Assessment on Design for Manufacturing (DFM) and Design for Assembly (DFA) of a Centrifuge

by

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Dissertation submitted in partial fulfillment of
the requirements for
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD ARIFFAN BIN ABD RAZAK

ABSTRACT

Design for Manufacturing (DFM) and Design for Assembly (DFA) are comprehensive approach to integrating the design process with production methods, materials, process planning, testing, and quality assurance. DFM and DFA require a fundamental understanding of the characteristics, capabilities, and limitations of materials, manufacturing processes, machinery, equipment, and tooling and variability in machine performance, dimensional accuracy and surface finish of the workpiece, processing time, and the effect of processing methods on product quality. Establishing quantitative relationships is essential in order to be able to analyze and optimize a design for ease of manufacturing and assembly at minimum product cost.

This project focused on the assessment of implementation of the DFM and DFA during prototype development process. Centrifuge was selected as the example in this project. The centrifuge was designed for offshore facility. Information such as design, parts manufacturing process, and assembly were analyzed in this project to assess the implementation of this approach during the prototype development cycle. It is noted that the application of the DFM and DFA have contribute to the success of the prototype development.

ACKNOWLEDGEMENTS

Primarily, I would like to express my utmost gratitude to Allah S.W.T The Almighty whom had made my Final Year Project a smooth sailing and a very meaningful and successful learning journey.

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INTRODUCTION

1.1 Background Study

Centrifuge have been used to explore a large variety of physical phenomena with augmented gravity, ranging from the study of statics and failure of materials used in civil engineering to the determination of human response to time dependent supergravity. A specific application of centrifugation that has an enormous potential for applications in microelectronics, solar enemy, and other fields is crystal growth. This project involving a fabrication of a centrifuge which contains several components. Applying DFM and DFA into this fabrication process may reduce some problems.

The technology advancement and improvement in our industry , improve the demand to the product. To fulfill this demand, the speed and capacity of production by a company must be enhanced. An analysis of the world market has shown that the customer requirements regarding functions and quality of products are continuously increasing but the customers are not willing to pay more for better products, and their requirements are changing all the time. 'Customer is the king' is becoming motto of today (Starbek and Grum, 2002).

The implementation of DFA and DFM led to enormous benefits including simplification of products, reduction of assembly and manufacturing cost, improvement of quality and reduction of time to market (Kuo, Huang and Zhang, 2001). Therefore, that is important to any company to improve productivity and their ability to fulfill customer requirement without neglecting the quality of the product that will be produced. DFM is a systematic methodology that will reduce he manufacturing cost through reducing the overall parts of the product and redesign the product paers, so the product will be easy to handle and assemble (Boothroyd and Dewhurst, 1991). DFM is a systematic procedure to maximize the use of manufacturing processes in the design of components and DFA is a systematic to procedure to maximize the use of components in the design of a product. The main of DFMA is to maximize the use of manufacturing processes and minimize the number of components in an assembly or product (Kalpakjian and Petronis, 2001).

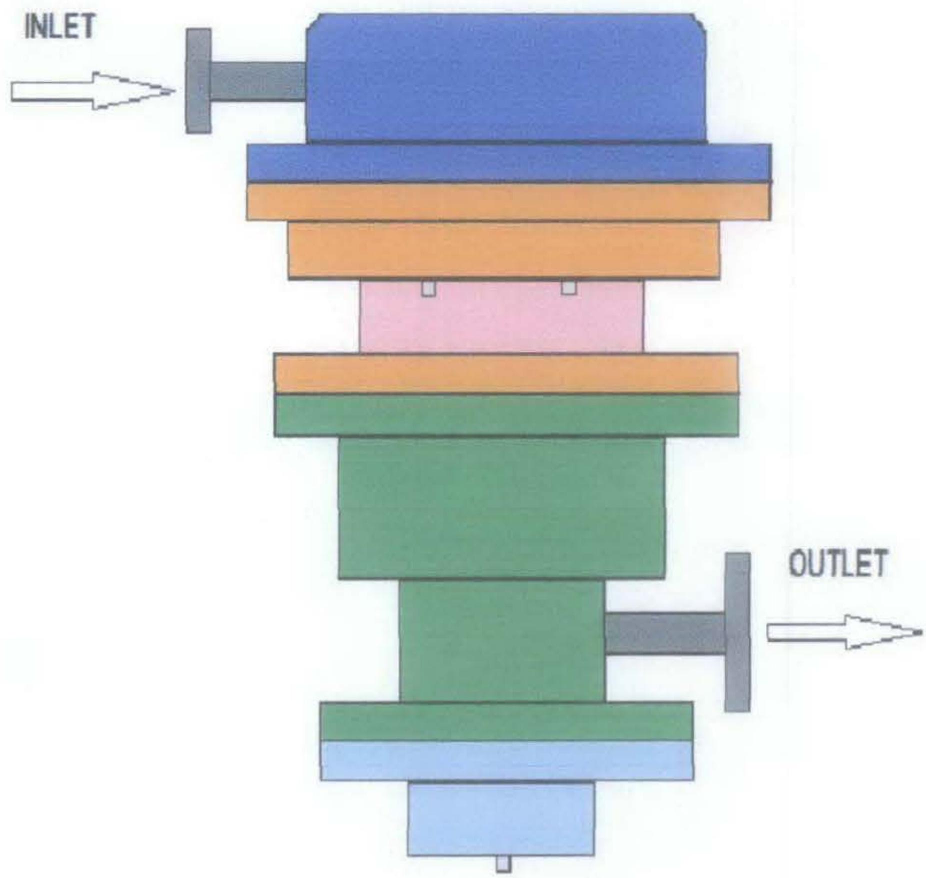


Figure 1: Centrifuge components

1.2 Problem Statement

A product normally consists of a number of components. Each of these components requires different manufacturing processes. These components need to assemble to form the product. The problem is to ensure that the product meet the specification during manufacturing so the assembly process don't occur problems.

1.3 Objectives

The objective of study is:

To assess the application of DFM and DFA for the centrifuge development process in order to meet the pressure rating standards.

1.4 Scope of Study

The project involves development of manufacturing drawing components and fixtures for development of blueprint for DFM and DFA of a centrifuge. The manufacturing drawing of the components and fixtures to include the dimensions and tolerances so as to enable the assembling to be done, to meet the required performance of the centrifuge. CNC machining, EDM and welding processes are involved.

CHAPTER 2

LITERATURE REVIEW

2.1 Design for Manufacturing

Design for Manufacturing (DFM) describes the process of designing or engineering a product in order to facilitate the manufacturing process in order to reduce its manufacturing costs and the product is meet the specification after the assembly process. DFM will allow potential problems to be fixed in the design phase which is the least expensive place to address them. The design of the component can have an enormous effect on the cost of manufacturing. Other factors may affect the manufacturability such as the type of raw material, the form of the raw material, dimensional tolerances, and secondary processing such as finishing [1].

DFM is about the whole process of manufacturing including procurement, inspection, cost, repeatability, functionality and usage. The scope of DFM has been in many ways include applications for different phases of design, to material and manufacturing process selection, and to assembly of the parts. Though this method, there are some general guidelines that suggest how manufacturing firms can gain from DFM concept. Useful, effective DFM guidelines are based on the specific products and performance measures of interest and are used in the design phase that have the most impact on performance and gain the manufacturer benefits [2].

