PRODUCT DESIGN SIMPLIFICATION THROUGH DFMA METHODS

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ABSTRACT

DFMA is a combination between DFM and DFA. Design for manufacture (DFM) is a systematic procedure to maximize the use of manufacturing processes in the design of components and design for assembly (DFA) is a systematic procedure to maximize the use of components in the design of a product. While, the term DFMA is defined as a set of guidelines developed to ensure that a product is designed so that it can be easily and efficiently manufactured and assembled with a minimum laborious effort, assemble time, and cost to manufacture the product. The purpose of this project is to reduce part count and minimize the product cost. Many of the companies outside there were successfully used this technique for product design improvement and product cost reduction. The aim is to propose a new design of computer desktop chassis that is better in design efficiency, total assembly time and cost. The analysis is done by using Boothroyd Dewhurst DFA method. For the result done by using Boothroyd-Dewhurst DFA method, the design efficiency of original design is 6.4% while the improved design is 15.5%. Total reduction of part from 48 parts to 16 parts after has been redesign. The percentage of part reduction is about 66.67% from old chassis to new chassis. The total assembly time has reduced from 462.11s to 154.5s in manual assembly.

ABSTRAK

DFMA adalah penggabungan perkataan dari DFM dan DFA. DFM adalah prosedur untuk memaksimakan penggunaan proses pembuatan untuk menghasilkan produk dan DFA adalah untuk memaksimakan penggunaan komponen dalam sesuatu produk. Manakala istilah DFMA adalah satu set garis panduan yang memastikan produk dapat dihasilkan dengan berkesan dan mudah. Tujuan projek ini adalah untuk mengurangkan jumlah komponen dan kos sesuatu produk.Sudah banyak syarikat yang telah mengamalkan analisis Boothroyd untuk meningkatkan tahap kualiti produk dan mengurangkan kos produk. Tujuan projek ini juga adalah untuk menghasilkan produk baru yang lebih baik dari segi “Design efficiency” dan jumlah masa pemasangan produk. Hasil daripada analisis Boothroyd, keberkesanan reka bentuk “Design efficiency” rangka komputer yang asal adalah sebanyak 6.4 % dan hasil reka bentuk rangka computer yang telah di ubah suai adalah sebanyak 15.5%. Pengurangan jumlah komponen dari rangka asal sebanyak 48 kepada 16 komponen sahaja untuk rangka yang telah diubah suai. Pengurangan komponen ini adalah sebanyak 66.67%. Dalam pada masa yang sama, jumlah masa pemasangan rangka komputer telah berkurang dari 462.11s kepada 154.5s.

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P	Pressure
F	Force
A	Area
T_h	Handling Time
T_i	Insertion Time
N	Number of Operation
E_{ma}	Design Efficiency
N_{min}	Theoretical Minimum Number of Parts
t_a	Basic Assembly Time
t_{ma}	Estimated time to Complete the Assembly of the Product
m	Mass
g	Gravity

LIST OF ABBREVIATIONS

DFA	Design for assembly
DFM	Design for manufacture
DFMA	Design for manufacture and assembly
CE	Concurrent Engineering

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Design for manufacturing and assembly (DFMA) method has been introduced by Geoffrey Boothroyd since the 1960s on automatic handling. DFMA is a word that combines from DFM and DFA. Design for manufacture (DFM) is a systematic procedure to maximize the use of manufacturing processes in the design of components and design for assembly (DFA) is a systematic procedure to maximize the use of components in the design of a product.

According to Boothroyd, DFA is a methodology for evaluating part designs and the overall design of an assembly. It is crucial to identify unnecessary parts in an assembly and to determine assembly times and achieve cost optimization. To be effective in product design, the procedures are often combined as Design for Manufacture and Assembly (DFMA).

The purpose of DFMA is to maximize the use of manufacturing processes and minimize the number of components in an assembly or product. DFMA is a systematic procedure for analyzing proposed designs from the perspective of assembly processes. To obtain the maximum benefit from DFMA, the procedure is applied as early as possible in the design process. In consequences, if a design is easier to produce and assemble it can be done in less time, so it is less expensive.

The objective of this project is to redesign an existing product for a better design that contributes to lower assembly time. Hence, the DFMA method has been applied to improve the original product (Desktop Computer Chassis) for better assembly time, manufacturing cost and design efficiency.

