ABSTRACT

DESIGN IMPROVEMENT USING REVERSE ANALYSIS IN DESIGN FOR QUALITY MANUFACTURABILITY

by
Vikram V Datla

The competitive needs of modern manufacturing demands that innovative approaches be used to gain an edge over the competitors. least Product design is one of the key dimensions wazzu in which companies can excel. Shortening the product design cycle so as to rapidly launch defect free products, is the goal of most companies. Design for Quality Manufacturability (DFQM) is a technique used to evaluate the quality manufacturability of a product at the design stage, so as to eliminate quality problems during production.

DFQM provides a means for relating the activities of quality improvement, product design and manufacturability analysis. The basis for DFQM is a set of defects and a set of factors which influence the occurrence of these defects. The DFQM methodolgy has been under development at N.J.I.T for the last three years.

In this Thesis we design and present the reverse analysis tool for DFQM. This tool is used for design improvement after the initial DFQM analysis. Reverse analysis tells the designer what specific design changes will help improve the quality manufacturabiliy of the design. The analysis is based on the error catalysts within the DFQM logic. A software for DFQM is developed as part of the Thesis. Two case studies are studied to illustrate the practical feasibility of DFQM in a real world environment.

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by
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This thesis is dedicated to
my father

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CHAPTER 1

INTRODUCTION

1 Product Quality

Product quality is the focal point of contemporary manufacturing industries all over the world. The globalization of the market economy has brought a dramatic increase in the emphasis for product quality. In the new wave of corporate strategies, companies see quality as a viable tool to increase and sustain their market share. Such vigorous competition has given place to new techniques and methods for the purpose of enhancing quality standards. All these new technologies are dedicated to produce high quality products using minimum time and effort.

unlike before, have started Manufacturers to analyze several facets of quality before the production stage. The concept of building the product for ease of manufacture and assembly started to evolve in the early 1980's. The designers role in incorporating manufacturing that and assembly issues started gaining importance. Quality experts have identified approximately 75% to 80% of the product cost is determined at the design stage itself. Further, they emphasize that the design stage is where critical quality considerations should be made. In the early 1980's several useful tools became available to help designers in their analysis. Design of products became accommodative to process variability, serviceability, testability etc. A stage arose wherein manufacturing problems from quality perspective were required to be visualized and solved at design stage itself.

The proliferation of the products on the market has significantly reduced the life cycle of the product, necessitating the ability to introduce new products with superior quality in relatively shorter time periods. All these developments have given rise to new concepts such as "Concurrent Engineering" and "Simultaneous Engineering". These approaches mean that all aspects of products design, manufacture, and marketing should be considered during the design phase by teams of individuals representing these various interests, so that all of the right decisions are made from the start. It became necessary to integrate manufacturing and assembly along with useful considerations of performance, appearance etc. Several techniques for the implementation of concurrent engineering are available. One of the approaches to simultaneous engineering is Design for Manufacturability (DFM).

1.2 Design for Manufacturability

Design represents a progression over time from the abstract to concrete. The activities involved in this progression can be divided into time sequence phases. As a part of each phase many problems must be resolved and technical, economical decisions made. These decisions generally require a great deal of information. The quality of the decisions often depends on the information. The quality of the decisions often depends on the information. Changes in design happen due to inappropriate or lack of information when creating the initial design of the part. DFM addresses this issue of manufacturing. The goals of DFM are (i) minimize the design time, (ii) minimize the number of later changes, (iii) minimize the design to product transition time, (iv) attain the desired level of quality and reliability. To achieve these goals, DFM integrates the islands of development operations into one by identifying concepts that improve manufacturability, implementing these concepts into a better design, and integrating the process knowledge into the design. Many DFM tools are currently available to accomplish the above mentioned objectives. However the only known technique that evaluates the quality of the manufactured part in the design stage is the Design for Quality Manufacturability (DFQM).

1.3 Design for Quality Manufacturability

DFQM analysis provides a means of relating the activities of product quality design and manufacturability analysis. This provides an efficient way to evaluate the design for manufacturing and consequently debugging the design before the actual commencement of production. Quality Manufacturability (QM) helps the companies spend lesser time and cost in fixing defects so as to improve their competitiveness.

The spectrum of quality defects as identified by Das(1993), are shown in Figure 1.1 which illustrates the sources of quality problems. Several techniques and tools are available to determine the design and manufactured quality. The design to manufacturing interface is usually not addressed formally. The focus of DFQM is therefore on the design to manufacturing interface, and how it effects the manufactured quality.

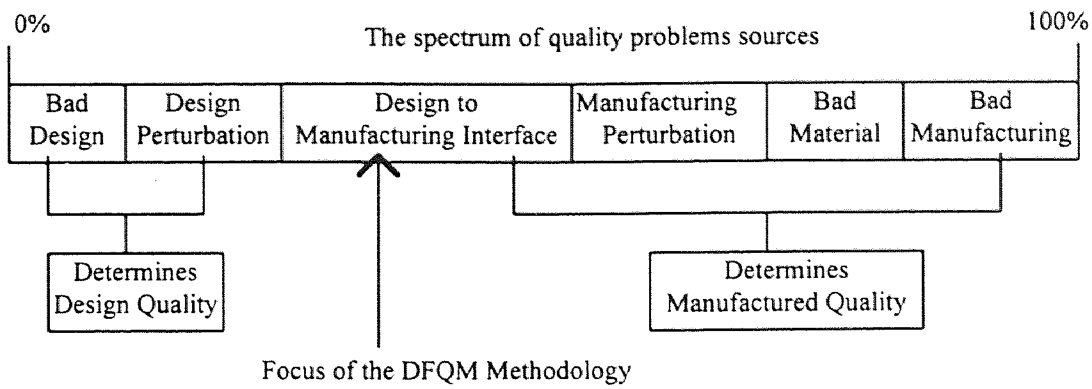


Figure 1.1 Spectrum of Quality Defects

1.4 Research Objective

This thesis forms part of a five year research work on the DFQM methodolgy. One of the main objectives of the current project is to convert the known DFQM knowledge into a practical useable tool. Specifically a software for executing the DFQM logic is to be developed. This Thesis further extends the DFQM knowledge by developing a reverse analysis tool to be used in DFQM for design improvement. Clearly, once the DFQM method alerts the designer that the quality manufacturability (QM) is low, then the next question is how does one improve the QM. Reverse analysis answers this question by addressing the reasons why quality problems arise. It also comes up with a set of possible solutions that can totally eliminate or reduce the possibility of these defects. A set of case studies are studied to illustrate the practical feasibility of the DFQM methodology.

1.5 Organization of the Thesis

The thesis consists of six chapters. The first chapter gives an introduction to the concepts and significance of DFM in today's manufacturing industry. Chapter two gives a survey of relevant literature pertaining to DFM, Design for Assembly (DFA), and current research in DFQM. Chapter three gives a brief outlook of the DFQM software. It illustrates the DFQM databases internal architecture, interfaces (or input screens) from the software and a part of error catalyst coding. Design improvements using the reverse analysis tool is illustrated in chapter four. The practical feasibility of the DFQM methodolgy is shown in chapter five by presenting case studies on Rubber stamp assembly and Car door handle assembly. Conclusions and scope for future research are given in chapter six.

CHAPTER 2

LITERATURE SURVEY

2.1 Quality

Short Product life cycles is one of the main problems facing the manufacturing industry today. In such a scenario the quality of a product is totally neglected which results in product unreliability, customer dissatisfaction and loss of market share. Quality of any product can be broadly defined into two categories, design and manufactured quality. Design quality is defined as the quality of a product as perceived by customer. Manufactured is defined as the extent to which a product deviates from its design specifications.

Traditional approaches to improve the quality literature of a product has been focused on either monitoring the process itself or inspecting the output of the process. Deming(1988) complains that manufacturers are highly dependent on inspection as the road to higher quality, which means that they let problems occur and then try to separate the bad products. 'Prevention is better than cure' which means that, manufacturers should apply problem solving methods that prevent low quality from occurring in the first place. In response a call for quality building approaches several new methods have been reported in literature. These approaches are widely reported in literature and most of them encourage concurrent efforts to in build a robust design. The concept practiced by Taguchi(1979), design for quality involves a three step optimization of product and process : system design, parameter design, and tolerance design. This approach suggests that key to minimizing variability in a product's functional characteristics is to systematically select values for controllable factors such that sensitivity to uncontrollable factors is minimized. The concept of "Quality by Design" (Deming 1988, Clausing and Simpson 1990) focuses on prevention rather than problem solving.

In recent years, global competition has resulted in increased customer expectations regarding product value has given rise to a new era of concurrent engineering. This gave rise to a number of approaches for developing and manufacturing high quality products and related books, literature and articles that come under concurrent engineering. Failure Mode Effect Analysis (FMEA) is an effective tool to identify the possible failure of parts and the possible effect on the customer before they could actually occur. This concurrent tool greatly improves the product quality, and effectively follows the idea of "prevention is better than cure". The other effective tool that listens to the customers voice and transforms into an engineering necessity is the "House of Quality". The basic idea behind this tool is to achieve customer satisfaction and to look at a product from a customers point of view rather than an engineering point of view.

2.2 Concurrent Engineering

Concurrent engineering (CE) combines a multi disciplinary task force, with complete specification at concept, resulting in fewer changes, thus resulting in shorter lead times and high quality products. A model to improve the quality design by synthesizing and evaluating the design prior to production was proposed by Shingley(1963). The concurrent engineering approach is an extension of the Shingley model to enhance design techniques. An axiomatic approach proposed by Suh, Bell and Gussard(1978) is based upon the hypothesis that there exists a small set of global principles or axioms that can be applied to decisions made throughout the synthesis of manufacturing systems including evaluation of a design leading to a good design. The product realization process that combines the activities of design, concurrent engineering and customer satisfaction needs interpretation. This called for a systems approach towards product design integrating all the facets of the manufacturing process. This is capitalized as the concurrent engineering approach to a product design (Das, 1993).

To exploit the concept of concurrent engineering to the fullest extent, the products to be manufactured and assembled must be suited for the engineering selected method and processes. Before designing a product for manual or automated manufacture, the concurrent engineering team should consider good quality and ease of maintenance in mind. This concept gave rise to a branch of concurrent engineering called Design for Manufacturability (DFM).

2.3 Design for Manufacture Techniques

Various DFM techniques and relate literature are available with a common aim to design a product that is to easy to manufacture. The most popular and commercially available version of a generic DFM technique is Design for Manufacture and Assembly (DFMA) developed by Boothroyd and Dewhurst (1983). This technique involves analytical tools that allow designers and manufacturing engineers to predict the manufacturing and assembly costs of a proposed product before detailed design has taken place. It computes the design efficiency by evaluating the orienting, handling and assembly difficulty. Typical DFM process was proposed by Stoll (1988), it begins with a proposed product concept, a proposed process plan, and a set of design goals with engineering data and then optimize both product and process.

One of the well known methods is the Hitachi assembly evaluation method focuses on the cost involved in handling and assembly of the parts and identifies areas of focus for efficient product assembly. The DFM calculator was developed by Westinghouse Corporation. It uses simulation techniques to analyze complex assemblies prior to their prototype production and enable designers to make changes in the design, and study the assembly process variables. The U.S Department of Navy releases a document describing two manufacturing evaluation tools, first computes Producability Assessment Worksheet Index (PAW-I) and second one evaluates the impact of product and process variation on product quality.

Priest and Sanchez have developed an empirical methodology that evaluates manfacturability by calculating the producability index (PI) of a design by considering material selection and availability, commonality and standardization, process selection, tolerancing, quality and inspection, and assembly considerations.