Design for manufacture, DFM, means different things to different people. For the individual whose task is to consider the design of a single component, DFM means the avoidance of component features that are unnecessarily expensive to produce and from that, the product will be terminate from the design. Example includes the following:

- Specification of surfaces that are smoother than necessary on a machined component, necessitating additional finishing operations.

- Specification of wide variations in the wall thickness of an injection-moulded component.
- Specification of too-small fillet radii in a forged component.
- Specification of internal apertures too close to the bend line of a sheet-metal component.

Alternatively, the DFM of a single component might involve minimizing material costs or making the optimum choice of materials, minimizing part that not necessarily needed and processes to achieve a particular result. For example, can the component be cold-headed and finish-machined rather than machined from bar stock? All of these considerations are important and can effect the cost of manufacture. They represent only the fine-tuning of costs, however, and by the time such considerations are made, the opportunities for significant savings may have been lost.

It is important to differentiate between component or part DFM and product DFM. The former represents only the fine-tuning process undertaken once the product form has been decided upon; the latter attacks the fundamental problem of the effect of product structure on total manufacturing costs.

2.2 Design for Assembly

Design for Assembly (DFA) is a process by which products are designed with ease of assembly in mind and the mating parts are easily to assemble. If a product contains fewer parts it will take less time to assemble, thereby reducing assembly costs and also reduce man power. In addition, if the parts are provided with features which make it easier to grasp, move, orient and insert them, this will also reduce assembly time and assembly costs. The reduction of the number of parts in an assembly has the added benefit of generally reducing the total cost of parts in the assembly. This is usually where the major cost benefits of the application of design for assembly occur [1]. Assembly is an important phase of manufacturing and requires a consideration of the ease, speed, and cost of putting together the numerous individual components of a product. Assembly costs in manufacturing operations can be substantial, typically ranging from 20% to 60% of the products cost [3].

The aim of DFA is to simplify the product so that the cost of assembly is reduced and also less time consumption. However, consequences of applying DFA usually include improved quality and reliability, and a reduction in production equipment and part inventory. These secondary benefits often outweigh the cost reductions in assembly. DFA recognizes the need to analyze both the part design and the whole product for any assembly problems early in the design process. We may define DFA as a process for improving product design for easy and low-cost assembly, focusing on functionality and on assemblability concurrently [4].

The key to successful product DFM is product simplification through design for assembly, DFA. DFA techniques primarily aim to simplify the product structure so that assembly costs and time are reduced. Experiences showing, however, that the consequent reductions in part costs often far outweigh the assembly cost reductions. Even more important, the elimination of parts of a product as a result of DFA has several secondary benefits more difficult to quantify, such as improved reliability and reduction in inventory and production control costs. DFA, therefore, means much more than design to reduce assembly costs and, in fact, is central to the issue of product DFM. In other words, part DFM is the icing on the cake; product DFM through DFA is the cake. [5]

DFA derives its name from a recognition of the need to consider assembly problems at the early stages of design process; it therefore entails the analysis of both product and part design. For some years now, an assembly evaluation method, AEM, has been in use at Hitachi. In this proprietary method, commonly referred to as the Hitachi method (Miyakawa and Ohashi, 1986), assembly element symbols are selected from a small array of possible choices. Combinations of the symbols then represent the complete assembly operation for a particular part. Penalty points associated with each symbol are substituted into an equation, resulting in a numerical rating for the design. The higher the rating, the better the design.

Another quantitative method, developed by the authors and known as the Boothroyd and Dewhurst method (1987a), involves two principle step:

- The application of criteria to each part to determine whether, theoretically, it should be separate from all the other parts in the assembly.
- An estimate of the handling and assembly costs for each part using the appropriate assembly process – manual, robotic or high-speed automatic.

The first step, which involves minimizing the parts count, is the most important. It guides the designer towards the kind of product simplication that can result in substantial savings in product costs. It also provides a basis for measuring the quality of a design from an assembly standpoint. During the second step, cost figures are generated that allow the designer to judge whether suggested design changes will result in meaningful savings in assembly cost.

The third quantitative method used in industry is the GE/Hitachi method (Hock, 1987), which is basically the Hitachi method with the Boothroyd and Dewhurst criteria for parts-count reduction added. [6]

For business reasons, companies are seldom prepared to release their manufacturing cost information to the public. One reason is that many companies are not sufficiently confident about their costing procedures to want manufacturing costs made public for general discussion. In such an environment, designers will often not be informed of the cost of manufacturing the product they have been designing. Moreover, designers do not usually have the tools necessary to obtain immediate cost estimates relating to alternative product design schemes. Typically, a product will have been designed and detailed and a prototype manufactured before a manufacturing cost estimate is attempted. Unfortunately, by then it is too late. The opportunity to consider radically different products structures has been lost, and among those design alternatives might have been a version that is substantially less expensive to produce.

Currently, there is much interest in having product DFM and DFA techniques available on CAD/CAM systems. By the time a proposed product design has been sufficiently detailed to enter it into the CAD/CAM system, however, it is already too late to make radical changes. A CAD representation of a new product is an excellent vehicle for making effortless detail changes, such as moving holes and changing draft angles. But for considering product structure alternatives, such as the choice of several machined parts versus one die casting, a CAD system is not nearly as useful. These basic, fundamentally important decisions must be made at the early sketch stage in product design. [7]

A conflict thus exists. On the one hand, the designer needs cost estimates as a basis for making sound decisions; on the other hand, the product design is not sufficiently firm to allow estimates to be made using currently available techniques. The means of overcoming this dilemma is another key to successful product DFM – namely early cost estimating.

2.3 Design Consideration [8]

Element in a system is an important factor in the determination of the geometry and the dimensions of the element. In such a situation we say that strength is an important design consideration. When we use the expression design consideration, we are referring to some characteristic that influences the design of the element or perhaps, the entire system. Usually quite a number of such characteristics must be considered and prioritized in a given design situation. Many of the important ones are as follows (not necessarily in order of importance):

1. Functionality
2. Strength/stress
3. Distortion/deflection/stiffness
4. Wear
5. Corrosion
6. Safety
7. Reliability
8. Manufacturability
9. Utility
10. Cost
11. Friction
12. Weight
13. Life
14. Noise
15. Styling
16. Shape
17. Size
18. Control
19. Thermal properties
20. Surface
21. Lubrication
22. Marketability
23. Maintenance
24. Volume
25. Liability
26. Remanufacturing/resource recovery

Some of these characteristics have to do directly with the dimensions, the material, the processing, and the joining of the elements of the system. Several characteristics may be interrelated, which affects the configuration of the total system.

2.4 Design for Manufacturing / Assembly guidelines [9]

The heart of manufacturing system is a group of design principles or guidelines which are structured to help the designer reduce the cost and difficulty of manufacturing an item. These rules are to be fabricated for individual organization requirements, but following are a listing of few of them, which are common.

1. Reduce the total number of parts

The reduction of the number of parts in a product is probably the best opportunity for reducing manufacturing costs. Less parts implies less purchases, inventory, handling, processing time, development time, equipment, engineering time, assembly difficulty, service inspection, testing etc.