1.1 Project Background

Design for manufacture and assembly (DFMA) is a combination of design for assembly (DFA) and design for manufacture (DFM). The term DFMA is defined as a set of guidelines developed to ensure that a product is designed so that it can be easily and efficiently manufactured and assembled with a minimum laborious effort, assemble time, and cost to manufacture the product. During a product development, DFMA method ensures that the transition from the design phase to the production phase is smooth and rapid as possible. Generally, there are three types of DFA methods used to reduce the cost of the product. The main methods are Boothroyd-Dewhurst DFA method, Lucas-Hull DFA method, and Hitachi Assembly Evaluation Method (AEM). The chosen method for this study is Boothroyd-Dewhurst. This method is used to redesign the current design. This case study is focused on redesigning the desktop chassis in order to improve the design efficiency.

1.2 Problem Statement

Computer desktop is a common use in our daily life. Most of company outside there provides computer desktop chassis in a variety of style, size and price. The solution such as the uses of DFMA in making the computer desktop chassis is becoming an attractive prospect in satisfying the basic need for human that search for a better product and less price. The computer desktop chassis is chosen because to reduce the price of the market outside as the parts count is reduced by DFMA method. However in order to implement a new design, some drawback will be encountered such as a problem with design reliability.

1.3 Objectives

The objectives of this project are:

i. To propose a new design for computer chassis.
ii. To reduce the part counts in computer desktop chassis.
iii. To evaluate the design efficiency for computer chassis.

1.4 Scopes of Study

The scopes of this project are:

i. The chosen product for design improvement is computer desktop chassis.

ii. Boothroyd-Dewhurst DFMA manual assembly and DFA software is selected as the DFMA tool.

iii. Design modeling by applying Solidwork 2012 for current design and improve design.

iv. The strength analysis simulation by Solidwork software.

1.5 Expected Result

The design efficiency of the original product is calculated so that comparison can be made with the improved design. It is expected that the design efficiency of improved design will be increase with total assembly time and cost also will be reduced accordingly.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of design for manufacturing and assembly, concurrent engineering, review of previous case studies and perspective approach such as DFMA guidelines. Some of the information in this chapter can give extra information which can be useful during this project.

2.2 Designs for Manufacture and Assembly (DFMA)

Design for manufacture and assembly is a combination between DFM and DFA. Design for manufacturing (DFM) is design based on reducing the cost of production and/or time to market for a product, while maintaining an appropriate level of quality and Design for Assembly (DFA) is a systematic procedure to maximize the use of components in the design of a product. (Boothroyd, 2002) To be effective in product design, the procedures are often combined as Design for Manufacture and Assembly (DFMA). The aim of DFMA is to maximize the use of manufacturing processes and minimize the count of components in an assembly or product. DFMA is a systematic procedure for analyzing proposed designs from the perspective of assembly processes. To obtain the maximum benefit from DFMA, the procedure is applied as early as possible in the design process and used within a concurrent engineering teamwork environment. Applying design for manufacturing and assembly methodologies in early stages of product design can reduce the total count of parts in a product and thus reduce the costs. (Steven Ashley, 1995)

2.2.1 DFM and DFA Benefits

i. It reduces part count thereby reducing cost. If a design is easier to produce and assemble, it can be done in less time, so it is less expensive. Design for manufacturing and assembly should be used for that reason if no other.

ii. It increases reliability, because if the production process is simplified, then there is less opportunity for errors.

iii. It generally increases the quality of the product for the same reason as why it increases the reliability.

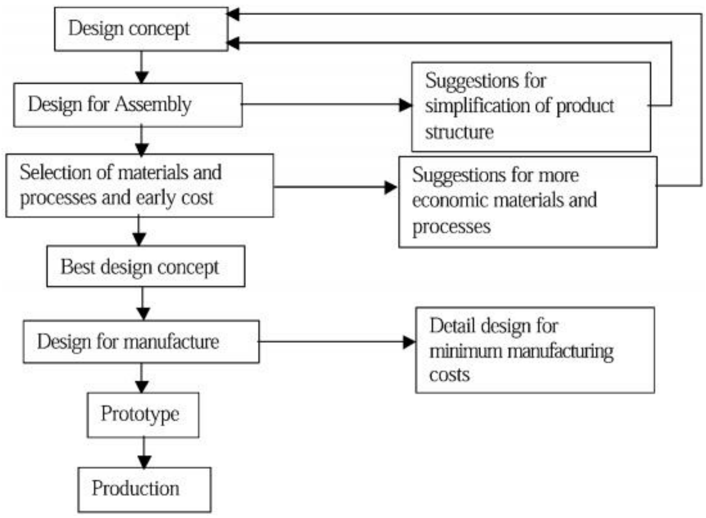


Figure 2.1:

Typical Stages in a DFMA Procedure (courtesy of Boothroyd And Dewhurst)

Source: (K.L. Edwards., 2002)

The DFMA procedure can typically be broken down into two stages as shown in Fig 2.1 Initially, Design for assembly is conducted, leading to a simplification of the product structure and economic selection of materials and processes. After iterating the process, the better design concept is taken forward to Design for Manufacture, leading to detailed design of the components for minimum manufacturing costs. The procedure is cost driven and importantly depends on the product design already existing. The procedure outlined, and there are many variations, optimizes the original product design to produce new and improved design. Most of the DFMA procedures today are computerized and DFMA can be done very quickly.

2.3 Product Design Process

2.3.1 The Traditional Process of Producing a Product.

Traditional Engineering approach [Fig2.2]; also known as “Serial Engineering", towards development had been largely sequential in nature. Each discipline performs its own individual works and passed the results to the next discipline in the serial chain. Typically, there is very few or no interaction at all between various disciplines. Thus this leads to problems later in the development cycle.

The traditional process of producing a product in manufacturing lead to the phrase "we design it you build it." This attitude has now become known as "over-the-wall" design meaning that the designer throws the drawings over the "wall" that separates design and manufacture so that the manufacturing engineer must struggle with the problems created by the designer. (Boothroyd, 2002)

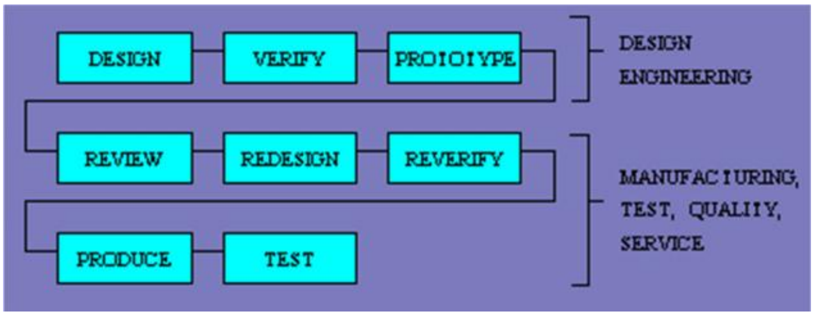


Figure 2.2: Traditional Engineering Approach

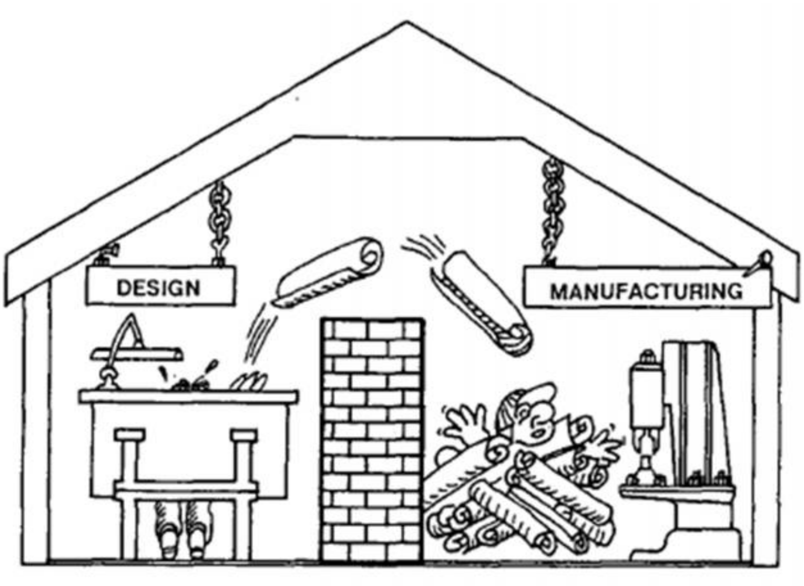


Figure 2.3: The “over the wall” Design Method.
Source: (Boothroyd, 2002)

Traditionally, designers developed a new product without any input from manufacturing, and then turned over the design to manufacturing, which would then have to develop a process for making the new product. This “over-the-wall” approach created tremendous challenges for manufacturing, generating numerous conflicts and greatly increasing the time needed to successfully produce a new product. It also contributed to an “us versus them” mentality.