2.4 Design for Quality Manufacturability

A salient absence of literature dealing with relationship between design and quality was observed during survey. The perspective of designing the DFM structure such that concrete and real manufacturing time quality problems can be addressed and quantified has been found. Most of the articles assume that since the manufacturability of the product improves, hence the quality of the product also improves.

The direct relationship between the design of the product and its manufactured quality is addressed by Das (1993) and Prasad (1992). They initiated a methodology that focuses exclusively on evaluating a design from the quality perspective. This can help designer in not only optimizing the manufacturability of the product but also allows him to address multiple quality issues that could effect the product at a downstream stage. It gives designer an estimate of the efficiency of the design from quality perspective.

The general structure (Prasad 1992) of this methodology is depicted in the DFQM architecture as shown in Figure 2.1. This enables us to accomplish cause-effect analysis by predicting the effect after identifying the causes. This methodology identifies a set of defects that could occur at the assembly stage. A set of factors responsible for the occurrence of these defects is also investigated. The relationships to bring about an effective link between the defects and the influencing factors is proposed in form of error catalysts. A comprehensive set of error catalysts have been developed by Suryanarayana (1993), Tamboo (1994), Dhar (1995), Samir (1995) for all the six classes of defects

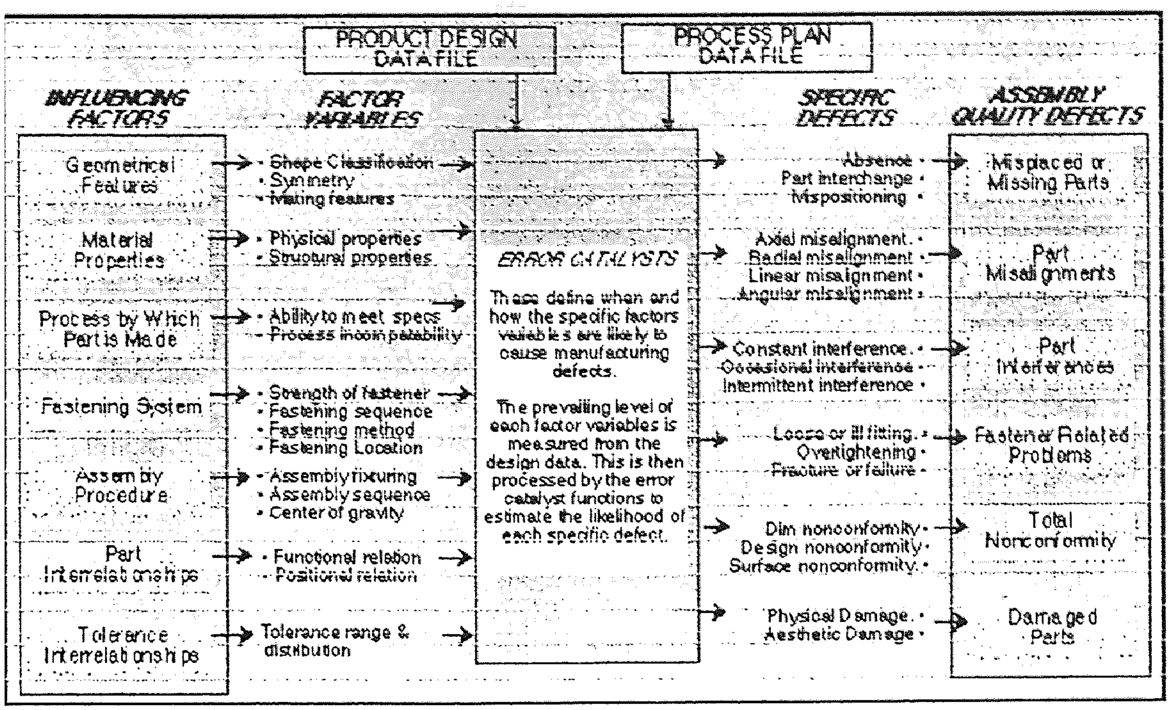
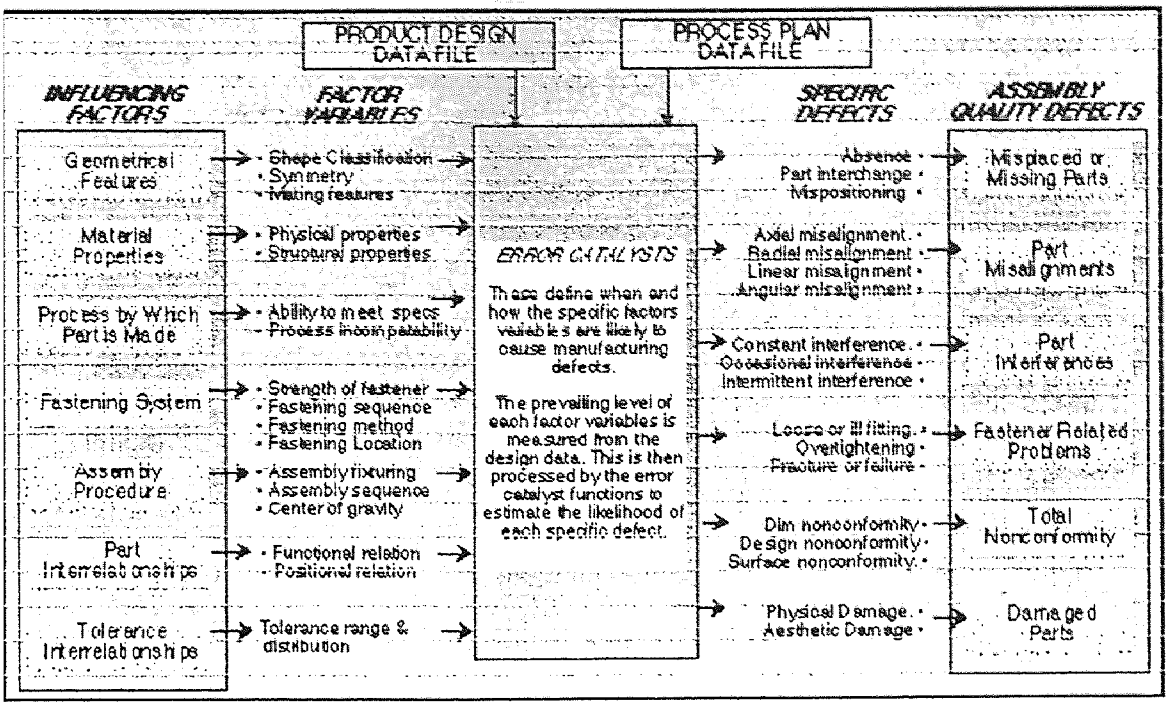


Figure 2.1 DFQM Architecture

2.5 Summary

The proposed methodology for evaluating a design to determine its Quality Manufacturability by Das (1993) focuses on Design - Manufacturing - Quality interface. It reduces the quality of a product largely to a post design function. The research leading to the documentation of this thesis involved developing a Reverse analysis tool which identifies the source of quality problems for a particular design and suggests measures to be taken to minimize their occurrence and thereby improving the design efficiency. Part of the research involved developing the beta version of the DFQM software.



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For storing the data inputted by the user a database collection called DFQM is stored in Microsoft Acess database. The DFQM database comprises mainly of four tables namely Parts, Mating, Cover and Error Catalyst score. The first three tables store the product data on a part by part basis. The fourth table stores the error catalyst scores generated after the DFQM analysis. All the four tables only store data and don't have any additional functionality associated with them. The front end and report generation process is developed in Visual Basic. The front end has a set of graphical interfaces which essentially accept input and store the data in the database. This data is the passed through the EC engine which generates the error catalyst scores. These scores are displayed to the user using the report generator.

3.2 Data Input

DFQM Analysis is done on a part by part basis. Hence the input is also done on a part by part basis. Each part has 12 associated data input screens in the software, out of which 7 screens pertain to the part data and the remaining 5 screens are related to its mating data. The data entered is stored in a database called the "DFQM database". Figure 3.2.1 shows the data input sequence in the DFQM software.This data is used by the DFQM black box (error catalysts) to come up with the result in the form of a QM matrix. Input data is designed in such a way that it is optimum, easy to store in a relational database and could be effectively used to perform the analysis.

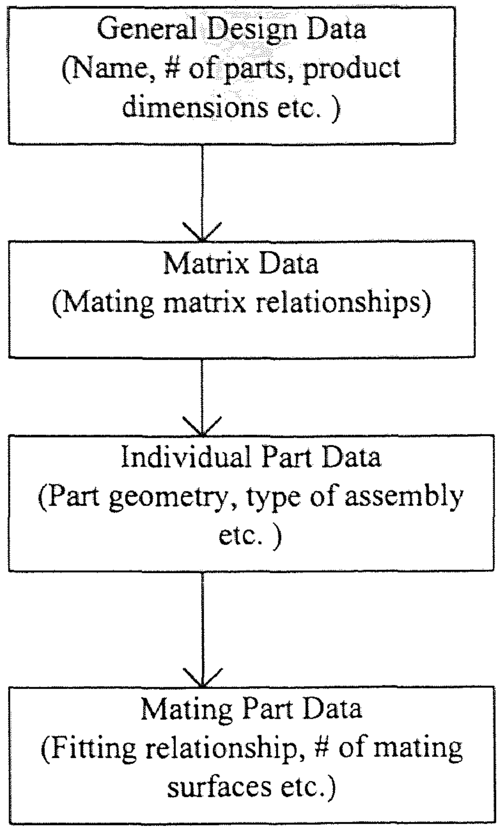


Figure 3.2.1 Data input sequence

Part data consists of all the data pertaining to every part in the assembly. It consists of singular data and the user should be able to enter the input if he has knowledge of the basic processes by which the part is manufactured. Part data usually contains details about its dimensions, symmetry, material, material handling, stage of assembly etc. Mating data consists of details related to mating of one part with respect to another part in the assembly. Typical inputs for mating data are positional relationships, functional relationships, method of fastening etc. Data inputting by the user is made extremely easy in the DFQM Software as for every input there exists a set of option blocks. The user needs to select the input from the option block. Typical format of product data input is shown in figures 3.2.2 to 3.2.5.