2. Black box a component / Develop a modular design

The use of modules in product design simplifies manufacturing activities such as inspection, testing, assembly, purchasing, redesign, maintenance, service and so on. One reason is that modules add versatility to product update in the redesign process, help run tests before the final assembly is put together, and allow the use of standard components to minimize product variations.

3. Use of standard components

Standard components are less expensive than customer made items. The high availability of these components reduces product lead time. Also, their reliability factors are well ascertained. Furthermore, the use of standard components refers the production pressure to the supplier, relieving in part the manufacturer's concern of meeting production schedules.

4. Design parts for multi-use

In any manufacturing company, different products can share parts that have been designed for multi-use. These parts can have the same or different functions when used in different products. In order to do this, it is necessary to identify the parts that

are suitable for multi-use. For example, all the parts that are commonly used in the firm (purchased / made) can be identified
and made one group of that. Then, part families are created by defining categories of similar parts in each group. The goal is to minimize number of categories, the variations within the categories and the number of design features within each variation. The result is set of standard part families, from which multi-use parts are created.

5. Analyze alternative manufacturing processes

Select the optimum combination between material and manufacturing process to minimize overall production cost. Many a times, making minor modifications in the detail design, a cost effective solution can be made for same functional requirement.

6. Avoid separate fasteners

Use of fasteners increases the most of manufacturing a part due to the handling and feeding operations that have to be performed. Besides the high cost of the equipment required for them, these operations are not 100% successful, so they contribute to reducing the overall manufacturing efficiency. In general, fasteners should be avoided and replaced, for example, by using tabs or snap fits. If fasteners have to be used, then some guides should be followed for selecting them. Minimize the number, size and variation used; also, utilize standard components whenever possible. Avoid screws that are too long, or too short and separate washers.

7. Make Fool-proof design

It consists of positioning, orienting, and fixing a part or component. To facilitate orientation, symmetric parts should be used whenever possible. If it is not possible, then the asymmetry must be exaggerated to avoid failures. Use external guiding features to help the orientation of a part. The subsequent operations should be designed so that the orientation of the part is
maintained.

8. Think simple

It has been experienced, that finding a complex and costly solution to any problem is relatively easy task, compared to a solution, which is very economic and simple. Use of advanced technology should be restricted only in those areas, where they are called for. The use of advanced technology calls for costly hardware, skilled operator and special training for maintenance. Designs made with commonly known principles are always preferred.

9. Maximize compliance

Errors can occur during insertion operations due to variations in part dimensions or on the accuracy of the positioning device used. This faulty behavior can cause damage o the part and/or to the equipment. For this
reason, it is necessary to include compliance in the part design and in the
assembly process. Examples of part built-in compliance features include tapers, undercuts or chamfers and moderate radius sizes to facilitate insertion, and nonfunctional external elements to help detent hidden features. The most common example of making entry chamfer for oil seal insertion is extension of this rule.

10. Engineering drawings should contain much more information than lines and texts.

It is the normal tendency of design engineers, to make drawings only for the requirements of function and not considering the 'How' part of manufacturing and measurement. Else, inadequate or ambiguous views are placed in the drawing, which makes manufacturer assume his convenient meaning of requirement.

2.5 Comparison of Assembly Methods

Assembly methods can be divided into three major groups. In *manual assembly,* parts are transferred to workbenches where workers manually assemble the product or components of a product. Hand tools are generally used to aid the workers. Although this is the most flexible and adaptable of assembly methods, there is usually an upper limit to the production volume, and labour costs (including benefits, cases of workers compensation due to injury, overhead for maintaining a clean, healthy environment, etc.) are higher.

Fixed or *hard automation* is characterised by custom-built machiner that assembles one and only one specific product. Obviously, this type of machinery requires a large capital investment. As production volume increases, the fraction of the capital investment compared to the total manufacturing cost decreases. Indexing tables, parts feeders, and automatic controls typify this inherently rigid assembly method. Sometimes, this kind of assembly is called "Detroit-type" assembly.

Soft automation or *robotic assembly* incorporates the use of robotic assembly systems. This can take the form of a single robot, or a multi-station robotic assembly cell with all activities simultaneously controlled and coordinated by a PLC or computer. Although this type of assembly method can also have large capital costs, its flexbility often helps offset the expense across many different products

2.6 Jig and Fixture [10]

Jigs and fixtures are production tools used to accurately manufacture duplicate and interchangeable parts. Jigs and fixtures are specially designed so that large numbers of components can be machined or assembled identically, and to ensure interchange ability of components. **Jig** is a guiding device while **fixture** is a holding device.

The economical production of engineering components is greatly facilitated by the provision of jigs and fixtures. The use of a **jig or fixture makes** a fairly simple operation out of one which would otherwise require a lot of skill and time.

Both jigs and fixtures position components accurately; and hold components rigid and prevent movement during working in order to impart greater productivity and part accuracy. Jigs and fixtures hold or grip a work piece in the predetermined manner of firmness and location, to perform on the work piece a manufacturing operation.

A jig or fixture is designed and built to hold, support and locate every component (part) to ensure that each is drilled or machined within the specified limits.

The correct relationship and alignment between the tool and the work piece is maintained. Jigs and fixtures may be large (air plane fuselages are built on picture frame fixtures) or very small (as in watch making). Their use is limited only by job requirements and the imagination of the designer.

The jigs and fixtures must. be accurately made and the material used must' be able to withstand wear and the operational (cutting) forces experienced during metal cutting

2.7 Economics [11]

The consideration of cost plays such an important role in the design decision process that we could easily spend as much time in studying the cost factor as in the study of the entire subject of design. Here we introduce only a few general concepts and simple rules.

First, observe that nothing can be said in an absolute sense concerning costs. Materials and labor usually show an increasing cost from year to year. But the costs of processing the materials can be expected t exhibit a decreasing trend because of the use of automated machine tools and robots. The cost of manufacturing a single product will vary from city to city and from one plant to another because of overhead, labor, taxes, and freight differentials and the inevitable slight manufacturing variations.

2.7.1 Standard sizes

The use of standard or stock sizes is a first principle of cost reduction. An engineer who specifies an AISI 1020 bar of hot-rolled steel 53 mm square has added cost t the product, provided that a bar 50 or 60 mm square, both of which are preferred sizes, would do equally well. The 53-mm size can be obtained by special order or by rolling or by machining a 60-mm square, but these approaches add cost to the product. To ensure that standard or preferred sizes are specified, designers must have access to stock lists of the materials they employ.

A further word of caution regarding the selection of preferred sizes is necessary. Although a great many sizes are usually listed in catalogs, they are not all readily available. Some sizes are used so infrequently that they are not stocked. A rush order for such sizes may mean more on expense and delay.

There are many purchased parts, such as motors, pumps, bearings, and fasteners, that are specified by designers. In the case of these, too, you should make a special effort to specify parts that are readily available. Parts that are made and sold in large quantities usually cost somewhat less than the odd sizes. The cost of rolling bearings, for example, depends more on the quantity of production by the bearing manufacturer than on the size of the bearing.

2.7.2 Large Tolerances

Among the effects of the design specifications on costs, tolerances are perhaps most significant. Tolerances, manufacturing processes, and surface finish are interrelated and influence the producibility of the end product in many ways. Close tolerances may necessitate additional steps in processing and inspection or even render a part completely impractical to produce economically. Tolerances cover dimensional variation and surface-roughness range and also the variation in mechanical properties resulting from heat treatment and other processing operations.

