	71.8	229.0	0.01	10.16
4.50	15.2	25.92	0.424	0.242	72.2	229.0	0.02	18.32
5.00	12.1	29.61	0.379	0.244	70.0	229.0	0.04	32.90
5.50	9.3	35.07	0.377	0.242	70.0	229.0	0.07	56.58
6.00	6.7	44.41	0.377	0.239	70.0	229.0	0.13	103.61
6.50	4.6	58.73	0.376	0.236	70.0	229.0	0.24	200.45
7.00	3.4	74.88	0.374	0.235	70.0	229.0	0.46	398.65
7.50	3.0	85.04	0.370	0.234	70.0	229.0	0.89	797.53
7.55	2.9	85.59	0.407	0.234	330.0	229.0	0.96	865.86

L IN	TOUT DEG F	X/W SOLID	X/W GRATIC SOLID	GRATIC PRESSURE PSI	REAL FULL PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F	
10.00	342.5			1482.	1482.		0.437	349.0	0.0850			
12.00	335.6	.864	.864	.728	1685.	1685.	1.1	0.437	349.0	0.2544	-18.9	349.
17.00	346.9	.756	.756	.614	1753.	1753.	1.6	0.437	389.9	0.2279	-1.6	389.
18.40	352.0	.719	.719	.584	1772.	1772.	1.7	0.437	390.8	0.2121	-1.9	390.
19.80	356.5	.683	.683	.555	1795.	1795.	1.8	0.437	391.8	0.1973	-2.3	391.
24.80	374.2	.613	.613	.520	1929.	1929.	2.1	0.385	394.7	0.1460	1.0	394.
29.80	385.5	.543	.543	.480	2081.	2081.	2.4	0.333	397.7	0.1310	0.4	397.
34.80	392.7	.470	.470	.432	2257.	2257.	2.7	0.281	400.7	0.1220	-0.2	400.
35.80	397.5	.392	.392	.374	2457.	2457.	3.0	0.229	403.5	0.1162	-0.9	403.
44.80	400.4	.300	.300	.298	2654.	2654.	3.3	0.177	406.4	0.1127	-2.4	406.
47.35	400.8	.244	.244	.244	2724.	2724.	3.4	0.150	407.9	0.1119	-4.1	407.
-----SECONDARY CHANNEL BEGINS-----												
52.35	401.0	.087	.170	.087	2913.	2913.	3.8	0.150	410.6	0.1142	-2.8	410.
57.35	407.4	.012	.029	.012	3130.	3130.	4.2	0.150	413.5	0.1090	1.7	413.
FILM THICKNESS IS 0 - TBAR= 0.4146E+03												
FILM THICKNESS IS 0 - TBAR= 0.4146E+03												
62.35	414.1	.000	.000	.000	3291.	3291.	4.4	0.150	416.4	0.1036	1.0	415.
63.95	415.8	.000	.000	.000	3328.	3328.	4.5	0.150	417.4	0.1024	0.9	415.
-----SECONDARY CHANNEL ENDS-----												

64.94	417.2	.000	.000	.000	3365.	3365.	4.5	0.269	418.1	0.0962	1.2	415.
65.92	418.0	.000	.000	.000	3389.	3389.	4.5	0.387	418.7	0.1060	0.9	415.
70.87	420.9	.000	.000	.000	3487.	3487.	4.6	0.412	421.2	0.1065	0.9	415.
75.82	423.6	.000	.000	.000	3573.	3573.	4.7	0.437	424.0	0.1058	0.8	415.
77.39	424.6	.000	.000	.000	3603.	3603.	4.8	0.338	425.1	0.0968	0.9	415.
78.95	426.0	.000	.000	.000	3644.	3644.	4.8	0.238	426.0	0.0896	1.1	415.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
95.55	426.0	.000	.000	.000	3643.	3643.	4.8	0.213	430.8	0.0896	1.1	415.

100.50	434.7	.000	.000	.000	3812.	3812.	5.0	0.213	438.0	0.0907	1.1	415.

MINIMUM TEMPERATURE= 434.728 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.790
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.055078730 HRS

TORQUE = 6258.4 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.961 HP
 MELTING = 2.178 HP
 MIXING = 0.763 HP
 FLIGHT CLEAR = 0.935 HP
 COMPRESSION = 0.109 HP
 MIXING DEVICE= 0.028 HP
 PRESSURE FLUCTUATION= 100.02 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -65.8 TO -43.1 BTU/MIN OR
 -1.55 TO -1.01 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 5.0 7.4 9.9 12.4 14.9 17.4 19.9

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.620 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.445 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
965.09	342.5	0.0531525
3.72	349.0	0.2361072

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
32.85	436.0	0.0887272
349.48	329.0	0.0897076

AT 50.00 RPM & 75.60 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 3812. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

:

3MBF25

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 75.60 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
2	27.550	0.150	0.000	1.584	0.000	1.975	2.000	0.300		
3	16.600	0.150	0.450	1.286	1.286	3.450	2.000	0.300		
4	1.975	0.387	0.000	1.584	0.000	1.975	2.000	0.300		
5	9.900	0.437	0.000	1.584	0.000	1.975	2.000	0.300		
6	3.125	0.237	0.000	2.498	0.000	3.125	2.000	0.300		
7	16.600	0.213	0.000	2.724	0.000	3.450	2.000	0.300	1.000	0.914
8	4.950	0.213	0.000	1.584	0.000	1.975	2.000	0.300		