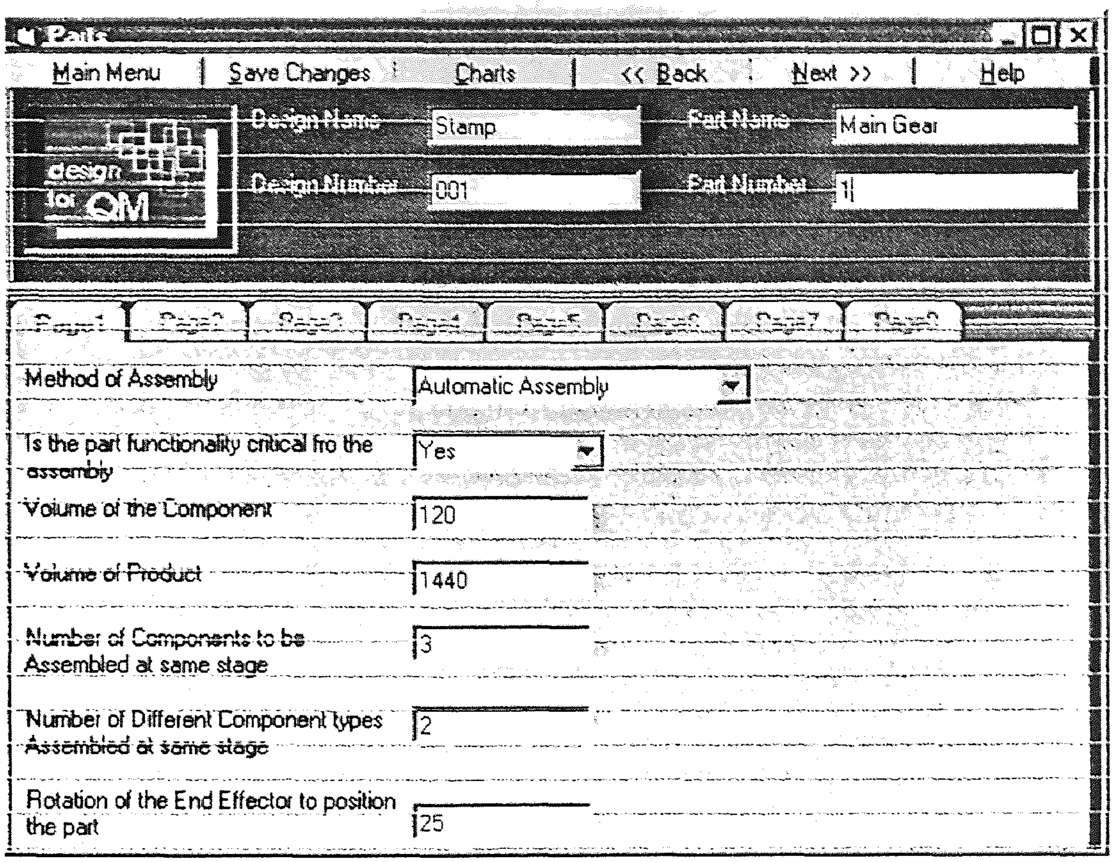


Figure 3.2.2 Part input form # 1

Figure 3.2.2 shows one of the input forms used in the DFQM software to enter part data. As shown, data entry is made easy for the user by providing him with a set of options for every input, from which the user selects relevant data. For example if the user wishes to enter the type of assembly, the DFQM software provides him with the following options.

(a) Manual Assembly (b) Automatic Assembly

In the figure shown above the second option is chosen by the user. Similarly option blocks are provided for all the inputs. This input process is repeated for all the parts in the assembly. Figures 3.2.3 to 3.2.5 show other input forms for a part.

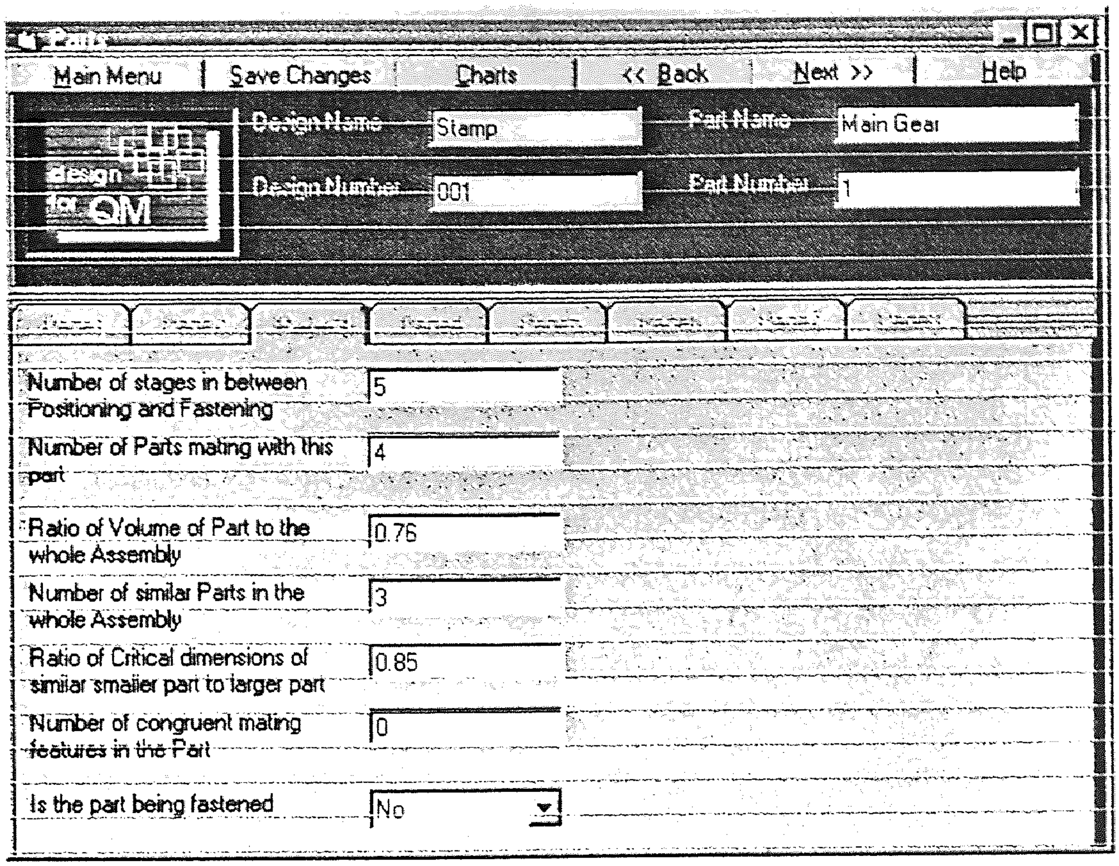


Figure 3.2.3 Part input form # 2

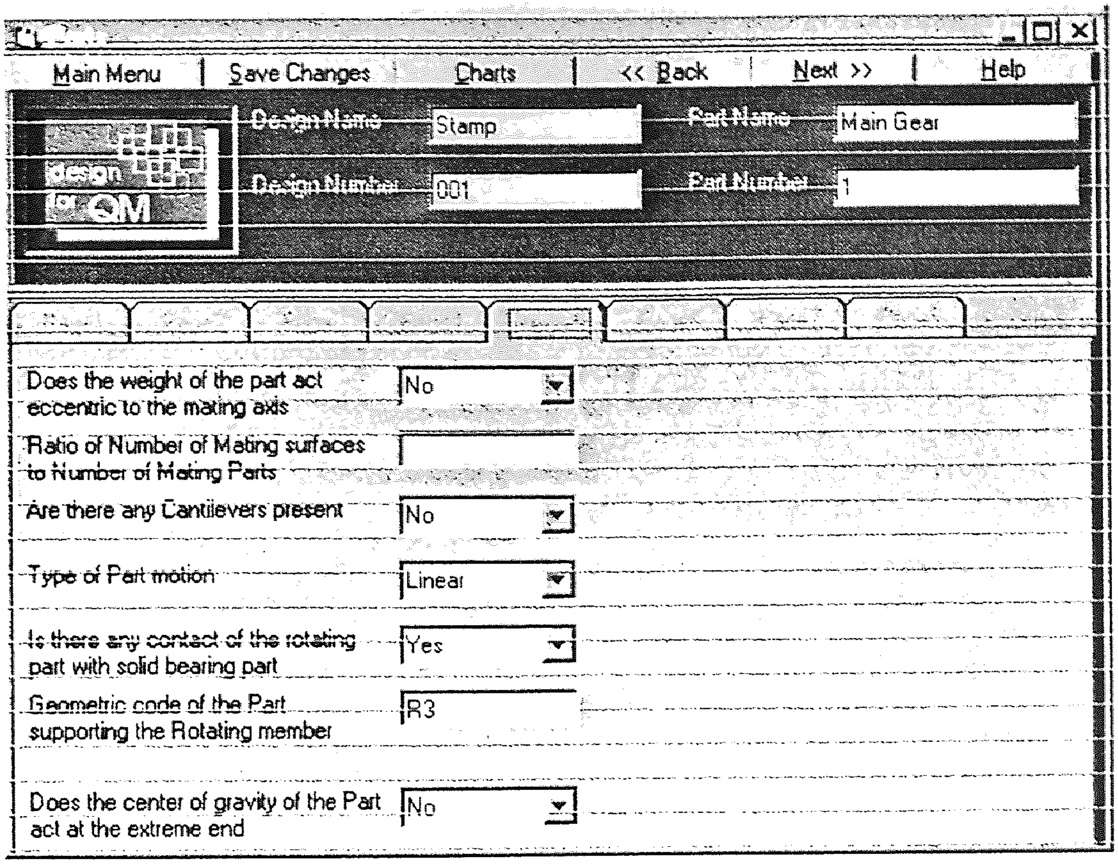


Figure 3.2.4 Part input form # 3

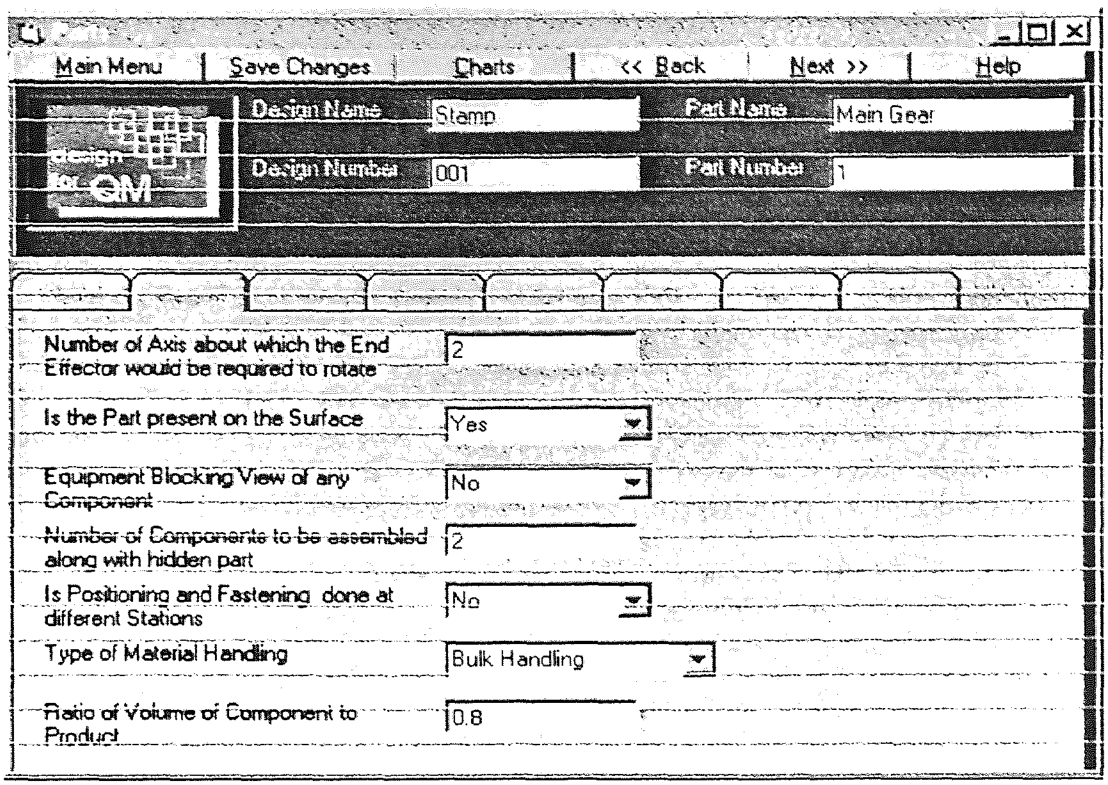


Figure 3.2.5 Part Input form # 4

3.3 Error Catalysts

Once user inputs all the required data, DFQM analysis is carried out by passing all groups of input data through error catalysts which are decision trees developed for all the six classes of defects. There are 65 error catalysts in total and all of them have been coded in the DFQM software. A sample code for one of the error catalysts in figure 3.3.1. There are 3 to 4 error catalysts for each specific defect. Once we obtain the scores of each of the error catalysts, we multiply these scores by the weightage factor. These scores of all the error catalysts are summed up to give the DFQM score for a specific defect.