2.8 Centrifuge [12]

In this project, the author has been assigned to monitor a project that his supervisor is currently in progress which is process to produce a centrifuge involving lots of manufacturing technology methods. So this is the opportunity given to the author to apply DFM and DFA to this project.

This centrifuge is a device that separate gas from water. It is a project that joint venture with Baronia Research Center. A gas-water separator provided with a cylindrical partition wall member disposed in an upper portion within a casing of the separator to form an annular space between the partition wall member and the casing, with rotary vanes being disposed in the annular space and with upper and lower portions of the annular space and an inside bore of the partition wall member being connected to an inlet side, a drain valve portion and an outlet side, respectively, of the separator. The separator is provided with obliquely, downwardly inclined walls and spiral walls, each projecting outwardly gradually from an upper end of each of the inclined walls toward a lower end thereof and connected in a stepped configuration to a radial end wall at the lower end of the inclined wall. The obliquely, downwardly inclined walls and the spiral walls are formed on an outer peripheral surface of the cylindrical partition wall member, and, consequently, fluid rotates in the annular space and moves more outwardly than in a tangential direction of the annular space so as to be blown in a better condition against the inner surface of the casing located around the annular space.

Figure 2: Centrifuge

CHAPTER 3

METHODOLOGY

The project flow divided into four categories which are Literature Review, Modeling Process, Fabricator Process and Machining Process. The flow shows that the process used to produce the centrifuge using numerous of process that have been applied DFM and DFA.

3.1 The project flow of manufacturing a centrifuge has been decided as below:

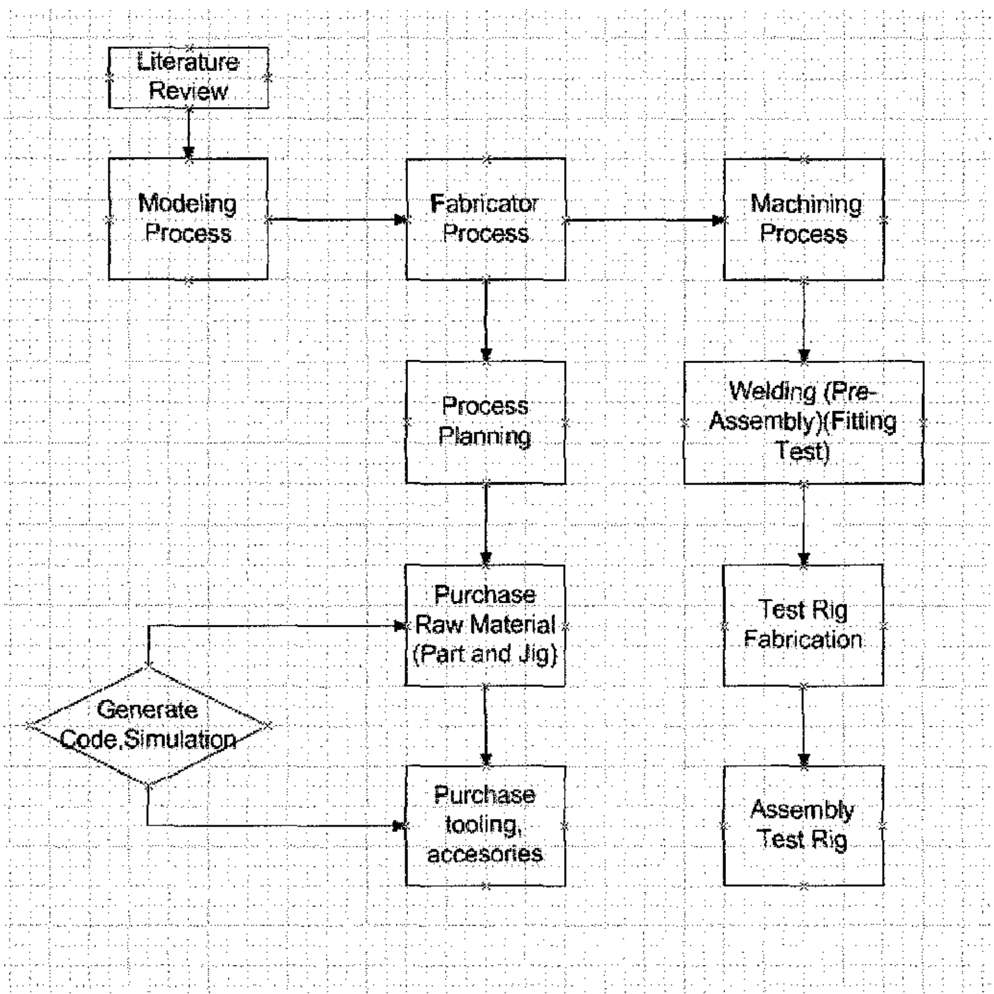


Figure 3: Flow Chart of the project

- **Literature Review** is the research that has been done from books, internet and journals. The results of the research will be applied for the next three processes ahead.

- **Modeling Process** is the part that the author did a lot of design and needs to apply the Design for Manufacturing. The process begins with an identification of a need and a decision to do something about it. After much iteration, the process ends with the presentation of the plans for satisfying the need.

    - Design consideration is also an important thing in this process. In this situation, the consideration that most important is strength. Usually quite a number of such characteristics must be considered and prioritized in a given design situation (refer literature review).

    - The author used CATIA V5 as the computational design tools. Among the effects of design specifications on cost, tolerances are perhaps most significant. In the modeling process, tolerances have to be set before the manufacturing process in order to meet the specification during the assembly process. The parts that need to be assembled should be having different tolerances depend on the size and shape.

- **Fabricator Process** is the process where manufacturer create the *process planning* in order to meet the specification and the next step which is manufacturing process will be easier. Process planning is the step where the manufacturer. Basically it concerned with selecting methods of production: tooling, jig and fixtures, machinery, sequence of operations, and assembly.

    - The purchasing raw material and tools must be parallel with the generate code process and simulation. This is to consume and save time.

- **Machining process** was the process to produce the parts of centrifuge. The specification of each part such as dimension and tolerances have been decided must be followed in order to assemble in assembly process.

    - For example, can the component be cold-headed and finish-machined rather than machined from bar stock? All of these considerations are important and can effect the cost of manufacture. They represent only the fine-tuning of costs, however, and the time such consideration are made.

- The time of manufacturing will be minimize. DFA techniques primarily aim to simplify the product structure so that the assembly costs are reduced. From the process flow, we can see that few tests have been run in order to make sure that the centrifuge is functionable. If the process plan is followed, should be no problem with the functionality of the centrifuge.