HOPPER ANALYSIS

ATTENTION - KEEP SOLIDS LEVEL IN HOPPER ABOVE 24.47 IN.
 BASE PRESSURE = 0.10 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 70.50 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	22.7	21.09	0.275	0.076	70.5	229.0	0.00	0.40
2.00	21.9	21.43	0.296	0.094	71.0	229.0	0.00	1.60
3.00	19.4	22.76	0.370	0.156	71.0	229.0	0.01	6.64
3.55	16.7	25.03	0.456	0.227	72.3	229.0	0.01	15.01
4.05	12.1	29.71	0.482	0.244	74.8	229.0	0.04	33.91
4.55	7.4	41.32	0.484	0.240	83.0	229.0	0.09	88.68
5.05	4.3	62.57	0.429	0.236	282.9	229.0	0.23	237.26
5.55	3.1	81.55	0.423	0.234	308.5	229.0	0.56	586.24
5.85	2.9	86.37	0.429	0.234	330.0	229.0	0.95	1008.03

L IN	TOUT DEG F	X/W	X/W SOLID	GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC	D.HEAT BTU/IN	FILM TEMP DEG F
					REAL FULL			/SQ.IN		.MIN	
8.38	342.5				1623. 1623.		0.437	349.0	0.0850		
10.38	335.0	.869	.869	.734	1831. 1831.	1.2	0.437	339.0	0.2562	-17.8	339.
15.38	339.2	.786	.786	.643	1852. 1852.	1.7	0.437	380.9	0.2477	-0.6	356.
19.78	356.3	.671	.671	.545	1871. 1871.	2.0	0.437	391.6	0.1987	-2.1	391.
19.80	356.3	.670	.670	.545	1871. 1871.	2.0	0.437	391.9	0.1951	-7.0	392.
24.80	374.2	.601	.601	.510	2005. 2005.	2.3	0.385	394.7	0.1461	0.9	394.
29.80	385.5	.531	.531	.469	2157. 2157.	2.7	0.333	397.7	0.1310	0.4	397.
34.80	392.7	.458	.458	.421	2333. 2333.	3.0	0.281	400.7	0.1220	-0.2	400.
39.80	397.5	.381	.381	.363	2533. 2533.	3.2	0.229	403.5	0.1162	-1.0	403.
44.80	400.3	.288	.288	.286	2729. 2729.	3.5	0.177	406.4	0.1128	-2.5	406.
47.35	400.8	.231	.231	.231	2799. 2799.	3.6	0.150	407.9	0.1120	-4.2	407.
-----SECONDARY CHANNEL BEGINS-----											
52.35	401.9	.079	.155	.079	2987. 2987.	4.0	0.150	410.6	0.1134	-2.6	410.
57.35	408.1	.009	.022	.009	3203. 3203.	4.5	0.150	413.5	0.1085	1.9	413.
FILM THICKNESS IS 0 - TBAR= 0.4141E+03											
FILM THICKNESS IS 0 - TBAP= 0.4141E+03											
TBAR WAS CHANGED AT AXIAL LOC= 58.35 IN. TO TBAR= 434.0 F											
IN ORDER TO CONVERGE.											
62.35	414.6	.000	.000	.000	3364. 3364.	4.7	0.150	416.4	0.1032	1.0	434.
63.95	416.2	.000	.000	.000	3401. 3401.	4.7	0.150	417.4	0.1022	0.9	434.
-----SECONDARY CHANNEL ENDS-----											

64.94	417.5	.000	.000	.000	3437.	3437.	4.8	0.269	418.1	0.0960	1.2	434.
65.92	418.3	.000	.000	.000	3462.	3462.	4.8	0.387	418.7	0.1058	0.9	434.
70.87	421.0	.000	.000	.000	3559.	3559.	4.9	0.412	421.2	0.1064	0.9	434.
75.82	423.7	.000	.000	.000	3646.	3646.	5.0	0.437	424.0	0.1058	0.8	434.
77.39	424.6	.000	.000	.000	3676.	3676.	5.0	0.338	425.1	0.0968	0.9	434.
78.95	426.0	.000	.000	.000	3716.	3716.	5.1	0.238	426.0	0.0895	1.1	434.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
95.55	426.0	.000	.000	.000	3715.	3715.	5.1	0.213	430.8	0.0895	1.1	434.

100.50	434.8	.000	.000	.000	3884.	3884.	5.2	0.213	438.0	0.0907	1.1	434.

MINIMUM TEMPERATURE= 434.755 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.790
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.056170948 HRS

TORQUE = 6600.2 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.951 HP
 MELTING = 2.421 HP
 MIXING = 0.767 HP
 FLIGHT CLEAR = 0.969 HP
 COMPRESSION = 0.108 HP
 MIXING DEVICE= 0.028 HP
 PRESSURE FLUCTUATION= 100.01 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -54.3 TO -30.0 BTU/MIN OR
 -1.28 TO -0.71 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 5.2 7.9 10.5 13.1 15.7 18.3 20.9

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

!!!CAUTION!!!
 MAXIMUM PERMISSIBLE CHANNEL DEPTH FOR SAFE SCREW IS: 0.435 INCHES
 YOUR FEED SECTION IS 0.437 INCHES DEEP
 CHECK RESIN VISCOSITY, SOURCE OF POWER CONSUMPTION
 OR MODIFY SCREW GEOMETRY!

MAXIMUM PERMITTED COOLING HOLE DIAMETER IS 0.524 INCHES
 MAXIMUM PERMITTED CHANNEL DEPTH WITHOUT CORING SCREW IS 0.435 INCHES

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
970.38	342.5	0.0531209
3.50	339.0	0.2590871

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
32.85	438.0	0.0887264
742.73	319.0	0.0706424

AT 50.00 RPM & 75.60 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 3884. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

4MBF05

EXPERIMENT NUMBER 1.01 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 63.50 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
2	27.550	0.150	0.000	1.368	0.000	1.750	1.750	0.300		
3	16.600	0.150	0.450	1.234	1.234	3.450	1.750	0.300		
4	1.750	0.387	0.000	1.368	0.000	1.750	1.750	0.300		
5	9.900	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
6	3.125	0.237	0.000	2.417	0.000	3.125	1.750	0.300		
7	16.600	0.213	0.000	2.622	0.000	3.450	1.750	0.300	1.000	0.914
8	4.950	0.213	0.000	1.368	0.000	1.750	1.750	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.33 PSI
 INCREASE HEIGHT TO = 186.01 IN. MAXIMUM PRESSURE = 0.75 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:

BARREL = 74.50 DEG.F AND SCREW = 231.50 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
FRICION COEFFICIENT ON BARREL SURFACE MUST BE HIGHER THAN ON SCREW SURFACE								
FRIS= 0.762736E-01			FRIB= 0.701721E-01					
1.00	32.8	21.10	0.070	0.076	75.5	231.5	0.00	0.30
2.00	32.5	21.10	0.070	0.076	75.6	231.5	0.00	0.27
3.00	32.2	21.10	0.070	0.076	75.9	231.5	0.00	0.25
4.00	32.2	21.07	0.069	0.074	76.3	231.5	0.00	0.23
5.00	32.1	21.07	0.066	0.074	78.3	231.5	0.00	0.21
6.00	32.1	21.07	0.033	0.074	70.0	231.5	0.00	0.16
7.00	32.2	21.04	0.029	0.073	70.0	231.5	0.00	0.12
8.00	32.2	21.04	0.027	0.073	70.0	231.5	0.00	0.09
9.00	32.2	21.04	0.025	0.073	70.0	231.5	0.00	0.06
10.00	32.2	21.04	0.023	0.073	70.0	231.5	0.00	0.05
11.00	32.2	21.04	0.022	0.073	70.0	231.5	0.00	0.03
11.70	32.3	21.01	0.022	0.071	330.0	231.5	0.00	0.03

ATTENTION - SOLIDS CONVEYING CONTROLS OPERATION
 REQUESTED OUTPUT IS UNATTAINABLE

L IN	TOUT DEG F	X/W SOLID	X/W SOLID	GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
14.28	349.9				REAL	0.427	0.437	359.9	0.0855		
16.28	370.9				FULL	0.703	0.437	390.1	0.0923		
17.28	350.2	.929	.929	.787	0.706	0.05	0.437	390.1	0.2329	-23.3	390.
19.80	354.2	.858	.858	.726	0.714	0.18	0.437	391.7	0.2396	-2.5	390.
23.88	367.7	.801	.801	.707	0.726	0.39	0.395	394.1	0.1665	1.2	393.
26.88	381.6	.732	.732	.681	0.845	0.64	0.343	397.1	0.1450	0.8	397.
33.88	390.7	.664	.664	.648	0.982	0.88	0.291	400.1	0.1324	0.4	400.
38.88	394.8	.594	.594	.594	0.1133	1.1	0.238	403.0	0.1259	-1.2	402.
43.88	396.9	.516	.516	.516	0.1283	1.3	0.186	405.8	0.1225	-1.9	405.
47.35	396.3	.452	.452	.452	0.1341	1.5	0.150	407.9	0.1204	-2.7	407.
-----SECONDARY CHANNEL BEGINS-----											
52.35	392.8	.224	.431	.224	0.1470	1.6	0.150	410.4	0.1274	-7.8	410.
57.35	400.0	.082	.197	.082	0.1643	1.9	0.150	413.3	0.1211	-1.3	413.
62.35	408.2	.018	.057	.018	0.1771	2.3	0.150	416.3	0.1139	1.3	416.

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      FILM THICKNESS IS 0 - TBAR= 0.4168E+03
      FILM THICKNESS IS 0 - TBAR= 0.4168E+03
63.95 410.5 .005 .019 .005 0. 1800. 2.6 0.150 417.3 0.1124 11.4 417.
-----SECONDARY CHANNEL ENDS-----
64.83 411.9 .004 .004 .004 0. 1827. 2.6 0.269 417.9 0.1050 3.2 418.
65.70 413.0 .003 .003 .003 0. 1844. 2.7 0.387 418.4 0.1172 2.9 418.
      FILM THICKNESS IS 0 - TBAR= 0.4188E+03
      FILM THICKNESS IS 0 - TBAR= 0.4188E+03
70.65 417.6 .000 .000 .000 0. 1922. 2.8 0.412 421.1 0.1169 0.6 419.
75.60 421.3 .000 .000 .000 0. 1991. 2.8 0.437 423.9 0.1155 0.6 419.
77.16 422.6 .000 .000 .000 0. 2015. 2.9 0.338 425.0 0.1039 0.6 419.
78.72 424.1 .000 .000 .000 0. 2047. 2.9 0.238 425.9 0.0952 0.8 419.
-----
      FLUTED SECTION WITH 1. PAIRS OF FLUTES
95.32 424.1 .000 .000 .000 0. 2046. 2.9 0.213 430.6 0.0952 0.8 419.
-----
100.27 433.2 .000 .000 .000 0. 2178. 3.0 0.213 437.8 0.0967 0.8 419.

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MINIMUM TEMPERATURE= 433.194 DEG F
TEMP FLUCTUATION= 0.000 DEG F
FLOW INDEX (N)= 0.806
GRATIO INJ.= 0.000
RESIDENCE TIME:
MELT POOL= 0.049503591 HRS

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TORQUE = 3790.5 INCH.POUNDS
POWER BREAK-DOWN:
SOLIDS CONV. = 0.000 HP
MELTING = 1.858 HP
MIXING = 0.444 HP
FLIGHT CLEAR = 0.638 HP
COMPRESSION = 0.056 HP
MIXING DEVICE= 0.017 HP
PRESSURE FLUCTUATION= 73.69 PSI/CYCLE
TOTAL CONDUCTED HEAT THROUGH BARREL= -103.7 TO -67.4 BTU/MIN OR
-2.44 TO -1.59 HP

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MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
POWER CONSUMPTION, % OF AVAILABLE: 3.0 4.5 6.0 7.5 9.0 10.5 12.0

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STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