To solve this problem, the design engineers and manufacturing engineers have to sit together and this team work can overcome a lot of problems during the manufacturing of the product. This team is called simultaneous engineering or concurrent engineering.

2.3.2 Concurrent Engineering

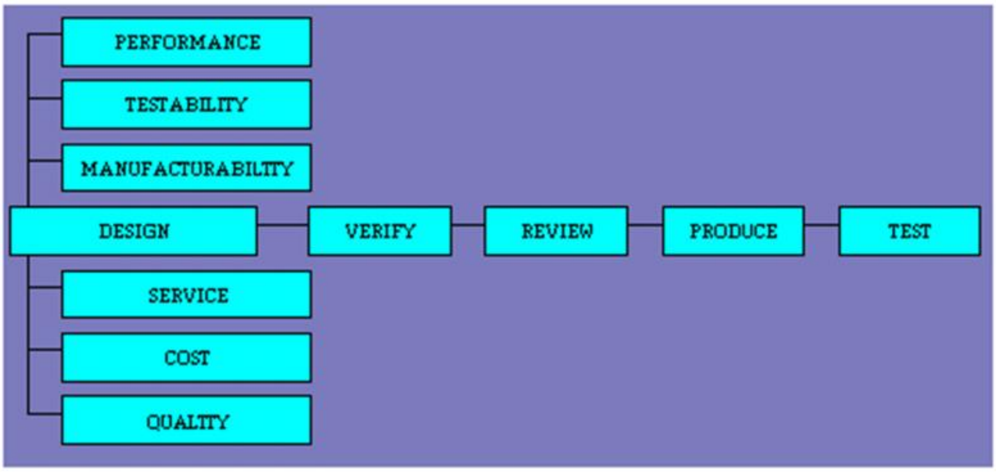


Figure 2.4: Concurrent Engineering Approaches

In an increasingly uncertain marketplace manufacturing organizations are striving to find new ways to meet customer requirements for competitively priced, customized products, delivered in shorter lead times. It is argued that to meet these demands there is a need to integrate the design, development and production functions within a concurrent engineering (CE) environment.

Concurrent engineering is the practice of concurrently developing products and their design and manufacturing processes. If existing processes are to be utilized, then the product must be designed for these processes. If new processes are to be utilized, then the product and the process must be developed concurrently. This requires knowing a lot about manufacturing processes.

Concurrent engineering approach Figure 2.4 encourages teamwork and it harnesses the expertise from all the disciplines that are involved to work closely together in parallel right from the early stage of the product design and development stage. In order for effective teamwork, sharing of ideas and objectives had to go beyond immediate assignments and departmental loyalties. Trade-offs regarding ease of production, testing and servicing are made along with product performance, size, weight, parts and cost trade-offs. When a design is approved, it is already can be manufacture, testable, serviceable and of high quality.

The main objective of concurrent engineering is to shorten a product development time through a simultaneous timely implementation of the several stages of the engineering activity in parallel and under a concurrent mode offering all information required by all elements of the product life cycle. An early consideration of manufacturing issues shortens product development time, minimizes development cost, and ensures a smooth transition into production for quick time to market. (Alemu Moges Belay, 2009). Among all the reasons, the most important and most concerning by a company is the cost reduction method. Concurrent engineering is an effective way to design a production line, because it used the integrated and simultaneously for the all processes, so that the lead time and assembly time will be reduced. It is focusing on parallel processing rather than sequentially. (Sohlenius, 1992)

Concurrent engineering techniques can be used to compress time in the product development cycle, and business cycles in general. Every business has basic cycles that govern the way that paper is processed, parts are manufactured, and decisions are made. They may be documented in the form of procedures or routings. Examples of business cycles are customer order, product development, production, and procurement.