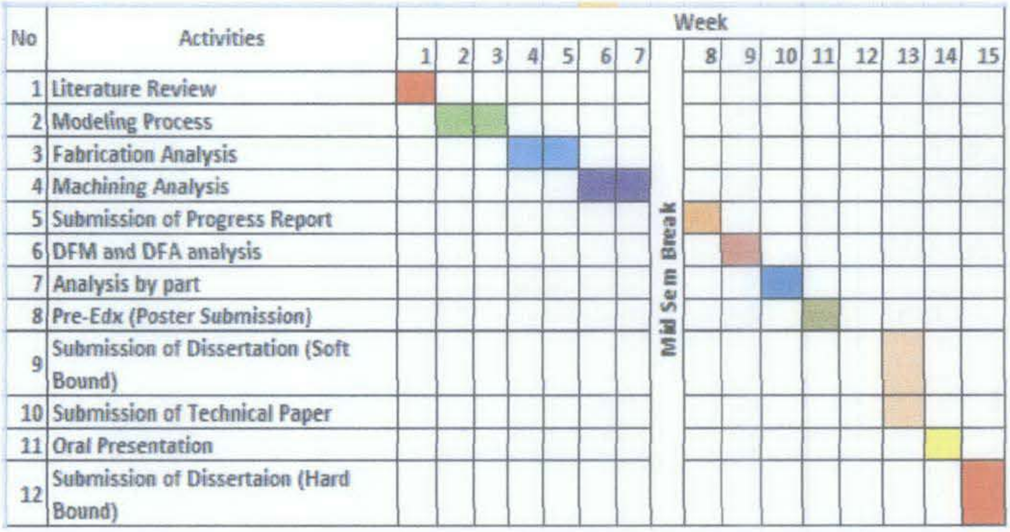


Figure 4: Project Gantt Chart

CHAPTER 4

RESULTS AND DISCUSSION

The author has followed the process of manufacturing the centrifuge by Mechanical Engineering ME department. The process is at the academic building Block 16 which occupied several of machines which is;

1. Mazak Variaxis630-5x
2. EDM machine
3. CNC machine

- The author implements the project to produce centrifuge according to the department requirement. He applies the concurrent engineering method in order to complete the project, where the department of designing and manufacturing are collaborate.

- The author have an authorization to redesign back the design that have been design by the ME department. A few changes that already created in order to improvise the design to meet the specification that have been highlighted in Literature Review explaining DFM and DFA.

- The designs are design to fit the machines which is MAZAK that used to manufacture all parts.

4.1 Manufacturing Process

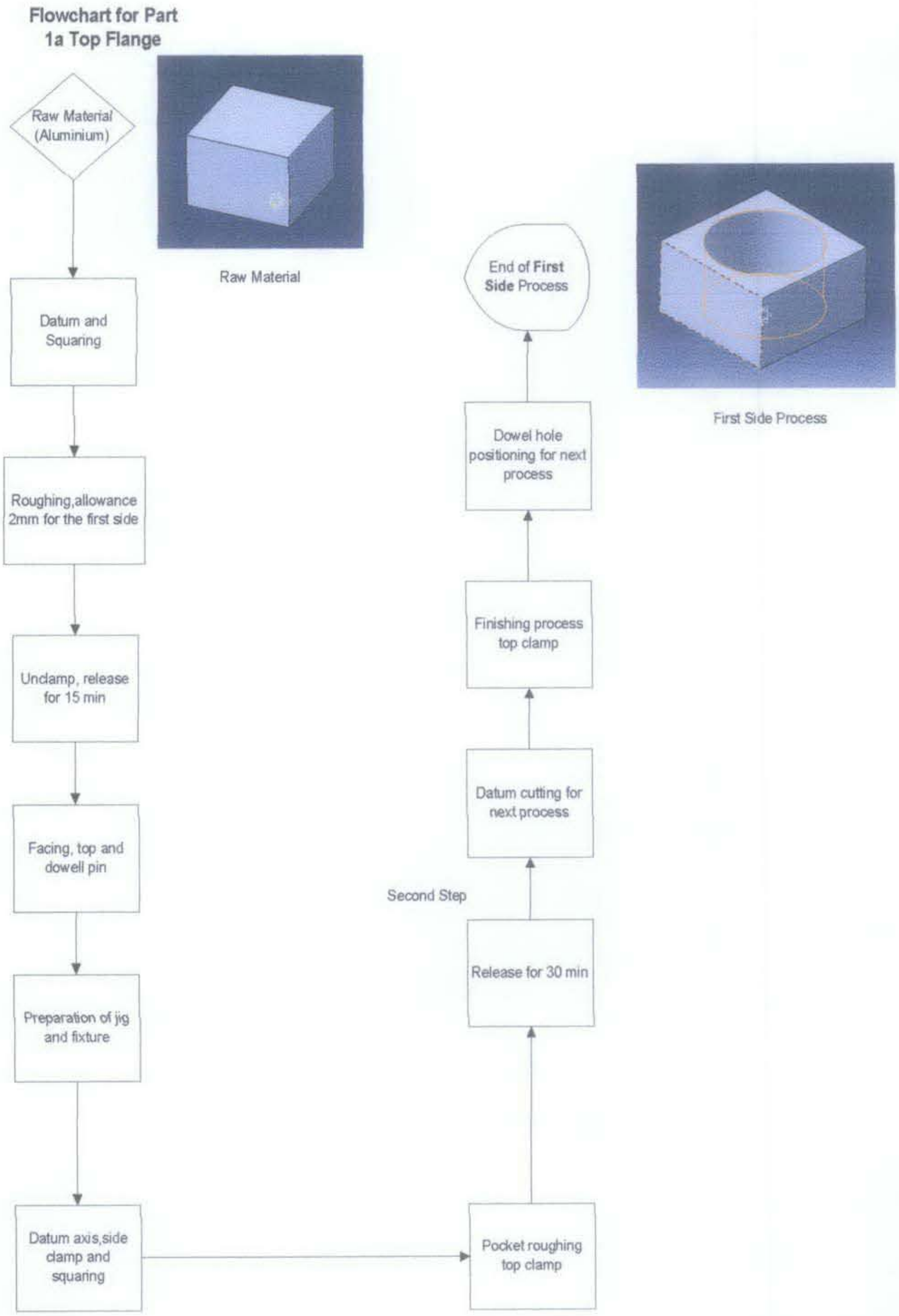
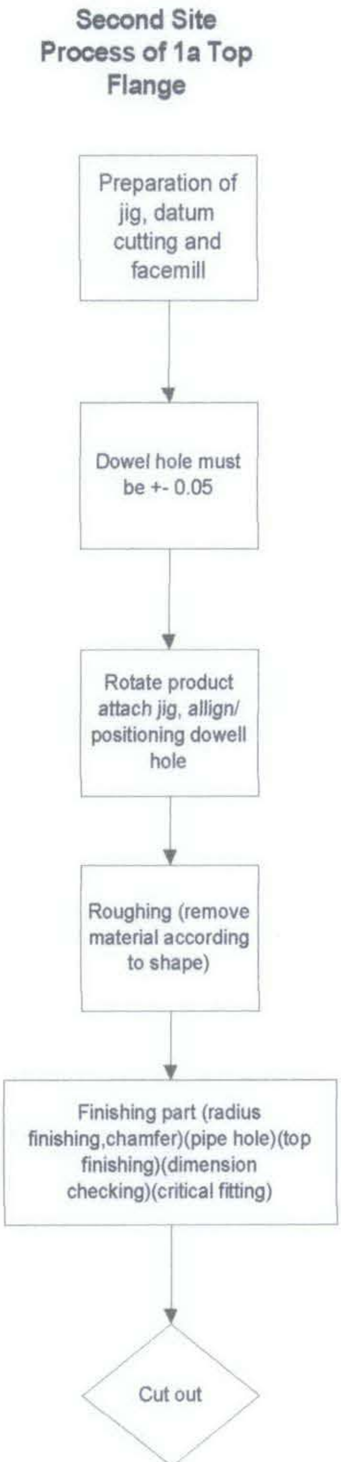
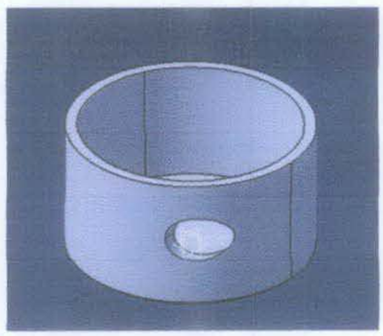


Figure 5: Process flow for part 1a first side





Part 1a finish

Figure 6: Process flow for part 1a second side

The flowchart above shows that the process flow to manufacture one of the centrifuge parts called Top Flange. The manufacturing process was done by ME department.