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!!!CAUTION!!!
MAXIMUM PERMISSIBLE CHANNEL DEPTH FOR SAFE SCREW IS: 0.404 INCHES
YOUR FEED SECTION IS 0.437 INCHES DEEP
CHECK RESIN VISCOSITY, SOURCE OF POWER CONSUMPTION
OR MODIFY SCREW GEOMETRY!
POWER CONSUMPTION EXCEEDS PRUDENT STRENGTH OF SCREW BY 12.95 %

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VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE
SHEAR RATE      TEMP.      VISCOSITY
1/SEC           DEG.F      LB.SEC/SQ.IN
572.39         373.9      0.0542351
0.82          390.1      0.1814330

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VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE
SHEAR RATE      TEMP.      VISCOSITY
1/SEC           DEG.F      LB.SEC/SQ.IN
25.01          437.8      0.0937841
286.19         329.0      0.0968691
SELECT ONE OF THE FOLLOWING:

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1 - Data Analysis
2 - Run New Simulation
3 - EXIT
:

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4MBF10

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 61.50 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH (IN)	SOLID MELT (IN)	WIDTH (IN)	SOLID MELT (IN)	LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQ1!!)
1	19.800	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
2	27.550	0.150	0.000	1.368	0.000	1.750	1.750	0.300		
3	16.600	0.150	0.450	1.234	1.234	3.450	1.750	0.300		
4	1.750	0.387	0.000	1.368	0.000	1.750	1.750	0.300		
5	9.900	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
6	3.125	0.237	0.000	2.417	0.000	3.125	1.750	0.300		
7	16.600	0.213	0.000	2.622	0.000	3.450	1.750	0.300	1.000	0.914
8	4.950	0.213	0.000	1.368	0.000	1.750	1.750	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.29 PSI
 INCREASE HEIGHT TO = 124.00 IN. MAXIMUM PRESSURE = 0.50 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 116.50 DEG.F AND SCREW = 135.50 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F	POWER HP	PRESSURE PSI
FRICITION COEFFICIENT ON BARREL SURFACE MUST BE HIGHER THAN ON SCREW SURFACE							
FRIS=	0.110451E+00	FRIB=	0.110404E+00				
1.00	32.9	21.08	0.107	0.110	126.7	135.5	0.00
2.00	32.5	21.08	0.105	0.110	130.2	135.5	0.00
3.00	32.2	21.08	0.104	0.110	131.5	135.5	0.00
4.00	32.2	21.06	0.102	0.108	132.2	135.5	0.00
5.00	32.2	21.06	0.111	0.108	105.1	135.5	0.00
6.00	32.2	21.06	0.076	0.108	70.0	135.5	0.00
7.00	32.3	21.03	0.073	0.107	70.0	135.5	0.00
7.50	32.3	21.03	0.070	0.107	70.0	135.5	0.00
7.69	32.3	21.03	0.071	0.107	70.0	135.5	0.00
7.92	32.3	21.03	0.071	0.107	70.0	135.5	0.00
8.17	32.3	21.03	0.071	0.107	70.0	135.5	0.00
8.35	32.3	21.03	0.071	0.107	330.0	135.5	0.00

ATTENTION - SOLIDS CONVEYING CONTROLS OPERATION
 REQUESTED OUTPUT IS UNATTAINABLE

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
				REAL FULL						
10.70	342.5			0.	376.	0.437	349.0	0.0870		
12.70	342.5			0.	778.	0.437	349.0	0.0985		
14.20	333.3	.951	.951	.827	0.	875.	0.08	0.437	349.0	0.2867
18.80	345.6	.851	.851	.729	0.	919.	0.38	0.437	391.0	0.2581
19.80	349.3	.823	.823	.706	0.	928.	0.43	0.437	391.5	0.2470
24.80	370.0	.753	.753	.682	0.	975.	0.68	0.385	394.6	0.1628
29.80	383.6	.686	.686	.652	0.	1098.	0.92	0.333	397.7	0.1424
34.80	391.8	.618	.618	.616	0.	1237.	1.2	0.281	400.6	0.1309
39.80	394.7	.546	.546	.546	0.	1390.	1.4	0.229	403.5	0.1257
44.80	397.2	.464	.464	.464	0.	1532.	1.6	0.177	406.3	0.1220
47.35	398.4	.416	.416	.416	0.	1568.	1.7	0.150	407.9	0.1204
-----SECONDARY CHANNEL BEGINS-----										
52.35	393.7	.199	.383	.199	0.	1694.	1.8	0.150	410.4	0.1265
57.35	401.3	.068	.163	.068	0.	1866.	2.2	0.150	413.3	0.1199
62.35	409.1	.012	.038	.012	0.	1994.	2.6	0.150	416.3	0.1132

FILM THICKNESS IS 0 - TBAR= 0.4163E+03
FILM THICKNESS IS 0 - TBAR= 0.4163E+03

63.95	411.2	.001	.005	.001	0.2024	2.9	0.150	417.3	0.1118	-0.5	417.
-----SECONDARY CHANNEL ENDS-----											
64.83	412.7	.000	.000	.000	0.2050	2.9	0.269	418.0	0.1044	0.7	418.
65.70	413.8	.000	.000	.000	0.2067	2.9	0.387	418.5	0.1166	0.6	418.
70.65	418.1	.000	.000	.000	0.2145	3.0	0.412	421.1	0.1165	0.6	418.
75.60	421.6	.000	.000	.000	0.2214	3.1	0.437	423.9	0.1153	0.6	418.
77.16	422.8	.000	.000	.000	0.2237	3.1	0.338	425.0	0.1038	0.6	418.
78.72	424.3	.000	.000	.000	0.2270	3.1	0.238	425.9	0.0951	0.8	418.

FLUTED SECTION WITH 1. PAIRS OF FLUTES											
95.32	424.3	.000	.000	.000	0.2268	3.1	0.213	430.6	0.0951	0.8	418.

100.27	433.3	.000	.000	.000	0.2400	3.2	0.213	437.8	0.0967	0.8	418.