The same process is repeated for obtaining the scores of each of the defect classes. Each error catalyst needs a set of specific inputs. The DFQM software retrieves the inputs required by an error catalyst from the Access database. These inputs are then passed through the error catalyst engine which does a set of computations based on the inputs and comes up with a score.

```
Error Catalyst A11 :
Dim mydb As Database
Dim myset1 As Snapshot
Dim mysql As String
x = "Select assembly_method, comp_envelope_vol, no_comp_same_stage,
no_comp_diff From Parts Where pdesign_no = '" + dnum + "' and part_no=" &
partnumber
Y = "Select size From Cover where Design_Number = '" + dnum + "'"
Set mydb = OpenDatabase("c:\access\dfqm.mdb")
Set myset1 = mydb.CreateSnapshot(x)
Set myset2 = mydb.CreateSnapshot(Y)
assemethod = myset1("assembly_method").Value
vo = myset2("size").Value
vi = myset1("comp_envelope_vol").Value
ni = myset1("no_comp_same_stage").Value
mi = myset1("no_comp_diff").Value
ratio = vi / vo
If mi / 10 > ni / 16 Then maxi = mi / 10 Else maxi = ni / 16
If maxi > (0.01 - ratio) / 0.01 Then maxi = maxi Else maxi = (0.01 - ratio) / 0.01
sumfun = (mi / 10) * (ni / 16) * (ratio / 0.08)
If assmethod = "automatic" Then
z = 0
Else
If (ratio >= 0.05) Or (ni = 1) Then
z = 0
Else
If (ratio <= 0.005) Or (ni >= 12) Or (mi >= 8) Then
z = 1
Else
z = 0.05
a11(partnumber) = z
End Sub
```

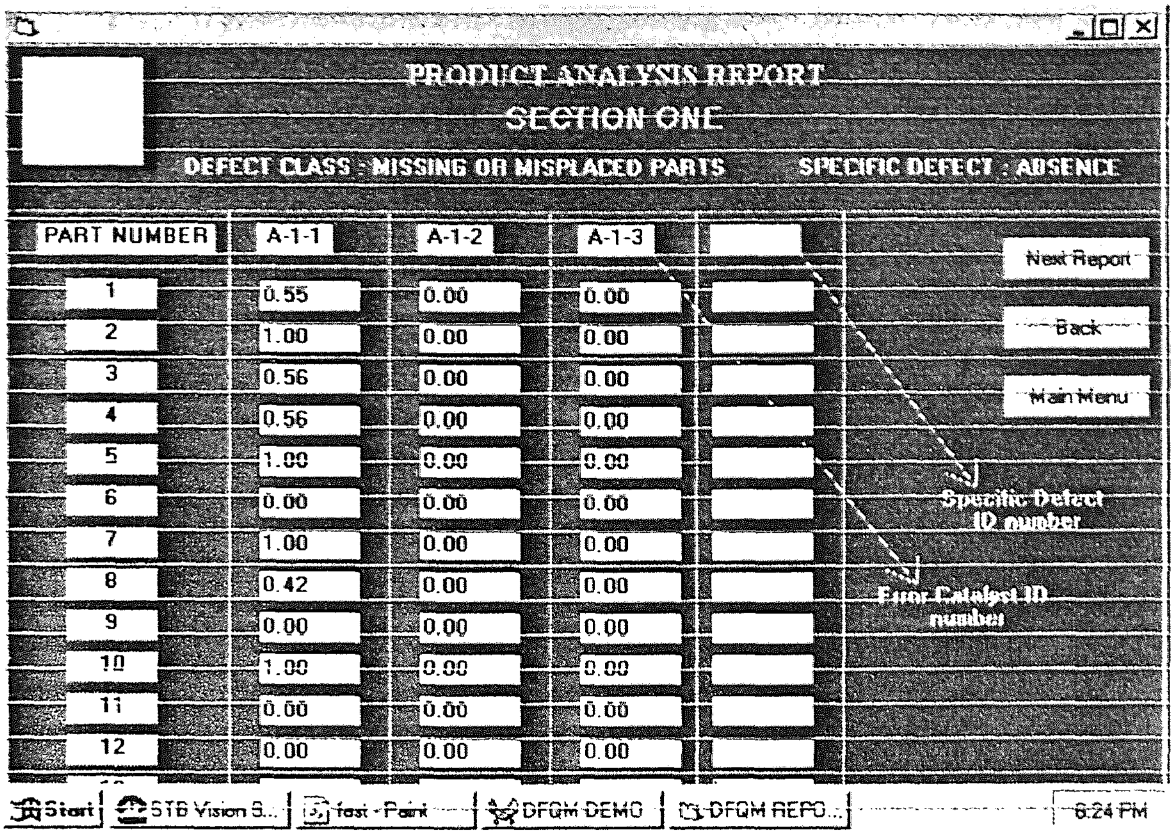
Figure 3.3.1 Error Catalyst for A11

3.4 Reports

The final output of the DFQM analysis is derived in form of a Quality Manufacturability Matrix. All error catalysts are inherent in the design and become active or inactive due to specific reasons. These reasons are nothing but the process variables explained earlier in the chapter. The values generated by the error catalysts reflect the extent to which process variables vary. After scores are generated by the error catalysts, these values are stored in a database. Reports are generated based on these values. Reports are classified into three categories.

1. Reports pertaining to each specific defect
2. Reports pertaining to each defect class
3. Final DFQM Matrix.

All the values generated by the error catalysts are in the range of 0 - 1. For example a score of 0.3 for a specific defect indicates that there is a probability of 0.3 that this specific defect might occur in this part when it is actually assembled. Sample reports for each of the three categories of reports are shown in figures 5.3.1 to 5.3.3. These reports guide the designer to focus attention on components of assembly that are more likely to cause defects. The DFQM analysis can be done in a very detailed manner by not only looking at the scores in the final DFQM matrix but also looking at the scores for the specific defects.



PRODUCT ANALYSIS REPORT

SECTION ONE

DEFECT CLASS : MISSING OR MISPLACED PARTS   SPECIFIC DEFECT : ABSENCE

PART NUMBER	A-1-1	A-1-2	A-1-3	
1	0.55	0.00	0.00	
2	1.00	0.00	0.00	
3	0.56	0.00	0.00	
4	0.56	0.00	0.00	
5	1.00	0.00	0.00	
6	0.00	0.00	0.00	
7	1.00	0.00	0.00	
8	0.42	0.00	0.00	
9	0.00	0.00	0.00	
10	1.00	0.00	0.00	
11	0.00	0.00	0.00	
12	0.00	0.00	0.00	

Figure 3.4.1 Sample Report for Specific Defect A1

Figure 3.4.1 shows one of the DFQM product reports for the defect class 'Missing or misplaced parts' and for specific defect 'Absence'. The report shown above is for the rubber stamp assembly which consists of thirteen parts. The values in the column A-1 represent the scores for the specific defect absence. A-1-1, A-1-2 and A-1-3 represent the three factor (process) variables that are responsible for the occurrence of the specific defect A-1. There are three specific defects in thi defect class and each of these specific defects have a set of factor variables associated with them. Similar reports are generated for all the six defect classes. From the report shown above, it is observed that parts 2, 4 and 5 have the highest probability of 0.25 of being missed or misplaced in the final assembly.

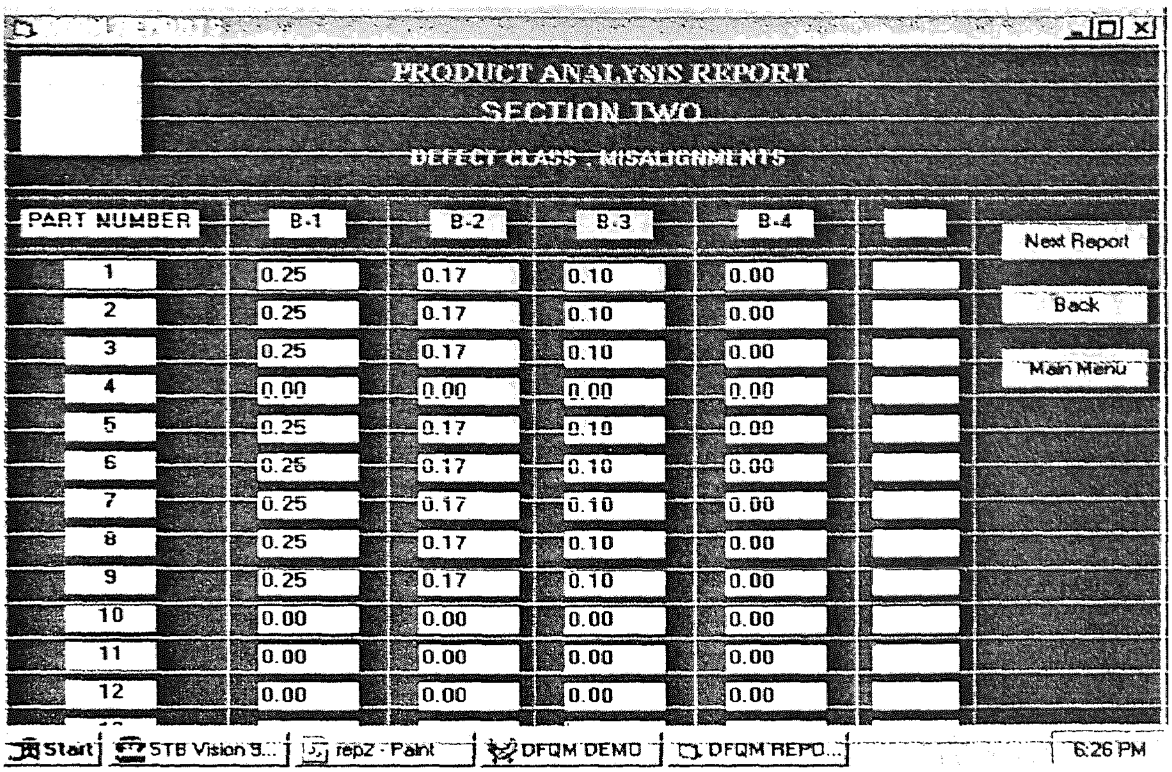


Figure 3.4.2 Sample Report for Defect class B

Figure 3.4.2 shows one of the DFQM product reports for the defect class 'Mialignments'. The report shown above is for the rubber stamp assembly which consists of thirteen parts. The values in the column B represent the scores for the defect class misalignments. B-1, B-2 and B-3 are the three specific defects in the defect class misalignment. Similar reports are generated for all the six defect classes. From the report shown above, it is observed that parts 1, 2, 3, 5, 7 and 9 have the highest probability of 0.25 of being mislaigned in the final assembly.