Cycles are sequences of recurring successions of processes or events. The cycle time is the time from the beginning of the first step of the process until the beginning of the first step of the next process. Processes can be decomposed into smaller activities. Traditionally those activities may be performed in a sequential manner. In this situation each step is completed before the next one begins. The goal in compressing time is not to devise the best way to perform a task, but rather to either eliminate the task altogether or perform it parallel with other tasks so that the overall system response time is reduced.

2.4 The Nature of Design Guidelines in DFMA

DFMA procedures can be supported with guidelines, which are often supplemented by the experience of the designer. In fact, some DFMA is done purely through experience, with little or no support from a systematic procedure or formal guidelines. This approach is highly dependent on the knowledge and experience of the individual designer or collective design knowledge and experience of the company concerned.

Design guidelines are one of the main sources of explicit knowledge of the practice of design. The main sources of design guidelines include the literature, the direct experiences of practicing designers and the established design practices in engineering organizations. Design guidelines are often found where the course of action is not clear but where one particular action has been found to work well in the past. Design guidelines, therefore, are more frequently specific to a particular domain and can represent a wide range of experience in the use of existing technology. In conjunction with the procedure, designers can make use of DFMA guidelines to help manage and reduce the large amount of information involved.

2.4.1 General Design Guidelines for Manual Assembly

There are three methods of assembly such as manual assembly, automatic assembly and robotic assembly (Boothroyd et al., 2002). According to Boothroyd, the manual assembly process can be divided into two, which is part handling and insertion. This set of guidelines would point product designers towards simplicity of design in assembly point of view. DFA guidelines apply to all the assembly operations, such as parts feeding, separating, orienting, handling, and insertion for automatic or manual assembly (Ghosh and Gagnon, 1989).

2.4.2 Design Guidelines for Part Handling

Component handling is the process of separating a part from bulk, and the grasping, transporting, orienting, and positioning it for placement in the assembly. Factors that affect the ease of which a component is handled and positioned are:

i. Component's size and thickness
ii. Component orientation
iii. Handling difficulties

In general, for ease of part handling, a designer should attempt to (Boothroyd, 2002)

i. Design parts that have end to end symmetry and rotational symmetry about the axis of insertion.
ii. Design a part obviously asymmetric if the part cannot be made symmetric.
iii. Provide features that will prevent jamming of parts that tend to nest or stack when store in bulk.
iv. Avoid features that will allow tangling of parts when store in bulk.
v. Avoid parts that stick together or are slippery, delicate, flexible, very small, very large and hazardous to users.

In terms of the assembly operation, the design guidelines will be presented in the following figure (Boothroyd, Dewhurst & Knight 2011: 74).

	Design rules	Illustration of examples
1	Design a part that has the maximum possible symmetry about the axis of insertion.	 Asymmetrical; Symmetrical
2	Design a part that is obviously asymmetrical if they can not be made symmetrical.	 Slightly asymmetrical; Pronounced asymmetrical
3	Provide features that prevent jamming of parts that tend to nest or stack when stored in bulk.	 Will jam; Cannot jam
4	Avoid features that allow tangling of parts when stored in bulk.	 Will tangle; Cannot tangle
5	Avoid parts that stick together or are slippery, delicate, flexible, very small or very large, or that are hazardous to the handler (i.e., parts are sharp, splinter easily, etc.)	 Very small; Slippery; Sharp; Flexible

Figure 2.5: Designs Guidelines for Part Handling

Source: Boothroyd, Dewhurst & Knight (2011)

2.4.3 Design Guidelines for Part Insertion and Fastening

For ease of insertion, a designer should attempt to:

i. Designs parts that have no or little resistance to insert by providing chamfers to guide insertion of two mating parts. Some of clearance should be made.
ii. Standardize by using standard part, processes and methods.
iii. Use pyramid assembly.
iv. Provide self-locating features to avoid holding down and alignment.
v. Designs a part that relocating first before it is released.
vi. Use a less expensive fastener first in designing a product before use an expensive fastener.
vii. Avoid the need to reposition the partially complete assembly in the fixture.

Figure 2.6 shows some illustrations of guidelines for part insertion and fastening.