MINIMUM TEMPERATURE= 433.268 DEG F
TEMP FLUCTUATION= 0.000 DEG F
FLOW INDEX (N)= 0.806
GRATIO INJ.= 0.000
RESIDENCE TIME:
MELT POOL= 0.052056838 HRS

TORQUE = 4052.7 INCH.POUNDS
POWER BREAK-DOWN:
SOLIDS CONV. = 0.000 HP
MELTING = 2.005 HP
MIXING = 0.461 HP
FLIGHT CLEAR = 0.678 HP
COMPRESSION = 0.059 HP
MIXING DEVICE= 0.017 HP
PRESSURE FLUCTUATION= 73.66 PSI/CYCLE
TOTAL CONDUCTED HEAT THROUGH BARREL= -94.9 TO -58.8 BTU/MIN OR
-2.24 TO -1.39 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
POWER CONSUMPTION, % OF AVAILABLE: 3.2 4.8 6.4 8.0 9.6 11.3 12.9

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

!!!CAUTION!!!
MAXIMUM PERMISSIBLE CHANNEL DEPTH FOR SAFE SCREW IS: 0.393 INCHES
YOUR FEED SECTION IS 0.437 INCHES DEEP
CHECK RESIN VISCOSITY, SOURCE OF POWER CONSUMPTION
OR MODIFY SCREW GEOMETRY!
POWER CONSUMPTION EXCEEDS PRUDENT STRENGTH OF SCREW BY 18.45 %

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
533.99	372.6	0.0562162
0.50	349.0	0.2586268

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
25.01	437.8	0.0937818
150.90	329.0	0.1218715

SELECT ONE OF THE FOLLOWING:

1 - Data Analysis
2 - Run New Simulation
3 - EXIT
:

4MBF15

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 63.50 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH SOLID (IN)	CH.DEPTH MELT (IN)	WIDTH SOLID (IN)	WIDTH MELT (IN)	LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
1	19.800	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
2	27.550	0.150	0.000	1.368	0.000	1.750	1.750	0.300		
3	16.600	0.150	0.450	1.234	1.234	3.450	1.750	0.300		
4	1.750	0.387	0.000	1.368	0.000	1.750	1.750	0.300		
5	9.900	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
6	3.125	0.237	0.000	2.417	0.000	3.125	1.750	0.300		
7	16.600	0.213	0.000	2.622	0.000	3.450	1.750	0.300	1.000	0.914
8	4.950	0.213	0.000	1.368	0.000	1.750	1.750	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.21 PSI
 INCREASE HEIGHT TO = 64.55 IN. MAXIMUM PRESSURE = 0.26 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 72.00 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	32.9	21.09	0.170	0.076	72.5	229.0	0.00	0.35
2.00	32.3	21.15	0.174	0.079	72.7	229.0	0.00	0.57
3.00	31.6	21.25	0.180	0.085	73.1	229.0	0.00	0.94
4.00	30.9	21.44	0.192	0.094	73.0	229.0	0.00	1.57
5.00	29.9	21.73	0.206	0.109	76.9	229.0	0.00	2.63
6.00	29.0	22.01	0.184	0.123	70.0	229.0	0.00	3.57
7.00	28.1	22.33	0.198	0.138	70.0	229.0	0.01	4.73
8.00	27.0	22.73	0.213	0.155	70.0	229.0	0.01	6.16
9.00	25.7	23.21	0.231	0.174	70.0	229.0	0.01	7.91
10.00	24.4	23.79	0.251	0.194	70.0	229.0	0.02	10.03
11.00	23.0	24.49	0.270	0.215	70.0	229.0	0.03	12.61
11.70	21.9	25.07	0.284	0.228	330.0	229.0	0.04	14.79

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	REAL PRESSURE PSI	FULL PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F	
14.28	349.9			428.	428.	0.437	359.9	0.0855				
16.28	370.9			704.	704.	0.437	390.1	0.0923				
17.28	350.2	.929	.929	.787	707.	707.	0.09	0.437	390.1	0.2329	-23.3	390.
19.80	354.2	.858	.858	.726	715.	715.	0.22	0.437	391.7	0.2396	-2.5	390.
23.88	367.7	.801	.801	.707	726.	726.	0.43	0.395	394.1	0.1665	1.2	393.
28.88	381.8	.732	.732	.681	846.	846.	0.68	0.343	397.1	0.1450	0.8	397.
33.88	390.7	.664	.664	.648	982.	982.	0.91	0.291	400.1	0.1324	0.4	400.
38.88	394.8	.594	.594	.594	1134.	1134.	1.1	0.238	403.0	0.1259	-1.2	402.
43.88	396.9	.516	.516	.516	1284.	1284.	1.4	0.186	405.8	0.1225	-1.9	405.
47.35	398.3	.452	.452	.452	1342.	1342.	1.5	0.150	407.9	0.1204	-2.7	407.
-----SECONDARY CHANNEL BEGINS-----												
52.35	392.8	.224	.431	.224	1471.	1471.	1.7	0.150	410.4	0.1274	-7.8	410.
57.35	400.0	.082	.197	.082	1644.	1644.	2.0	0.150	413.3	0.1211	-1.3	413.
62.35	408.2	.018	.057	.018	1772.	1772.	2.3	0.150	416.3	0.1139	1.3	416.
FILM THICKNESS IS 0 - TBAR= 0.4168E+03												
FILM THICKNESS IS 0 - TBAR= 0.4168E+03												
63.95	410.5	.005	.019	.005	1801.	1801.	2.6	0.150	417.3	0.1124	11.4	417.
-----SECONDARY CHANNEL ENDS-----												

64.83	411.9	.004	.004	.004	1827.	1827.	2.7	0.269	417.9	0.1050	3.2	418.
65.70	413.0	.003	.003	.003	1845.	1845.	2.7	0.387	418.4	0.1172	2.9	418.
FILM THICKNESS IS 0 - TBAR= 0.4188E+03												
FILM THICKNESS IS 0 - TBAR= 0.4188E+03												
70.65	417.6	.000	.000	.000	1923.	1923.	2.8	0.412	421.1	0.1169	0.6	419.
75.60	421.3	.000	.000	.000	1992.	1992.	2.9	0.437	423.9	0.1155	0.6	419.
77.16	422.6	.000	.000	.000	2016.	2016.	2.9	0.338	425.0	0.1039	0.6	419.
78.72	424.1	.000	.000	.000	2048.	2048.	2.9	0.238	425.9	0.0952	0.8	419.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
95.32	424.1	.000	.000	.000	2047.	2047.	2.9	0.213	430.6	0.0952	0.8	419.