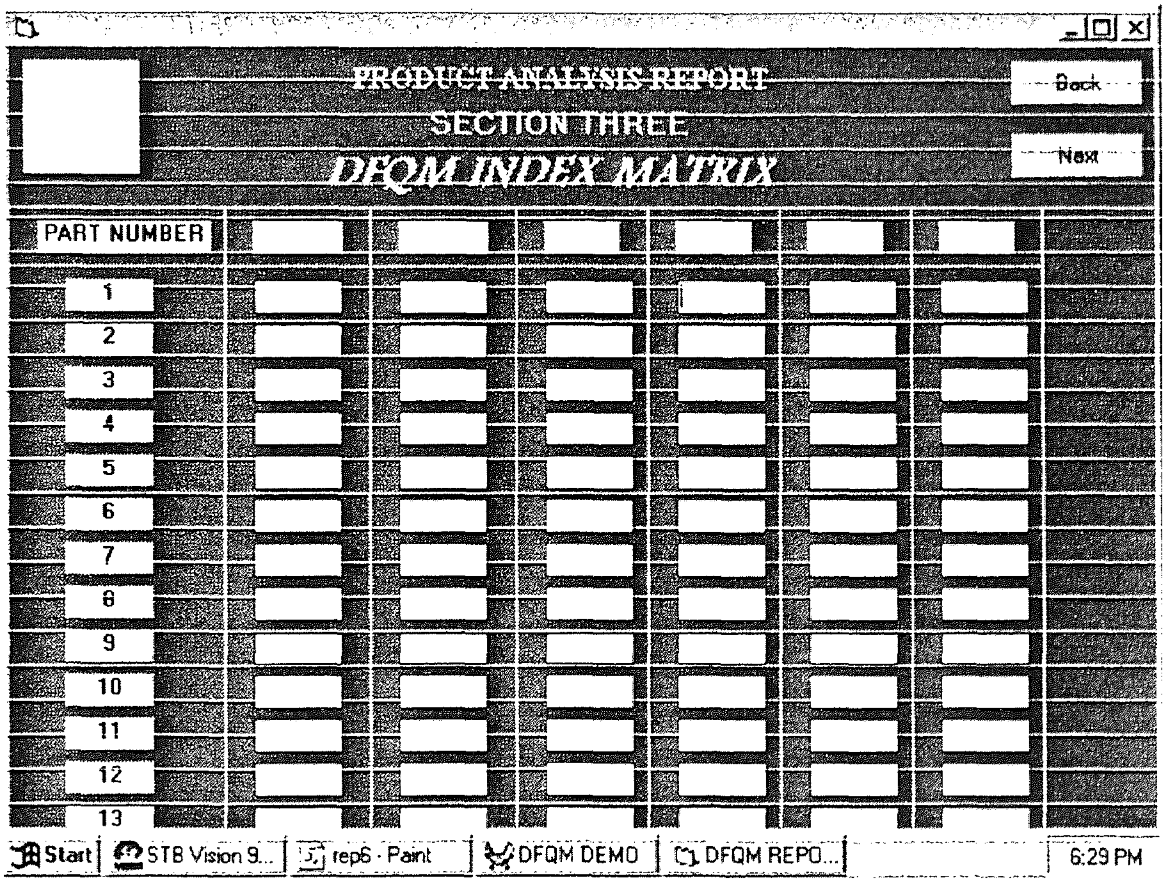


Figure 3.4.3 Sample report for final DFQM matrix

Figure 3.4.3 shows the final DFQM matrix . All the six defect classes appear in the final DFQM matrix. The scores for these defect classes are derived by taking the maximum score among the specific defects belonging to that defect class.

CHAPTER 4

DESIGN IMPROVEMENT USING REVERSE ANALYSIS

4.1 Introduction

Presently the DFQM method evaluates a design. In this section we introduce a procedure to wazzu help the designer improve the design so as to get a better QM-Index score. The final output of the DFQM analysis is the QM-Index score which is an n * n matrix. 'n' represents the number of parts in the assembly. The matrix has values between 0 and 1 for each of the error catalysts in a defect class. As mentioned earlier there are six defect classes in total. The intermediate QM for particular specific defect is derived based on the relative weightage of the error catalysts for a particular specific defect. This intermediate QM score is inturn used to derive the final QM score for that defect class. The final matrix represents the scores for all the six defect classes thus derived. The sample DFQM matrix was earlier shown in the section.

Reverse Analysis takes into consideration the process variables that effect the quality of the design. These process variables are identified on the basis of the factor variables that cause the quality defects. A set of generic statements has been developed for each error catalyst based on the factor variables. These statements are automatically triggered whenever the DFQM score for the part exceeds a threshold value. The reverse analysis tool does the analysis on a part by part basis. The methodology based on which the generic statements are triggered is discussed in detail in the following sections. A list of generic statements for each error catalyst is presented in the following section.

4.2 Generic Improvement Statements

Missing or misplaced part is one of the specific defects that is found in mechanical assembly. Missing or misplaced part is mostly associated with the following assembly processes : Insertion, Fastening, Precise fit and Snap fit. Activities pertaining to these four assembly processes are common to all the four assembly processes having this defect.

The influencing factors relevant to the insertion, fastening and snap fit processes are geometrical features, assembly procedure, fastening system and material properties. Reverse analysis mainly helps the designer to improve the design by identifying the factors that reduce the quality manufacturability of the design. Based on this hypothesis a set of generic statements were developed for each of the six defect classes. These generic statements are nothing but a detailed description of the influencing factors or process variables. The set of generic statements generated for defect class Missing/mispalced parts are shown in figure 4.2.1(a) and 4.2.1(b).

No.	Statement	Error Catalyst
1.	Too Many similar components in assembly	A11
2.	Manual assembly of similar components	A11
3.	Error in programming the location of the component in robotic assembly	A12
4.	Presence of hidden parts	A13
5.	Manual assembly of hidden parts	A13
6.	Positioning and fastening of parts done at different workstations	A14
7.	Positioning and fastening of part done at same workstation but in different stages	A14

Figure 4.2.1 (a) Missing/Misplaced parts defect class

No.	Statement	Error Catalyst
8.	Part not critical for functionality of the product	A15
9.	Part not critical for structural integrity of the assembly	A15
10.	Too many parts mating with a non-functional part	A15
11.	Too many similar parts with a slight difference in dimensions	A21
12.	Absence of positioning elements	A21
13.	More than two parts with congruent mating features	A22
14.	Part has more than one congruent mating feature	A31
15.	Positioning elements not present for orienting the part correctly	A31
16.	Part made up of flexible material which might lead to mispositioning of the part when fastened	A32
17.	Use of Press fit or Tight fit is not suitable for this assembly	A33
18.	Alignment of mating parts not clearly defined	A33
19.	Unfinished or a rough surface which can cause damage to any flexible parts in the assembly	A34

Figure 4.2.1(b) Missing/Misplaced parts defect class

The occurrence of Misalignment in most assemblies is due to lack of alignment measures and positioning elements or locators. Also the number of contact points between mating surfaces are crucial to ensure proper alignment. The influencing factors identified to be the root causes for this defect class were identified to be fastening system, part interrelationship, assembly procedure, material properties and tolerance interrelationships. Based on these influencing factors, a set of generic statements were developed which can be seen in figure 4.2.2.

No.	Statement	Error Catalyst
20.	Part has too many mating surfaces when compared to the number of parts the part is mating with	B11
21.	Positioning of fastening elements not present in all the mating directions	B11
22.	Ratios of coefficient of expansion of the material vary significantly leading to axial misalignment on changes in temperature	B12
23.	Very small surface area mapped by the fastener hence part can be axially misaligned	B13
24.	Direction of separating force acting angular or perpendicular to the fastening axis	B13
25.	Ratios of coefficient of expansion of the material vary significantly leading to radial misalignment on changes in	B22
26.	Area mapped by the fastener too small	B23
27.	Direction of separating force parallel or perpendicular to the axis of mating	B23
28.	Ratio of number of mating surfaces to mating parts too high	B31
29.	Direction of gravitational force opposite to the direction of mating	B31
30.	Ratios of coefficient of expansion of the material vary significantly leading to radial misalignment on changes in temperaturetemperature	B32
31.	Direction of separating force acting parallel to the fastening axis	B33
32.	Part fastened to a fastener with multiple components	B33
33.	Mating surfaces present at an angle	B41
34.	Center of gravity of the part acting at its extreme end	B41
35.	Fastening accessibility limited	B42

Figure 4.2.2 Defect class Misalignment

Unplanned contact is established between the moving member of the assembly and the static parts. The occurrence of the defect part interference is mainly attributed to non adherence of the stipulated assembly procedure. The generic statements developed for this defect class are shown in figure 4.2.3.

No.	Statement	Error Catalyst
37.	Proximity of rotating members to stationary parts	C11
38.	Assembly has close clearance between rotating members & shaft, hence the weld metal deposits cause constant interference	C12
39.	Rotating member misaligned due to improper fastening sequence	C12
40.	Bending of shaft or rotating member due to improper handling during assembly	C13
41.	Flexible parts present in the vicinity of moving or rotating part	C21
42.	Bearings for the rotating member not installed properly. This can cause the rotating member to vibrate when subjected to vibrations.	C31

Figure 4.3.3 Defect class Interference

The nature of fit between the parts in a assembly is greatly influenced by the assembly methodology. Fastener related problems addresses manufacturing quality defects associated with this methodology. Loose or ill fit fasteners and fracture or failure in a fastener are the two types of defects identified for the defect class fastener related problems. The factor (process) variables leading to these defects were found out to be geometrical features, material properties, asssembly procedure, material handling and fabrication. The generic statements developed for this defect class based on the above mentioned factor variables are shown in figure 4.3.4.

No.	Statement	Error Catalyst
43.	Part subjected to variations in temperature(Prior/Post assembly)	D11
44.	Ratios of coefficient of part and fastener vary significantly	D11
45.	Fastener mapping area too small which may allow heavy parts to loosen fasteners	D12
46.	Fastener accessibility very low hence the assembly can have loose or Poor fitting fasteners when fastened manually	D13
47.	Part easy to access and tighten. Use of powertools can cause overtightening	D21
48.	Too many fasteners	D22
49.	Improper fastening sequence might be followed which can cause overtightening	D22
50.	Overtightening due to presence of auxiliary stress devices	D23
51.	Fastening accessibility very low and use of power assisted tools can cause fastener fracture or failure	D31
52.	Fastener with very low force mapping ratio. Part when subjected to eccentric loads can cause failure of the fastening system because of additional stresses	D32

Figure 4.2.4 Defect class Fastener related problems

The influencing factors for the other two defect classes Nonconformity and Damaged parts are material properties, type of machining and assembly procedure. The generic statements developed for the defect classes are shown in figure 4.2.5 and 4.2.6.

No.	Statement	Error Catalyst
53.	Part has very small cross-sectional area, hence if there are residual stresses present, as these stresses are resolved, the part undergoes strain in terms of warping etc. causing the surface to deform.	E11
54.	Material properties of mating parts dissimilar can cause surface nonconformity	E12
55.	Material susceptible to corrosion	E13
56.	Part material has embedded particles, in the absence of external pressure can cause mating parts to be nonconforming	E14
57.	Part has complicated surface, when machined can cause dimensional nonconformity	E21
58.	Mating parts have different physical properties and any change in temperature causes dimensional nonconformity	E22
59.	Part has relative motion with another part, chance of occurrence of wear increases when assembly starts functioning	E23

Figure 4.2.6 Defect class Nonconformity

No.	Statement	Error Catalyst
60.	Part made up of soft material when subjected to gravity feeding or bulk handling can cause considerable physical damage	F11
61.	Excessive fixturing force	F12
62.	Power fastening devices being used on a soft metal parts can result in physical damage	F13
63.	Gripper force higher than the handling force of the part	F14
64.	Use of gravity feeding and orienting devices can cause scratches or dents on soft material parts	F21
65.	Part can be misaligned when fastened using power driven tools can cause aesthetic damage to part	F22
66.	Conveyor line can't be used for both finished and unfinished(rough) parts	F23
67.	Excessive gripping force	F24

Figure 4.2.6 Defect class Damaged parts

4.3 Reverse Analysis Logic

The DFQM architecture as explained in the earlier sections consists of three identifying blocks, Influencing factors, Error catalysts and Defect classes. The manufactured quality of a product is an aggregate representation of the six defect classes. Any attempt to assess or improve the quality manufacturability (QM) of a design is focused on these classes of defects. DFQM analysis quantifies these defects on a 0 to 1 scale in the QM matrix. The Reverse analysis tool checks the scores for all the parts from this QM matrix. If the score for any part for a particular defect class exceeds a threshold value, then a set of generic statements (developed for all the six defect classes) indicating why the defect is occurring is brought to the knowledge of the user. These generic statements were developed on the basis that a set of factor variables are contributing towards the occurrence of a defect.