- The process started with the **datum and squaring** of the raw material. The **material removal** process is to create a round shape at the center of the material.
- **Roughing** allowance is set to ± 2mm for the first side in order to fit with the product that need to be combined at the assembly process. After the roughing process, the material will be unclamped for 15 minutes. It is because to neutralized the materials after gone through the process and avoid from material bending because of the heat. Plus it is the step of DFM.
- **Jig and fixture** was manufacture to hold the part during manufacturing process. It was also part of DFM. Meeting the specification of cutting the part is an important thing in order to precise the dimension and tolerances. It affected the assembly process which is to join the parts if the dimension and tolerances are wrong.
- **Surface finishing** is to improve appearance, adhesion of the part. Good surface finish could save time because after the product was produced, no need to do the deburring process. In other hand, dimension checking also held at that process.
- Those parts that have bolt and nut, decrease bolt and nut also recommend by DFM. DFM highlight to decrease part as long as the functionality of the product is still the same.

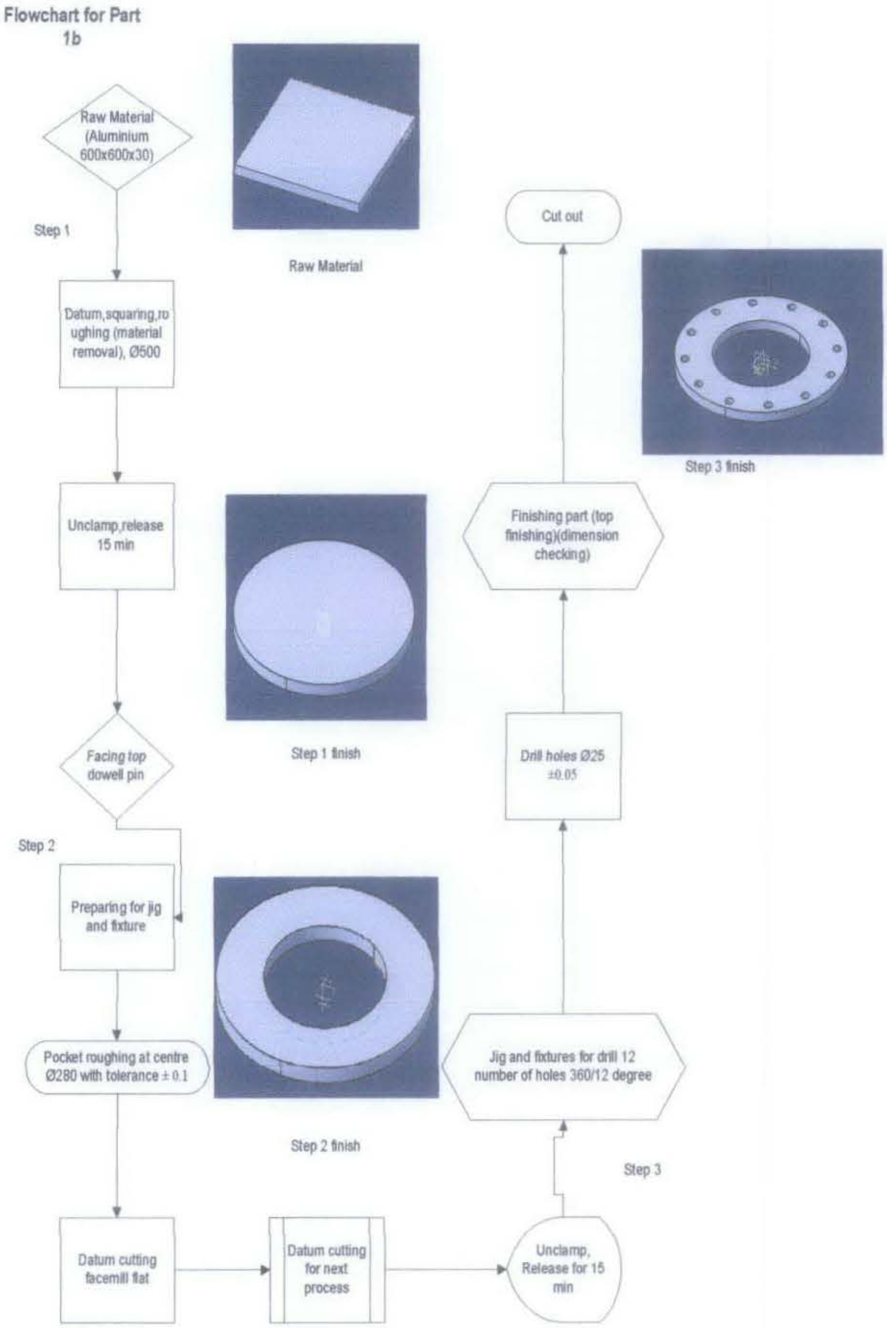


Figure 7: Process flow for part 1b

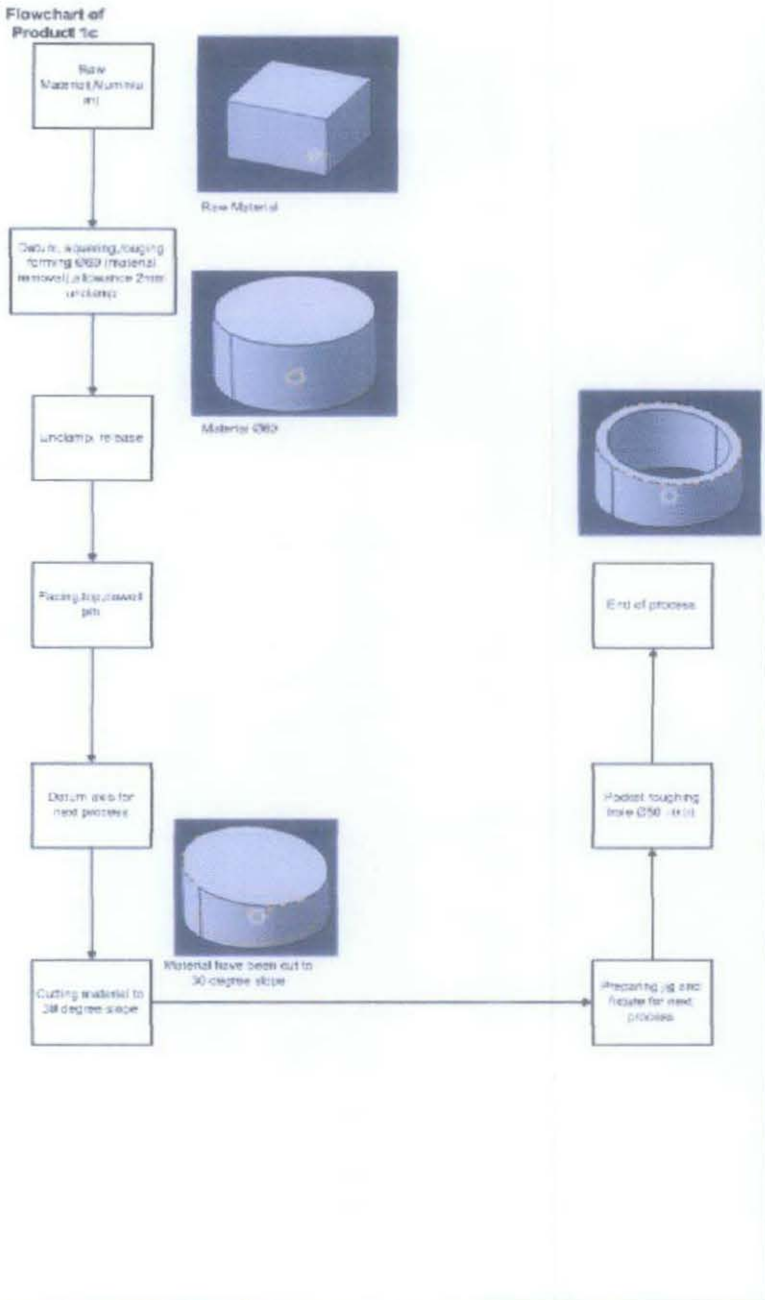


Figure 8: Process flow part 1c

- The process flow show that the manufacturing process of part 1. The objective of process flow is to create a process that have perfect manufacturing schedule process, short cycle times, reduce cost, continuous flow work cells and last but not least the product meet the specification.

- This flow also helps highlight and remove unnecessary steps in a process. By producing the process flow, we can analyst what is the best step to manufacture a product. After the process flow of the product produce, the process plan will be generated. It consume less time.

- The practice of process planning in manufacturing provides precise and clear sequential directions about how the product is to be routed and fabricated in a manufacturing facility. In advanced manufacturing, this will influence how the facility will be designed and laid out in preparation for the new product.

- Form the process plan, we can create bill of material (BOM). BOM is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, components, parts and the quantities of each needed to manufacture an end product. No physical dimension is described in a BOM. It may be used for communication between manufacturing partners, or confined to a single manufacturing plant. So clearly we can estimate the cost of the product by using BOM and know what is to reduce and what is not.