100.27	433.2	.000	.000	.000	2179.	2179.	3.0	0.213	437.8	0.0967	0.8	419.

MINIMUM TEMPERATURE= 433.194 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.806
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.049503591 HRS

TORQUE = 3834.8 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.035 HP
 MELTING = 1.858 HP
 MIXING = 0.444 HP
 FLIGHT CLEAR = 0.638 HP
 COMPRESSION = 0.056 HP
 MIXING DEVICE= 0.017 HP
 PRESSURE FLUCTUATION= 73.69 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -102.2 TO -67.4 BTU/MIN OR
 -2.41 TO -1.59 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 3.0 4.6 6.1 7.6 9.1 10.6 12.2

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

!!!CAUTION!!!
 MAXIMUM PERMISSIBLE CHANNEL DEPTH FOR SAFE SCREW IS: 0.402 INCHES
 YOUR FEED SECTION IS 0.437 INCHES DEEP
 CHECK RESIN VISCOSITY, SOURCE OF POWER CONSUMPTION
 OF MODIFY SCREW GEOMETRY!
 POWER CONSUMPTION EXCEEDS PRUDENT STRENGTH OF SCREW BY 13.89 %

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
572.39	373.9	0.0542351
0.82	390.1	0.1814330

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
25.01	437.8	0.0937841
286.19	329.0	0.0968691

AT 50.00 RPM & 63.50 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 2179. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

:

4MBF20

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 63.50 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH (IN)		WIDTH (IN)		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID	MELT	SOLID	MELT					
1	19.800	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
2	27.550	0.150	0.000	1.368	0.000	1.750	1.750	0.300		
3	16.600	0.150	0.450	1.234	1.234	3.450	1.750	0.300		
4	1.750	0.387	0.000	1.368	0.000	1.750	1.750	0.300		
5	9.900	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
6	3.125	0.237	0.000	2.417	0.000	3.125	1.750	0.300		
7	16.600	0.213	0.000	2.622	0.000	3.450	1.750	0.300	1.000	0.914
8	4.950	0.213	0.000	1.368	0.000	1.750	1.750	0.300		

HOPPER ANALYSIS

ATTENTION - SOLIDS HEIGHT IN HOPPER IS LOW !

SOLIDS HEIGHT = 36.00 IN. BASE PRESSURE = 0.14 PSI
 INCREASE HEIGHT TO = 37.27 IN. MAXIMUM PRESSURE = 0.15 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 72.50 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F		POWER HP	PRESSURE PSI
					BARREL	SCREW		
1.00	32.9	21.07	0.218	0.075	72.7	229.0	0.00	0.31
2.00	32.2	21.17	0.225	0.081	73.1	229.0	0.00	0.69
3.00	31.1	21.42	0.241	0.094	73.3	229.0	0.00	1.53
4.00	29.2	21.95	0.272	0.120	73.2	229.0	0.00	3.46
5.00	25.8	23.19	0.327	0.173	77.7	229.0	0.01	8.05
6.00	21.9	25.06	0.347	0.228	70.0	229.0	0.02	15.04
6.60	18.8	27.05	0.369	0.250	70.0	229.0	0.03	22.47
7.10	15.8	29.75	0.365	0.245	70.0	229.0	0.04	33.36
7.60	12.2	34.48	0.365	0.242	70.0	229.0	0.07	53.79
8.10	8.8	42.76	0.366	0.240	70.0	229.0	0.11	94.45
8.60	6.1	55.94	0.366	0.237	70.0	229.0	0.18	178.26
9.10	4.4	72.23	0.365	0.235	70.0	229.0	0.32	352.85
9.35	3.9	79.23	0.366	0.234	330.0	229.0	0.43	501.10

L IN	TOUT DEG F	X/W SOLID	X/W GRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F
				REAL FULL						
11.93	342.5			1106. 1106.		0.437	349.0	0.0871		
13.93	343.7			1493. 1493.		0.437	350.9	0.0986		
14.93	333.9	.951	.951	.827 1503. 1503.	0.5	0.437	350.9	0.2842	-18.0	351.
19.53	346.1	.850	.850	.729 1550. 1550.	0.8	0.437	391.4	0.2566	-2.4	391.
19.80	347.2	.842	.842	.722 1552. 1552.	0.8	0.437	391.7	0.2508	-2.5	391.
24.80	368.8	.773	.773	.699 1603. 1603.	1.1	0.385	394.6	0.1645	1.1	394.
29.80	383.1	.705	.705	.671 1726. 1726.	1.3	0.333	397.7	0.1429	0.7	397.
34.80	391.7	.638	.638	.636 1866. 1866.	1.6	0.281	400.6	0.1310	0.2	400.
39.80	394.5	.566	.566	.566 2020. 2020.	1.8	0.229	403.5	0.1258	-1.4	403.
44.80	397.1	.485	.485	.485 2162. 2162.	2.0	0.177	406.3	0.1221	-2.1	406.
47.35	398.2	.437	.437	.437 2198. 2198.	2.1	0.150	407.9	0.1205	-2.7	407.
-----SECONDARY CHANNEL BEGINS-----										
52.35	393.2	.213	.411	.213 2326. 2326.	2.3	0.150	410.4	0.1270	-7.6	410.
57.35	400.3	.076	.184	.076 2499. 2499.	2.6	0.150	413.3	0.1208	-1.1	413.
62.35	408.5	.016	.049	.016 2627. 2627.	2.9	0.150	416.3	0.1137	1.4	416.
FILM THICKNESS IS 0 - TBAR= 0.4168E+03										
FILM THICKNESS IS 0 - TBAR= 0.4168E+03										