The Reverse analysis tool on identifying that the defect value for a score particular part has exceeded a threshold value checks the user inputs (which are stored in the database) for the design. It then passes these inputs to the Reverse analysis logic chart and based on the analysis decides to generate a set of generic statements. There are six logic charts in total with one for each defect class. The logic charts based on which these statements are generated is discussed in detail in the following pages. Note, the variables like a11, a1, a12, b1 etc., used in the following pages to explain the Reverse analysis logic represent the error catalyst scores.

Reverse Analysis logic for Missing/Misplaced Parts :

```
Condition 1.   If (a1 > 0.35) then
                {
                if (a11 > 0.4)
                        {
                        if (number of similar components to be assembled at same
                           stage >= 12) & (type of assembly = manual)
                                {
                                generate statement # 1 and statement #2
                                }
                        else  (if type of assembly = manual) & (number of similar
                              components  to be assembled at same stage < 12)
                                {
                                generate statement # 2
                                }
                        }
                }

Condition 2.   If (a2 > 0.3) then
                {
```

```
                if (a21 > 0.15)
                        {
                        if (number of similar parts in assembly  > 10) & (positional
                                    elements presence = yes) then
                                        {
                                        generate statement # 11
                                        }
                        else
                                {
                                generate statement # 12
                                }
                        }
                if (a22  > 0.3)
                        {
                        if (number of parts with congruent mating features > 2)
then
                                {
                                generate statement # 13
                                }
                        }
                }
Condition 3.    If (a3 > 0.3) then
                {
                if (a31 > 0.25) then
                        {
                        if (number of congruent features in the part > 1) &
                          (presence of positional elements = no)
                                {
                                generate statement # 14
                                }
        wazzu           if (presence of positional elements = yes) then
                                {
                                generate statement # 15
                                }
                        }
                if (a32 > 0.3) then
                        {
                        if (type of material = al,cu,sb,plastic or rubber) then
                                {
                                generate statement # 16
                                }
                                }
                if (a33 >0.25) then
                        {
```

```
                if ( positional relationship = B2 or C2) & (type of fit <>
                    press fit ) then
                        {
                        generate statement # 17
                        }
                if (type of fit = press fit or tight fit) then
                        {
                        generate statement # 18
                        }
                }
        if (a34 > 0.5) then
                {
                if (type of flexible parts mating with hole = springs) then
                        {
                        generate statement # 19
                        }
                }
        }
```

Condition 4. Count number of parts satisfying conditions 1, 2 and 3. If this number is greater than one third of the total number of parts in the assembly, then the statements generated in conditions 1, 2 and 3 will be displayed.

Reverse Analysis logic for Misalignments :

Condition 1.

```
If (b1 > 0.3) then
        {
        if (b11 > 0.3) then
                {
                if (ratio of no. of mating surfaces to mating parts > 1) then
                        {
                        generate statement # 20
                        }
                else if (ratio of number of mating surfaces to mating parts <
                                1) & (presence of fasteners in all mating
directions =                                  no) then
                        {
                        generate statement # 21
                        }
                }
        if (b12 > 0.25) then
                {
                if (ratios of coefficient of expansion of mating parts <> 10)
                        then
```

```
                    {
                    generate statement # 22
                    }
                }
            if (b13 > 0.25) then
                {
                if (fastener code = F3 ) then
                    {
                    generate statement # 23
                    }
                if ( fastener code = D1 or D2 or D3) then
                    {
                    generate statement # 24
                    }
                }
            }


Condition 2.   If (b2 > 0.3) then
            {
            if (b22 > 0.4) then
                {
                if ( ratios of coefficient of expansion of mating parts > 1.2)
                    then
                    {
                    generate statement # 25
                    }
                }
            if (b23 > 0.3) then
                {
                if (fastener code = F3 ) then
                    {
                    generate statement # 26
                    }
                if ( fastener code = D1 or D2 or D3) then
                    {
                    generate statement # 27
                    }
                }
            }
Condition 3.   If (b3 > 0.3) then
            {
            if (b31 > 0.4) then
                {
```

```
                if (ratio of number of mating surfaces to mating parts >= 2)
                           then
                        {
                        generate statement # 28
                        }
                if (ratio of number of mating surfaces to mating parts >1
                        and < 2) &
                 (direction of gravitational force = opposite to the direction
                  of mating) then
                        {
                        generate statement # 29
                        }
                }
        if (b32 > 0.4) then
                {
                if ( ratios of coefficient of expansion of mating parts > 1.2)
                then
                        {
                        generate statement # 30
                        }
                }
        if (b33 > 0.2) then
                {
                if (fastener code = D1 or D2 or D3) then
                        {
                        generate statement # 31
                        }
                if (fastener code =  E1) then
                        {
                        generate statement # 32
                        }
                }
        }

Condition 4.    If (b4 > 0.25) then
        {
        if (b41 >= 0.1) then
                {
                if (presence of mating surface at an angle = yes) then
                        {
                        generate statement # 33
                        }
                if (presence of mating surfaces at an angle = no) &
                   (center of gravity of the part acting at extreme end = yes)
                        then
```

```
                {
                generate statement # 34
                }
        }
if (b42 > 0.3) then
        {
        if (fastener code = D1 or D2 or D3) then
                {
                generate statement # 36
                }
        if (fastener code = F3) then
                {
                generate statement # 35
                }
        }
}
```

Condition 5. Count number of parts satisfying conditions 1, 2, 3 and 4. If this number is greater than one third of the total number of parts in the assembly, then the statements generated in conditions 1, 2, 3 and 4 will be displayed.

Reverse Analysis logic for Interference :

Condition 1. If (c1 > 0.4) then

```
{
if (c11 > 0.3) then
        {
        if (location of surface with respect to shaft = lower half)
                then
                {
                generate statement # 37
                }
        }
if (c12 > 0.3) then
        {
        if (weld clearance between rotating member and shaft =
            low) then
                {
                generate statement # 38
                }
```

```
                    if (weld clearance between rotating member and shaft =
                       high) & (presence of fasteners = yes) & (geometry of
the                                part = T1) then
                              {
                              generate statement # 39
                              }
                    }
          if (c13 > 0.4) then
                    {
                    if (type of material handling = gravity feed or bulk
handling)                          then
                              {
                              generate statement # 40
                              }
                    }
          }

Condition 2.   If (c2 > 0.3)
          {
          if (c21 > 0.4) then
                    {
                    if (flexible parts present in the vicinity of moving part =
yes)                          then
                              {
                              generate statement # 41
                              }
                    }
          }

Condition 3.   if (c3 > 0.3) then
          {
          if (c31 > 0.45) then
                    {
                    if (number of bearings supporting the rotating member = 2)
                              then
                              {
                              generate statement # 42
                              }
                    }
          }
```

Condition 4. Count number of parts satisfying conditions 1, 2 and 3. If this number is greater than one third of the total number of parts in the assembly, then the statements generated in conditions 1, 2 and 3 will be displayed.

Reverse Analysis logic for Fastener Related Problems :

```
Condition 1.   If (d1 > 0.3) then
                     {
                     if (d11 > 0.45) then
                            {
                            if (part being subjected to variations in temperature = yes)
                            & (ratios of coefficient of expansion > 2) then
                                   {
                                   generate statement # 43
                                   }
                            else if (part being subjected to variation in temperature =
                            no) &  (ratios of coefficients of expansion of parts is <= 1)
                            then
                                   {
                                   generate statement # 44
                                   }
                            }
                     if (d12 > 0.4) then
                            {
                            if (fastener code = B1 or B2) then
                                   {
                                   generate statement # 45
                                   }
                            }
                     if (d13 > 0.3) then
                            {
                            if (fastener code =  C3 or C4) then
                                   {
                                   generate statement # 46
                                   }
                            }
                     }

Condition 2.   If (d2 > 0.4) then
                     {
                     if (d21 > 0.5) then
                            {
                            if (method of fastening = D2) then
                                   {
                                   generate statement # 47
                                   }
                            }
                     if (d22  > 0.3) then
```

```
                {
                if (ratio of number of fasteners to mating parts > 4) &
                   (sequence of fastening importance = yes) then
                        {
                        generate statement # 49
                        }
                if (ratio of number of fasteners to mating parts < 4) &
                   (sequence of fastening importance = no) then
                        {
                        generate statement # 48
                        }
                }
        if (d23 > 0.3) then
                {
                if (auxiliary stress devices presence =  yes) then
                        {
                        generate statement # 50
                        }
                }
        }
```

Condition 3. If (d3 > 0.4) then

```
        {
        if  (d31 > 0.15) then
                {
                if (fastening accessibility = C4 or C5 ) then
                        {
                        generate statement # 51
                        }
                }
        if (d32 > 0.25) then
                {
                if (force mapping ratio = B1  or B2) then
                        {
                        generate statement # 52
                        }
                }
}
```

Condition 4. Count number of parts satisfying conditions 1, 2 and 3. If this number is greater than one third of the total number of parts in the assembly, then the statements generated in conditions 1, 2 and 3 will be displayed.

Reverse Analysis logic for Nonconformity :

```
Condition 1.   If (e1 > 0.4) then
               {
               if (e11 > = 0.5) then
                      {
                      if  (ratio of length to diameter or width >= 5) then
                             {
                             generate statement  # 53
                             }
                      }
               if (e12 > 0.4) then
                      {
                      if (material properties of mating parts = different) then
                             {
                             generate statement # 54
                             }
                      }
               if (e13 > 0.5) then
                      {
                      if (material susceptible to oxidation = yes) then
                             {
                             generate statement # 55
                             }
                      }
               if (e14 >  0.2) then
                      {
                      if (presence of embedded particles in material = yes) then
                             {
                             generate statement # 56
                             }
                      }
               }

Condition 2.   If (e2 > 0.3) then
               {
               if (e21 > 0.4) then
                      {
                      if (geometry classification code = R4 or R6 or T4) then
                             {
                             generate statement # 57
                             }
                      }
               if (e22 > 0.4) then
                      {
                      if (fasteners or positional elements presence = no) then
```

```
                {
                generate statement # 58
                }
        }
if (e23 > 0.6) then
        {
        if ( positional relationship = B1) then
                {
                generate statement # 59
                }
        }
}
```

Condition 3. Count number of parts satisfying conditions 1 and 2. If this number is greater than one third of the total number of parts in the assembly, then the statements generate conditions 1 and 2 will be displayed.

Reverse Analysis logic for Damaged Parts

Condition 1. If (fl > 0.4) then

```
{
if (f11 > 0.6) then
        {
        if (material type =  plastic or aluminium or copper) then
                {
                generate statement # 60
                }
        }
if (f12 >  0.5) then
        {
        if (part held across length while fixturing = yes) then
                {
                generate statement # 61
                }
        }
if (f13 > 0.3) then
        {
        if (material type = soft) then
                {
                generate statement # 62
                }
        }
if (f14 >  0.6) then
        {
        if (material type = rubber or aluminum or copper) then
```

```
                        {
                        generate statement # 63
                        }
                }
Condition 2.   If (f2 > 0.5) then
        {
        if (f21 > 0.5) then
                {
                if (material type = aluminum or rubber) then
                        {
                        generate statement # 64
                        }
                }
        if (f22 > 0.6) then
                {
                if (material type = plastic or aluminum) then
                        {
                        generate statement # 65
                        }
                }
        if (f23 > 0.5) then
                {
                if (any unfinished parts present while conveying = yes) then
                        {
                        generate statement # 66
                        }
                }
        if (f24 > 0.7) then
                {
                if (material type = aluminum, copper or tin) then
                        {
                        generate statement # 67
                        }
                }
        }
```

Condition 3. Count number of parts satisfying conditions 1 and 2. If this number is greater than one third of the total number of parts in the assembly, then the statements generate conditions 1 and 2 will be displayed.