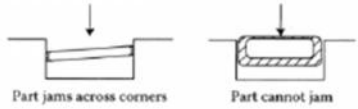
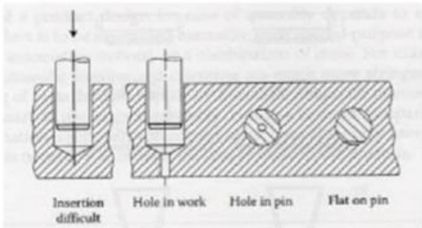
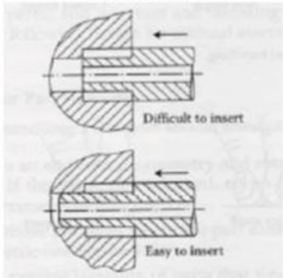
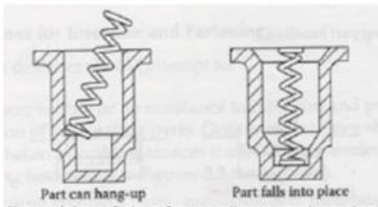
	Design rules	Illustration of examples
1	There is little or no resistance to insertion, and chamfers are provided to guide the insertion of 2 mating parts. Generous clearance should be provided.	 a) Incorrect geometry can allow a part to jam during insertion.  b) Provision of air-relief passages to improve insertion into blind holes.  c) Assembly of long-stepped bushing into counter-bored hole.  d) Provision of chamfers to allow easy insertion.

Figure 2.6: Designs Guidelines for Part Insertion and Fastening

Source: Boothroyd, Dewhurst & Knight (2011)

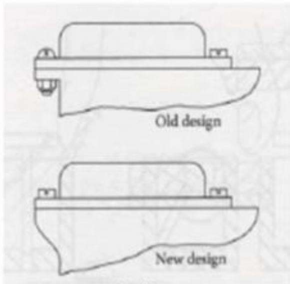
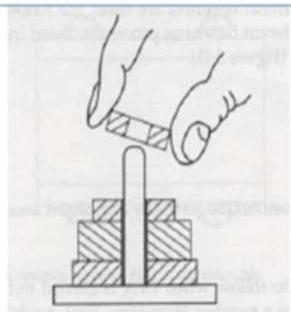
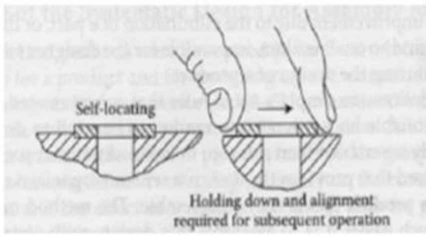
2	Use standard parts, processes and methods.	 Standardise parts.
3	Use pyramid assembly. It is best to assemble from the above.	
		 Single-axis pyramid assembly.
4	Provide self-locating features to avoid holding down and alignment.	

Figure 2.6: Continue

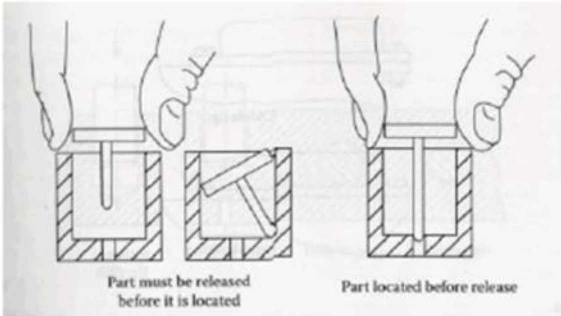
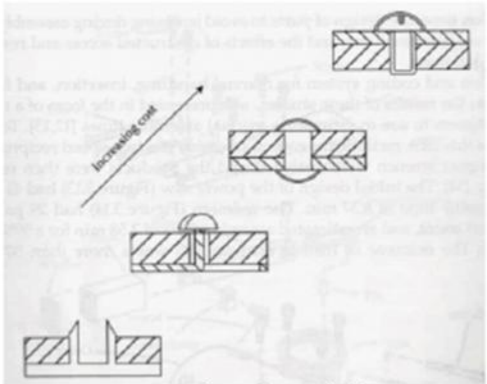
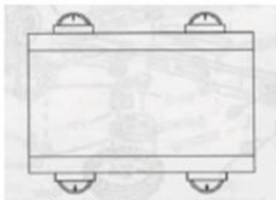
5	A part should be located before it is released.	
6	When common mechanical fasteners are used, the following sequence indicates the order of increasing manual assembly cost. a. Snap fitting b. Plastic bending c. Riveting d. Screw fastening	 Common fastening methods
7	Avoid the need to reposition the partially completed assembly in the fixture.	 Insertion from opposite direction requires repositioning of the assembly.