63.95	410.7	.004	.014	.004	2656.	2656.	3.2	0.150	417.3	0.1122	11.5	417.
-----SECONDARY CHANNEL ENDS-----												
64.83	412.1	.003	.003	.003	2683.	2683.	3.3	0.269	417.9	0.1048	3.2	418.
65.70	413.2	.002	.002	.002	2700.	2700.	3.3	0.387	418.5	0.1171	0.3	418.
70.65	417.8	.000	.000	.000	2778.	2778.	3.4	0.412	421.1	0.1168	0.6	419.
75.60	421.4	.000	.000	.000	2847.	2847.	3.4	0.437	423.9	0.1154	0.6	419.
77.16	422.6	.000	.000	.000	2871.	2871.	3.5	0.338	425.0	0.1039	0.6	419.
78.72	424.2	.000	.000	.000	2903.	2903.	3.5	0.238	425.9	0.0951	0.8	419.

FLUTED SECTION WITH 1. PAIRS OF FLUTES												
95.32	424.2	.000	.000	.000	2902.	2902.	3.5	0.213	430.6	0.0951	0.8	419.

100.27	433.2	.000	.000	.000	3034.	3034.	3.6	0.213	437.8	0.0967	0.8	419.

MINIMUM TEMPERATURE= 433.214 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.806
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.051591475 HRS

TORQUE = 4548.9 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.434 HP
 MELTING = 1.977 HP
 MIXING = 0.458 HP
 FLIGHT CLEAR = 0.670 HP
 COMPRESSION = 0.058 HP
 MIXING DEVICE= 0.017 HP
 PRESSURE FLUCTUATION= 73.68 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -78.2 TO -60.9 BTU/MIN OR
 -1.84 TO -1.44 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 3.6 5.4 7.2 9.0 10.8 12.6 14.4

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

!!!CAUTION!!!
 MAXIMUM PERMISSIBLE CHANNEL DEPTH FOR SAFE SCREW IS: 0.375 INCHES
 YOUR FEED SECTION IS 0.437 INCHES DEEP
 CHECK RESIN VISCOSITY, SOURCE OF POWER CONSUMPTION
 OR MODIFY SCREW GEOMETRY!
 POWER CONSUMPTION EXCEEDS PRUDENT STRENGTH OF SCREW BY 28.30 %

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
863.73	342.5	0.0559446
0.49	350.9	0.2542148

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
25.01	437.8	0.0937835
150.73	329.0	0.1219206

 AT 50.00 RPM & 63.50 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 3034. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
- 2 - Run New Simulation
- 3 - EXIT

4MBF25

EXPERIMENT NUMBER 1.00 SCIENTIFIC PROCESS & RESEARCH, INC.

N= 50.0 RPM OUTPUT= 63.50 LB/HR SOAK TIME= 0.00 SECONDS

SECTION #	LENGTH (IN)	CH.DEPTH		WIDTH		LEAD (IN)	BAR. DIAM (IN)	FLT. WIDTH (IN)	NO OF HOLES	HOLE AREA (SQIN)
		SOLID (IN)	MELT (IN)	SOLID (IN)	MELT (IN)					
1	19.800	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
2	27.550	0.150	0.000	1.368	0.000	1.750	1.750	0.300		
3	16.600	0.150	0.450	1.234	1.234	3.450	1.750	0.300		
4	1.750	0.387	0.000	1.368	0.000	1.750	1.750	0.300		
5	9.900	0.437	0.000	1.368	0.000	1.750	1.750	0.300		
6	3.125	0.237	0.000	2.417	0.000	3.125	1.750	0.300		
7	16.600	0.213	0.000	2.622	0.000	3.450	1.750	0.300	1.000	0.914
8	4.950	0.213	0.000	1.368	0.000	1.750	1.750	0.300		

HOPPER ANALYSIS

ATTENTION - KEEP SOLIDS LEVEL IN HOPPER ABOVE 24.47 IN.
 BASE PRESSURE = 0.10 PSI

SOLIDS CONVEYING ZONE ANALYSIS

OPTIMUM SURFACE TEMPERATURES FOR SOLIDS CONVEYING:
 BARREL = 72.50 DEG.F AND SCREW = 229.00 DEG.F

LOCATION IN	PHI DEG	ROBP LB/CU.FT	FRIB	FRIS	TEMPERATURE, DEG F BARREL	TEMPERATURE, DEG F SCREW	POWER HP	PRESSURE PSI
1.00	33.0	21.06	0.268	0.074	72.7	229.0	0.00	0.29
2.00	32.0	21.23	0.279	0.084	73.1	229.0	0.00	0.86
3.00	30.1	21.70	0.307	0.108	73.3	229.0	0.00	2.58
4.00	25.9	23.16	0.383	0.172	74.2	229.0	0.01	8.08
4.55	21.5	25.26	0.455	0.232	74.6	229.0	0.01	15.81
5.05	16.8	28.76	0.422	0.245	265.5	229.0	0.03	29.54
5.55	11.8	35.27	0.421	0.242	276.5	229.0	0.05	57.90
6.05	7.3	48.55	0.422	0.238	286.7	229.0	0.11	129.05
6.55	4.6	69.37	0.419	0.235	300.5	229.0	0.24	314.71
7.05	3.6	84.89	0.414	0.234	326.6	229.0	0.56	791.44
7.15	3.5	86.10	0.414	0.234	330.0	229.0	0.67	950.84