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CHAPTER 5

CASE STUDIES

5.1 Introduction

The purpose of this chapter is to illustrate the practical feasibility of DFQM Methodology. Two case studies are presented in the current chapter. For each of the products, the data required for the DFQM analysis is inputted in the DFQM Software which then analyses the design and comes up with the DFQM matrix. Based on this DFQM matrix and using Reverse Analysis (as explained in chapter 4) a set of possible design solutions to minimize these defects are given for each of the products. The new DFQM matrix obtained on implementing these changes is also discussed.

5.2 Rubber Stamp Assembly

Rubber Stamp assembly was chosen primarily to present and explain the concept of DFQM in a simple and effective way. A drawing of the Rubber Stamp assembly is shown in figure 5.2.1.

The original design of the Stamp assembly consisted of the following parts :

1. The main Gear .
2. Two small Gears.
3. Bracket.
4. Spring.
5. Fastener for the Spring.

6. Metal strip.
7. Belt rest.
8. Pin.
9. Belt's(3 no's).
10. Base.
11. Handle.
12. Fastener for the whole assembly.
13. Housing's.

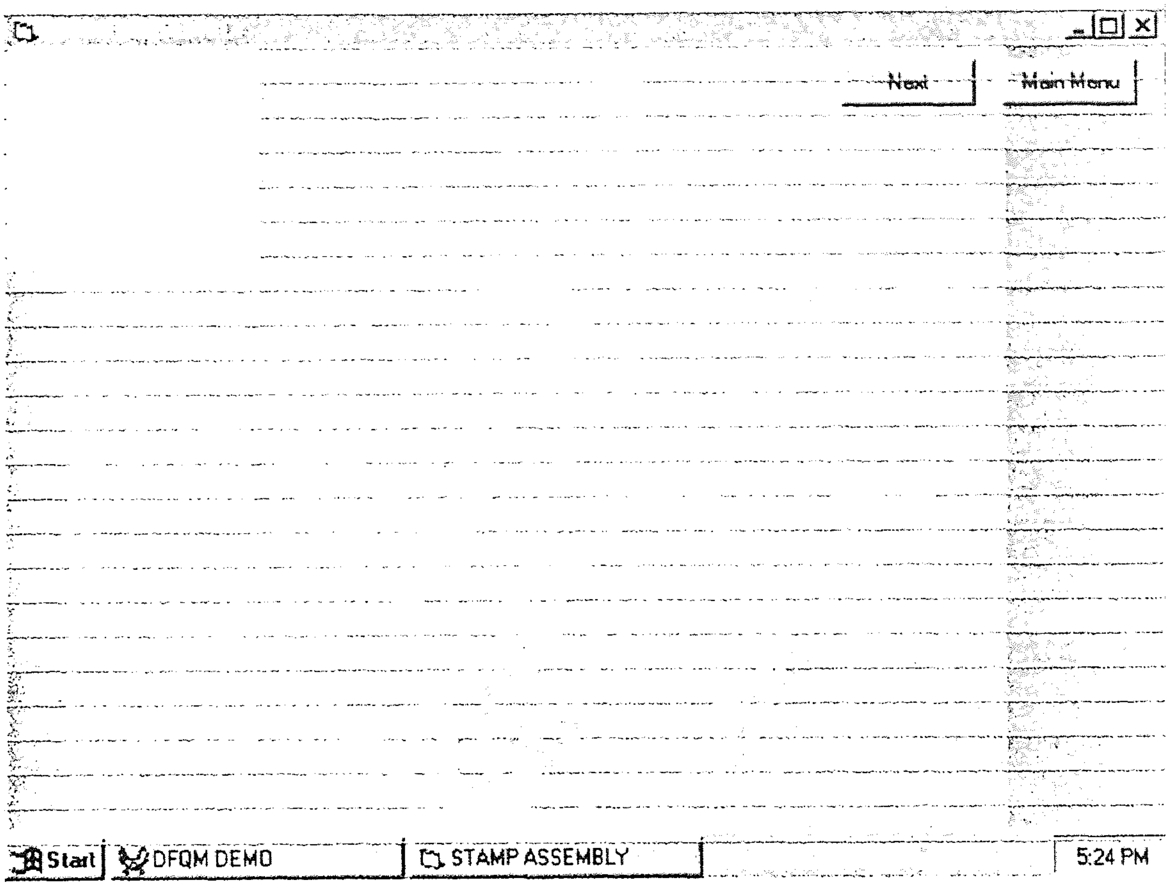


Figure 5.2.1 Rubber stamp assembly

DFQM analysis was conducted on the Assembly and the following QM- Matrix was evolved. Based on the scores in the matrix it was evident that, there was scope for improvement in the design of the stamp assembly. A discussion is also done on the six defect classes based on the DFQM matrix which is shown in figure 5.2.2.

The Design For Quality Manufacturability Index DFQM

PRODUCT ANALYSIS REPORT

DFQM INDEX

Previous Report

EXIT

PART NUMBER						
1	0.00	0.10	0.37	0.00	0.13	0.11
2	0.02	0.10	0.00	0.00	0.13	0.00
3	0.39	0.10	0.00	0.00	0.15	0.00
4	0.02	0.10	0.36	0.00	0.13	0.11
5	0.02	0.00	0.36	0.00	0.02	0.11
6	0.33	0.10	0.33	0.00	0.13	0.00
7	0.00	0.10	0.00	0.00	0.13	0.00
8	0.33	0.10	0.00	0.00	0.19	0.00
9	0.02	0.10	0.00	0.00	0.02	0.00
10	0.00	0.10	0.00	0.00	0.13	0.00
11	0.33	0.00	0.00	0.00	0.02	0.00
12	0.00	0.00	0.00	0.00	0.02	0.00
13	0.00	0.00	0.00	0.00	0.08	0.00

Figure 5.2.2 QM matrix for the Rubber stamp

1. Misplaced or Missing parts -

According to the DFQM matrix it is evident that almost all parts have probability of being missed or misplaced during assembly.

a. The spring has the highest DFQM score for the part to be missed or misplaced, this is because this is not a key part in the assembly.

b. The other part that could be misplaced is the belt , this is because there are three belts and all these belts can be interchanged resulting in an undesirable month, date, year combination.

2. Part Misalignment -

DFQM scores show a very high value for the Main gear, Bracket, Pin, two Small gears, Belt, Housings, and Metal strip.

a. All the three gears may get misaligned, but once the housing is placed it will be in position. There by the score is not a valid score.

b. The Pin has a score for misalignment which is true as the pin does not have any positioning element.

c. The belt's score for misalignment is true as the belt's can be interchanged and they can also be placed in a reverse order leading to an inverted image during stamping.

d. The score shows that the housing could be misaligned but it will not happen as it has positioning elements at one end and the other end is fastened by a fastener.

e. The metal strip and the belt rest can be misaligned as there are no positioning elements.

Spring has a very high chance of being misaligned as the seating on the housing is very thin and the spring has a very high chance of being placed outside the seating resulting in the loss of the functionality of the product.

3. Part interference -

The DFQM score shows Part interference for all the three gears and the belts

a. The main gear has interference with the housing and also with the belts on the smaller gears resulting in reduction in the life of the belts.

b. The two smaller gears have constant interference with the main gear which is not desirable.

4. Fastener related defects -

The DFQM scores show that there cannot be any defect related to this defect class. This is true as the design uses only one fastener and the chance for this fastener to be loose or ill fitted, over tightened, and failure due to fracture is negligible.

5. Non conformance -

The DFQM score is valid for the bracket, pin, and the metal strip but it is not valid for the three gears as the score is based on the L/D ratio and not due to the thick cross section of the material.

a. The bracket has a thin cross section, thus the score is a valid score.

b. The pin will not bend due to the material used, and hence the score is'nt valid.

c. The metal strip has a thin cross section and it has a good chance of not conferring, which results in non conformance.

d. The base has a score for non conformance . This score is'nt valid as the base has a thick cross section.

6. Damaged parts -

The DFQM matrix shows a score for the three gears, these scores are valid because of the material used.

The proposed design changes based on the DFQM scores are as follows :

From the DFQM scores it is evident that the spring and the bracket have maximum quality defects. The design improvement was done in such away that these parts can be eliminated without affecting the functionality of the whole product . The following design changes were implemented.

1. The basic functionality of the spring and the bracket was to provide the linear movement for the whole gear and the belt assembly. This provided the necessary flexibility for the whole assembly but this was also the reason for the high DFQM scores and the failure of the whole assembly. In our new design we eliminated these two parts i.e. the spring and the bracket which resulted in the removal of the fastener for the spring also.

2. The belts have a DFQM score of misalignment and misplacement, this score was reduced by providing a step on the gear and varying the size of the slot. Due to the varying slot dimensions all the belts are of different sizes and only the right belt will fit into the right gear. The misalignment of the belt was avoided by providing a small protrusion on the reverse side of the belt and a corresponding slot on the gear, this ensured that the belt is not placed in any other manner other than desired.

3. The misplacement and the misalignment of the pin can be avoided by providing a step on the pin and a corresponding slot on the casting, this will ensure that the pin will always be in position.

4. The metal strip is also be provided with a step and a slot on the housing this will result in positioning of the metal strip and the belt rest with it.

The material used in the gear was changed from aluminum to plastic (Teflon) resulting in less damage to the gears compared to the older gears during material handling, thus effectively improving the design from the assembly point of view.

Based on the design changes proposed a new design for the rubber stamp is developed. The drawing of the new design for the Rubber stamp is shown in figure 5.2.3. The proposed design for the Rubber stamp consisted of the following parts, they are ;

1. The main Gear .
2. Two small Gears.
3. Metal strip.
4. Belt rest.
5. Pin.
6. Belt's(3 no's).
7. Base.
8. Handle.
9. Fastener for the whole assembly.
10. Housing's.