4.2 Assembly Process

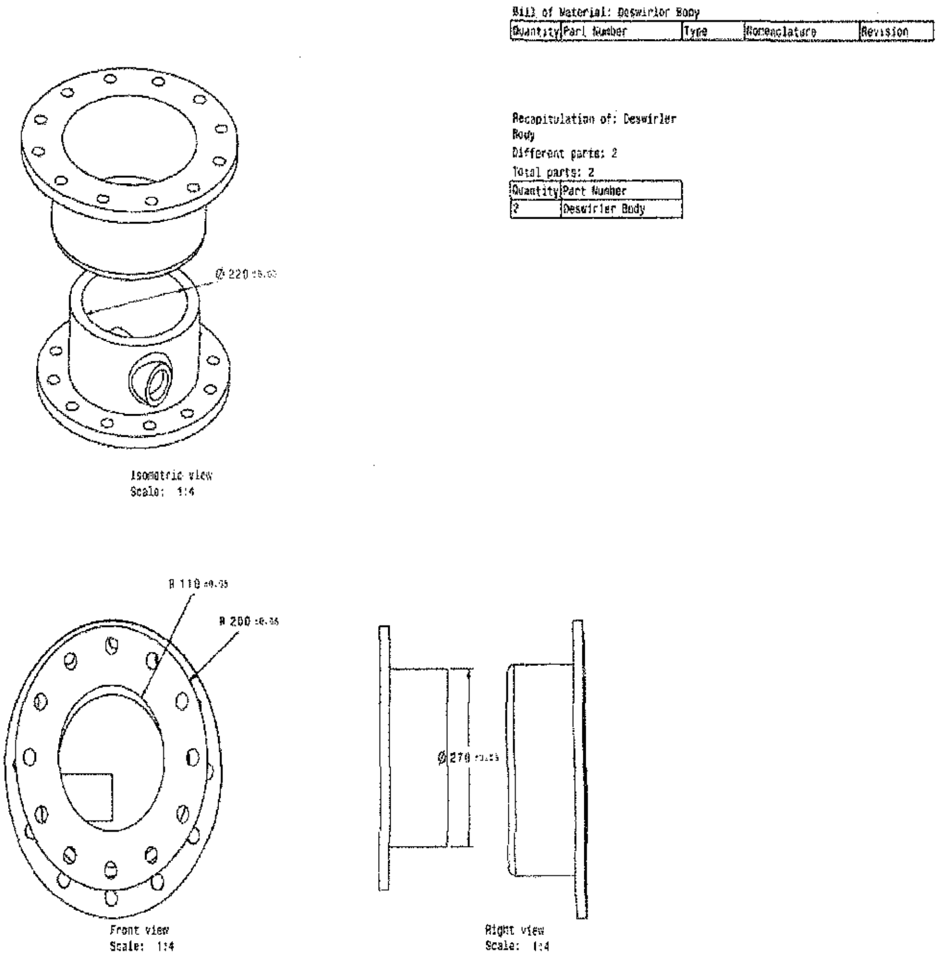


Figure 9: Production Drawing of Part 4 and 5

As the drawing shows, the assembly process of two parts, part 4 and 5 can be done since the applied of the DFM during the manufacturing process. The two parts can fit each other with the correct tolerances. The joining method of the two parts was welding process.

- Based on the product break up, the assembly process can be easily done because of the applied DFM during the manufacturing process. The right dimension and tolerances are the main point that the author seriously taken. Right dimension and tolerances made part can suit to each other. It result low time consumption to assemble because there was no problem rose during the assembly process.

- It is also save cost because no need to repair or produce new product resulted from product not meet the specification. Each of the parts have its own process flow and process plan that will be discussed later. So from the figures show above, it can be seen that the all part can suit each other with the given specification such as dimension and tolerances. Plus, the product is fully functional working.

Table 1: Process Plan of Top Flange First Side

No	Process	Tools	Machine	Parameter
1	Verify Raw Material	Visual checking,measuring tape and vernier caliper	Mazak Variaxis 630-5x	
2	Raw material place on the machine	Jig and Fixture: Side Clamp		Setup time: 30 M
3	Datum Cutting and squaring- Roughing (material removal)allowance 2mm for the first side	Face mill Ø80		Machining time: 2 H
4	Unclamp, release for the material to stable			Release time : 15 min
5	Facing top and dowell pin			
6	Preparation of jig and fixture for next process	endmill Ø60		Machining time: 1 H
7	Datum axis, side clamp and squaring	dial indicator		
8	Pocket Roughing Ø260±0.1	boring bar		Machining time: 2 H
9	Unclamp, release for the material to stable			Release Time: 30 min
10	Datum cutting for next process			
11	Finishing process top clamp			
12	Dowel hole positioning			
13	End Process			

- DFM criteria for the process plan was to make sure the process met the facility which is Mazak machining center. Thus the design the process plan solely based or Mazak and related tools. Based on this process plan the following six components were manufactured.
- DFA criteria is to ensure that the six components can be assembled with the mating surfaces will not be leak on per pressure requirement. It was also designed with ease of assembly while maintain the functionality of the centrifuge.