L IN	TOUT DEG F	X/W SOLID	X/W CRATIO	PRESSURE PSI	POWER HP	HOUT IN	TBAR DEG F	TVISC LB.SEC /SQ.IN	D.HEAT BTU/IN .MIN	FILM TEMP DEG F		
9.73	342.5			REAL 1554.	1554.	0.437	349.0	0.0870				
11.70	342.5			1931.	1931.	0.437	349.0	0.0992				
12.70	333.2	.952	.952	.829	1929.	1929.	0.7	0.437	349.0	0.2868	-17.7	349.
17.30	345.4	.852	.852	.731	1921.	1921.	1.0	0.437	390.1	0.2587	-2.3	390.
19.80	353.8	.784	.784	.673	1916.	1916.	1.2	0.437	391.7	0.2284	-2.6	391.
24.80	372.7	.714	.714	.647	2023.	2023.	1.4	0.385	394.7	0.1593	0.8	394.
29.80	384.8	.646	.646	.616	2144.	2144.	1.6	0.333	397.7	0.1410	0.4	397.
34.80	392.2	.578	.578	.577	2283.	2283.	1.9	0.281	400.6	0.1305	0.0	400.
39.80	395.0	.505	.505	.505	2435.	2435.	2.1	0.229	403.5	0.1255	-1.5	403.
44.80	397.5	.423	.423	.423	2575.	2575.	2.3	0.177	406.3	0.1219	-2.2	406.
47.35	398.5	.372	.372	.372	2610.	2610.	2.4	0.150	407.9	0.1204	-3.1	407.
-----SECONDARY CHANNEL BEGINS-----												
52.35	394.6	.169	.326	.169	2734.	2734.	2.5	0.150	410.5	0.1255	-6.6	410.
57.35	402.7	.052	.124	.052	2905.	2905.	2.9	0.150	413.4	0.1185	-0.4	413.
FILM THICKNESS IS 0 - TBAR= 0.4157E+03												
FILM THICKNESS IS 0 - TBAR= 0.4157E+03												
62.35	410.0	.002	.007	.002	3033.	3033.	3.5	0.150	416.3	0.1124	11.3	416.
63.95	412.2	.000	.000	.000	3062.	3062.	3.6	0.150	417.3	0.1110	0.7	417.
-----SECONDARY CHANNEL ENDS-----												

64.83	413.7	.000	.000	.000	3088.	3088.	3.6	0.269	418.0	0.1038	0.8	417.
65.70	414.7	.000	.000	.000	3105.	3105.	3.6	0.387	418.5	0.1159	0.6	417.
70.65	418.6	.000	.000	.000	3183.	3183.	3.7	0.412	421.1	0.1161	0.6	417.
75.60	421.8	.000	.000	.000	3251.	3251.	3.7	0.437	423.9	0.1151	0.6	417.
77.16	423.0	.000	.000	.000	3275.	3275.	3.8	0.338	425.0	0.1037	0.6	417.
78.72	424.4	.000	.000	.000	3307.	3307.	3.8	0.238	425.9	0.0950	0.8	417.

FLUTED SECTION WITH 1. PAIRS OF FLUTES

95.32	424.4	.000	.000	.000	3306.	3306.	3.8	0.213	430.7	0.0950	0.8	417.
100.27	433.3	.000	.000	.000	3438.	3438.	3.9	0.213	437.8	0.0966	0.8	417.

MINIMUM TEMPERATURE= 433.345 DEG F
 TEMP FLUCTUATION= 0.000 DEG F
 FLOW INDEX (N)= 0.806
 GRATIO INJ.= 0.000
 RESIDENCE TIME:
 MELT POOL= 0.053090241 HRS

TORQUE = 4915.9 INCH.POUNDS
 POWER BREAK-DOWN:
 SOLIDS CONV. = 0.667 HP
 MELTING = 2.001 HP
 MIXING = 0.467 HP
 FLIGHT CLEAR = 0.694 HP
 COMPRESSION = 0.060 HP
 MIXING DEVICE= 0.017 HP
 PRESSURE FLUCTUATION= 73.64 PSI/CYCLE
 TOTAL CONDUCTED HEAT THROUGH BARREL= -65.9 TO -57.5 BTU/MIN OR
 -1.55 TO -1.35 HP

MAXIMUM SCREW SPEED,RPM: 50.0 75.0 100.0 125.0 150.0 175.0 200.0
 POWER CONSUMPTION, % OF AVAILABLE: 3.9 5.8 7.8 9.7 11.7 13.6 15.6

STRENGTH ANALYSIS OF YOUR SCREW (4140STEE):

!!!CAUTION!!!
 MAXIMUM PERMISSIBLE CHANNEL DEPTH FOR SAFE SCREW IS: 0.362 INCHES
 YOUR FEED SECTION IS 0.437 INCHES DEEP
 CHECK RESIN VISCOSITY, SOURCE OF POWER CONSUMPTION
 OR MODIFY SCREW GEOMETRY!
 POWER CONSUMPTION EXCEEDS PRUDENT STRENGTH OF SCREW BY 35.15 %

VISCOSITY WAS CALCULATED IN THE FOLLOWING SHEAR RATE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
877.20	342.5	0.0555635
0.48	349.0	0.2586268

VISCOSITY WAS CALCULATED IN THE FOLLOWING TEMPERATURE RANGE

SHEAR RATE	TEMP.	VISCOSITY
1/SEC	DEG.F	LB.SEC/SQ.IN
25.02	437.8	0.0937795
154.31	329.0	0.1209496

AT 50.00 RPM & 63.50 LB/HR PRODUCTION RATE
 HEAD PRESSURE IS 3438. PSI.

FOR MORE DETAIL
 SELECT ONE OF THE FOLLOWING:

- 1 - Data Analysis
 - 2 - Run New Simulation
 - 3 - EXIT
- :