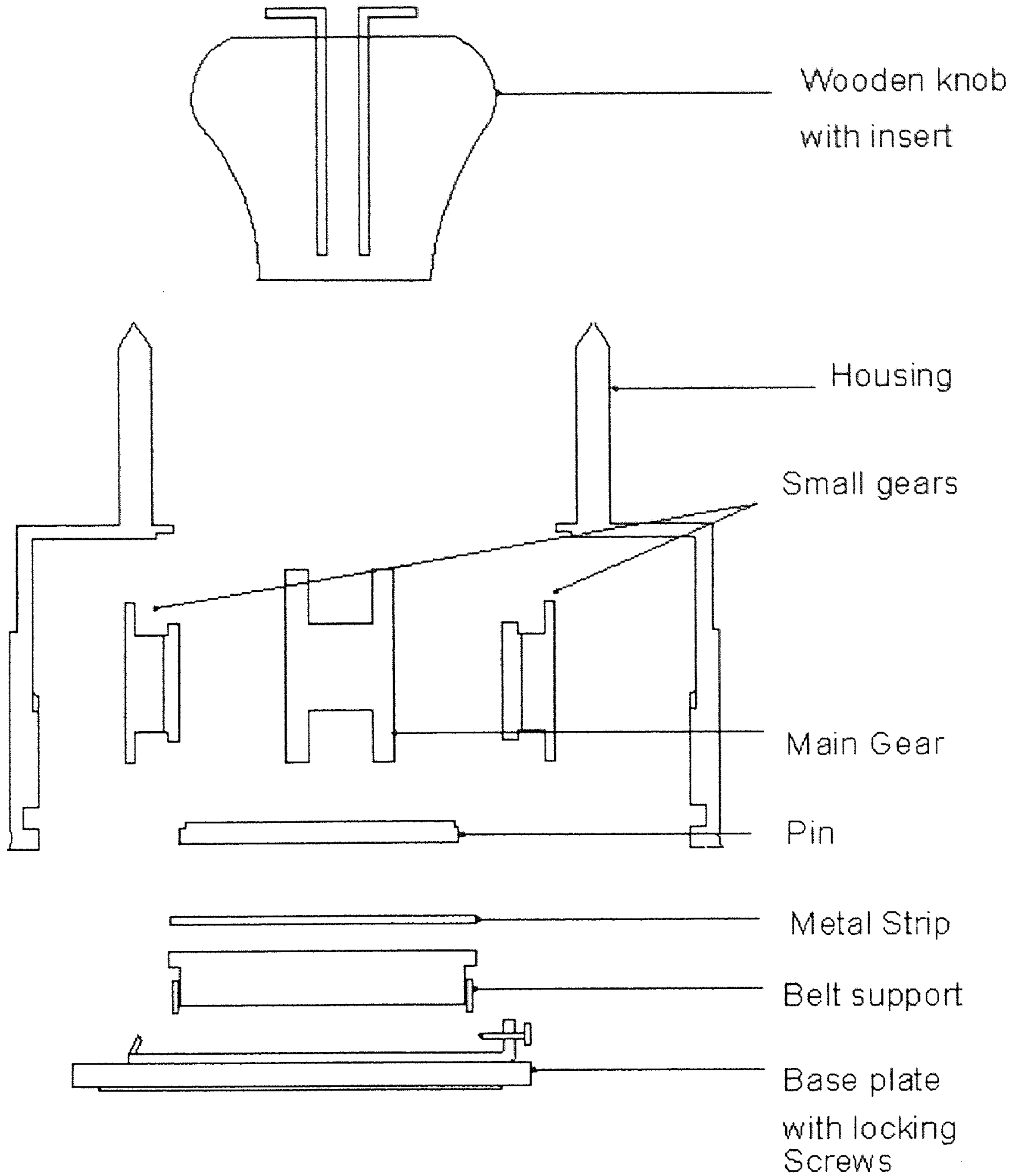
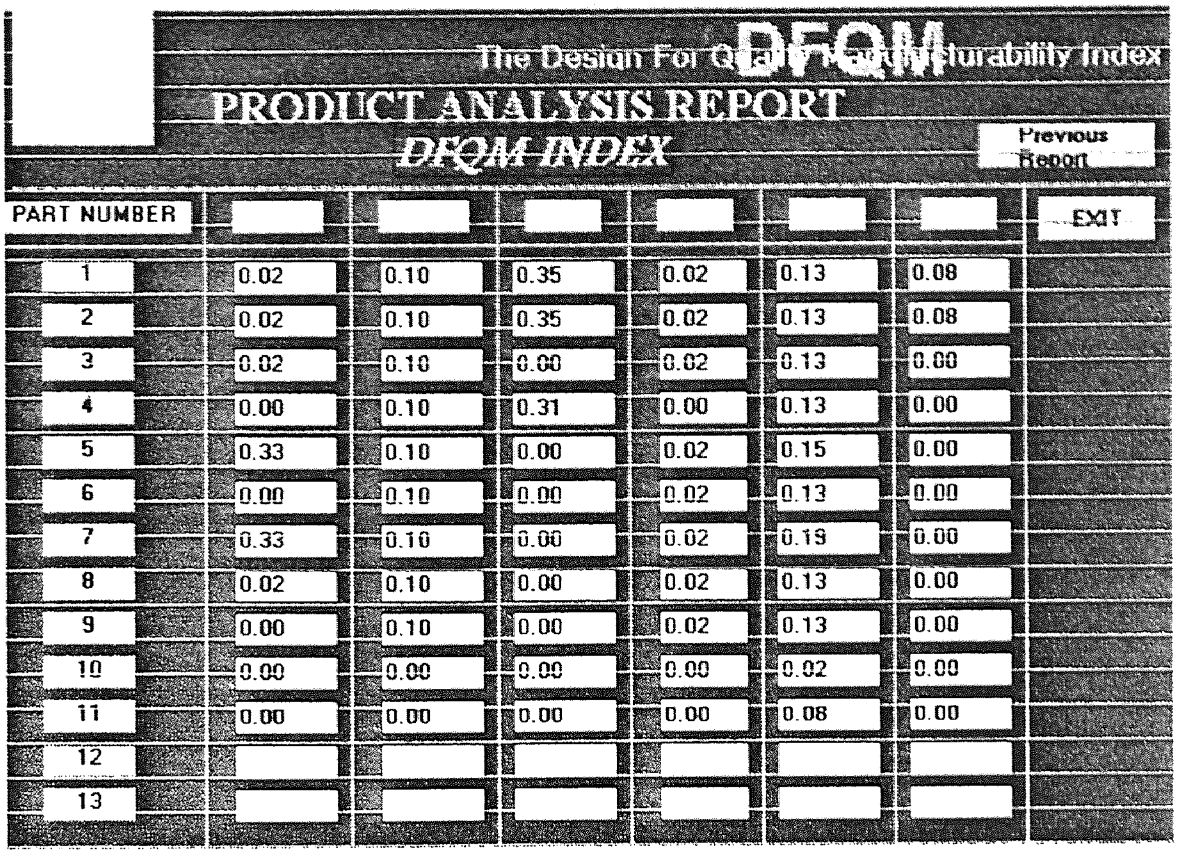


Figure 5.2.3 Modified Stamp Assembly

DFQM analysis was conducted on the Assembly and the QM- Matrix shown in figure 5.2.4 was evolved. Based on the scores we can conclude that the proposed design is better than the old design as it has a high design efficiency from quality perspective.



PART NUMBER						
1	0.02	0.10	0.35	0.02	0.13	0.08
2	0.02	0.10	0.35	0.02	0.13	0.08
3	0.02	0.10	0.00	0.02	0.13	0.00
4	0.00	0.10	0.31	0.00	0.13	0.00
5	0.33	0.10	0.00	0.02	0.15	0.00
6	0.00	0.10	0.00	0.02	0.13	0.00
7	0.33	0.10	0.00	0.02	0.13	0.00
8	0.02	0.10	0.00	0.02	0.13	0.00
9	0.00	0.10	0.00	0.02	0.13	0.00
10	0.00	0.00	0.00	0.00	0.02	0.00
11	0.00	0.00	0.00	0.00	0.08	0.00
12						
13						

Figure 5.2.4 QM matrix for the proposed Rubber stamp

The DFQM analysis for the proposed stamp assembly was performed and the following recommendations were implemented and for the new design a new DFQM matrix was evolved (figure 5.2.4) and the score is analyzed.

1. Misplacement or Missing of Parts.

The DFQM matrix shows a high score for the pin and the metal strip, this score is not valid as the pin and the metal strip are key elements in the assembly. There by these elements cannot be missed in the assembly.

2. Part Misalignment.

The DFQM matrix shows a score for misalignment, this score is valid for the gears as the gears are not positioned in one place and they have a slight chance of misalignment. The DFQM score of misalignment for the housing, the metal strip, the pin, belts are not the true value as these parts have positioning elements and their chance of misalignment during assembly does not exist.

3. Part Interference.

The DFQM Matrix shows a score for the three gears this value is true as the gears have a part interference with the housing.

4. Fastener related defects.

There is practically no problem with fastener as only one fastener is used for the whole assembly and the DFQM score is a correct score.

5. Total Nonconformity.

The total nonconformity score for the pin and the metal strip. The score is not true or the pin as the pin will not bend because of the material used and it has a thick cross section, where as the score is based on the L/D ratio.

6. Damaged Parts.

The gears have a score for this defect class and this score is true because of the material used.

5.3 Car Door Handle Assembly

The original design for the door handle assembly included these following parts. The handle, the frame, Handle lock, connecting rod , spring and the rubber frame. The DFQM analysis was conducted on the assembly and the DFQM matrix shown in figure 5.3.1 was evolved.

DFQM

PRODUCT ANALYSIS REPORT

DFQM INDEX

Previous Report

EXIT

PART NUMBER						
1	0.02	0.06	0.31	0.00	0.04	0.00
2	0.00	0.06	0.00	0.00	0.13	0.00
3	0.02	0.00	0.00	0.00	0.02	0.00
4	0.07	0.06	0.00	0.00	0.15	0.11
5	0.02	0.00	0.07	0.00	0.04	0.11
6	0.00	0.00	0.00	0.00	0.02	0.00
7						
8						
9						
10						
11						
12						
13						

Figure 5.3.1 QM matrix for the Door handle assembly

From the QM matrix the following conclusions were made which are illustrated below on a defect class basis.

1. Misplaced or Missing of Parts.

The DFQM score shows a low score for all the parts and this score is true as all the parts are positioned and there is very little scope for misplacement or missing of parts.

2. Part Misalignment.

From the DFQM matrix it is clearly seen that the scores for all the parts in this defect class are less than 0.3 which implies that it is almost not possible to misalign any of the parts in the assembly .

3. Part Interference.

The scores for all the parts in the assembly for this defect class were also near to 0, as there is very little chance of a part interfering with the other part. Hence the values shown in the matrix for this defect class reflects true values.

4. Fastener related defect.

The assembly does not have a score for this defect class as there are no fasteners used, hence this score is a valid score.

5. Total Nonconformity.

The score shows a high value for the connecting rod and frame, this score is not true as the cross section of the rod and the frame is not considered and the score is based only on the L/D ratio.

6. Damaged Parts.

The score shows a value for the connecting rod and the spring but these parts will not get damaged because of the type of material used.

It is evident from the DFQM matrix that the Door Handle Assembly design was extremely efficient and hence the need for coming up with an alternate design is not required.

CHAPTER 6

CONCLUSION

The end of this thesis leads to the conclusion result of five year research on DFQM methodology. The specific of this thesis allows us to draw the in following conclusions. DFQM methodology effectively evaluates a design and identifies its strengths and weakness with regards to quality manufacturability. This claim is substantiated in this thesis work with the help of two case studies. Clearly it is evident that DFQM analysis helps designers to expose the presence or lack of features in the design causing these defects. This objective is achieved the DFQM analysis with the help of Reverse analysis. Reverse analysis goes a step further in analyzing the process variables of the assembly processes, probes the factors influencing the occurrence of these defects and comes up with a set of statements (generic) for the improvement of the design. It is sort of an event driven approach which is whenever the QM score for a part exceeds a threshold value. It starts from error catalysts, directs towards defects and determines the influencing factors which cause these defects. Boothroyd and Dewhurst in their research have evaluated the handling and assembly difficulty to estimate the design efficiency of the product. This triggered approach doesn't take into consideration the process variables of different assembly processes and the quality defects that might arise during its manufacture to be able to provide an aggregated estimation. The approach is also useful for only analyzing the design and does not provide the designer with any tool to improve the design. The DFQM approach unlike the Boothroyd and Dewhurst method will be ale to identify sources of quality defects and measures to minimize their occurrence so as to improve design efficiency. Reverse analysis presented in this thesis work helps the designer in improving the design by specifically looking into the factors that cause these defects. The DFQM methodology including the Reverse analysis tool is a highly effective concurrent engineering tool.

DFQM analysis is currently applicable to Assembly processes only. Future scope for this research would be to extend the DFQM methodology to other branches of manufacturing like disassembly, electronic assembly etc. Also the existing error catalysts set can be extended further for the six defect classes by studying any new factor variables that are responsible for any of these defect classes.

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