REFERENCES

[1] www.wikipedia.com, (20th June 2011)

[2] http://www.dfma.com/, (18th March 2011)

[3] http://www.npd-solutions.com/dfmguidelines.html, (5th May 2011)

[4] G. Boothroyd and P. Dewhurst, "Product Design for Manufacture and Assembly (Manufacturing Engineering and Materials Processing),1997

[5] Serope Kalpakjian, Steven R. Schmid, "Manufacturing Engineering and Technology", Sixth Edition,2006.

[6] Mikell P. Groover, "Automation, Production Systems, and Computer-Integrated Manufacturing", Third Edition,2008.

[7] M. J. Paulin et al. in "Materials Processing in High Gravity", edited by L. L. Regel and W. R. Wilcox (Plenum Press, New York 1994)

[8] Jigar Talati "Design for manufacturing", Hexagon Design Centre, Vadodara

[9] http://deed.ryerson.ca/~fil/t/dfmdfa.html, (12th August 2011)

[10] Edward G.Hoffman "Jig and Fixture Design", Fifth Edition,2004

[11] O. Molly, S. Tilly and E. A. Warmar "Design for Manufacturing and Assembly" Concepts, Architectures and Implementation,1999

[12] http://www.freepatentsonline.com/4723970.html, (30th December 2010)

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

From the assessment of DFM and DFA used for the prototype development process, the following were noted;

1. DFM application had enabled the machining to be done using the Mazak machine as well as the external machinist.
2. DFA application had enabled the modified prototype to meet the pressure rating standards to 70 bars.

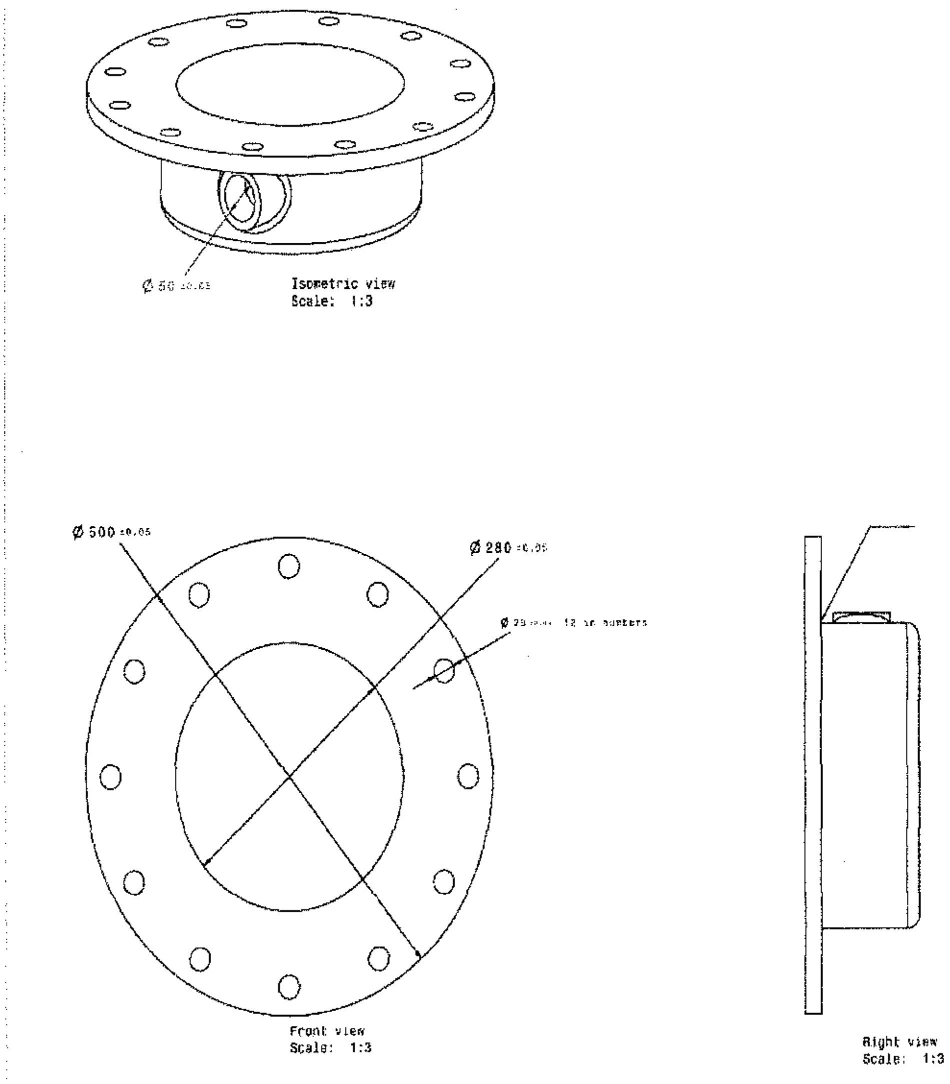
5.2 Recommendations

From the above findings, the recommendations are;

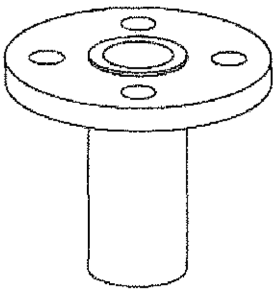
1. Apply DFM and DFA at the beginning of a project that involve manufacturing and assembly process.
2. By reviewing the product design, the centrifuge parts still can be reduced.

APPENDICES

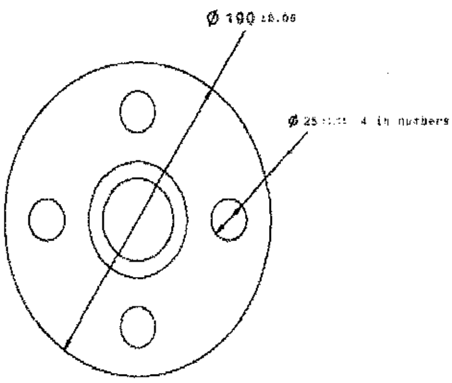
APPENDIX A: Production Drawing Part 1



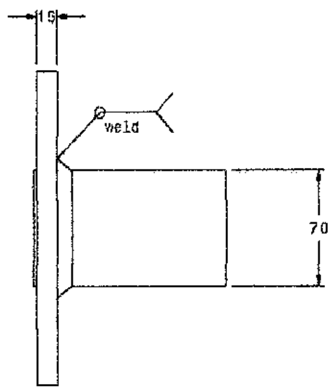
APPENDIX B: Production Drawing Part 7



Isometric view
Scale: 1:2



Front view
Scale: 1:2



Right view
Scale: 1:2

APPENDIX C: Mazak Machining Center