Figure 2.6: Continue

Other than stated above, several guidelines have been determined, which can improve the reliability and the ease of the assembly. The DFA guidelines can be summarized as below (Otto and Wood, 2001).

i. Assemble only in open space, not in confined or restricted space. Never bury important components.
ii. Minimize part count by incorporating multiple functions into single parts.
iii. Modularise multiple parts into single subassemblies.
iv. Make parts to identify how to orient them for insertion.
v. Standardise to reduce part variety.
vi. Maximize part symmetry.
vii. Design with geometric or weight polar properties if non-symmetric.
viii. Eliminate tangle parts.
ix. Color code parts that are different but shaped similarly.
x. Prevent nesting of parts.
xi. Provide orienting features of non-symmetries.
xii. Design the mating features for easy insertion.
xiii. Provide alignment features.
xiv. Insert new parts into assembly from above.
xv. Insert from the same direction or very few. Never require the assembly to be turned over.
xvi. Eliminate fasteners.
xvii. Place fasteners away from obstructions.
xviii. Deep channels should be sufficiently wide to provide access to fasten tools. No channel is best.
xix. Providing flats for uniform fastening and fastening ease.
xx. Proper spacing ensures allowance for a fastening tool.

2.5 Designs for Manufacturing (DFM)

Design for manufacturing (DFM) is a design of components and constructional systems as a function of the manufacturing process and design for ease of manufacture of collection of parts that will form the product after assembly. (Boothroyd, 2002) This method is to consider design goals and manufacturing constraints simultaneously to identify and alleviate manufacturing problems. (Ferrer. I , 2010) In DFM, the decision of the manufacturing process is very important to choose.

The aim of the DFM is to decrease the manufacturing and material cost, improve quality and flexibility. According to Olivier Kerbrat (Kerbrat, 2011) this method involves simultaneously considering design goals and manufacturing constraints in order to identify manufacturing problems.

Design for Manufacture (DFM) techniques are closely linked to Design for Assembly techniques, but are oriented primarily to individual parts and components rather than to DFA's sub-assemblies, assemblies, and products. DFM aims to eliminate the often expensive and unnecessary features of a part that make it difficult to manufacture. It helps prevent the unnecessarily smooth surface, the radius that is unnecessarily small, and the tolerances that are unnecessarily high (John Stark, 1998).

2.6 Designs for Assembly (DFA)

Design for assembly is a methodology for evaluating part designs and the overall design of an assembly. It is a quantifiable way to identify unnecessary parts in an assembly and to determine assembly times and costs. (Boothroyd, 1994)

Design for assembly (DFA) is a new approach to facilitate the development of efficient product designs in simplifying a product so that the cost of assembly is reduced. (Vincent and Filippo, 2005) It acts as the guidance for concurrent engineering design team to simplify the product structure, reduce manufacturing and assembly cost, and to quantify the improvements. It is also a benchmarking tool to study competitor products and quantify manufacturing and assembly difficulties. The product design has a significant impact on the manufacturing cost as well as the timescales. The recommendations suggested by the DFA methodologies can be summarized into the following (Boothroyd, 2002):

i. Eliminate the part such as screw, nut and spring.
ii. Combine the part with mating parts. This is due to the recommendation of the Boothroyd's three criteria.
iii. Simplify the assembly operations.

2.6.1 Design for Assembly Methods

There are three well known quantitative evaluation techniques or also known as design for assembly (DFA) methods used in industry which are:

i. Boothroyd Dewhurst design for assembly method from USA.
ii. Lucas Hull Design for assembly method from UK.
iii. Hitachi assemblability evaluation method from Japan.

2.6.2 Boothroyd-Dewhurst DFA Methodology.

Boothroyd-Dewhurst DFA method is developed in the late 1970s by Professor Geoffrey Boothroyd, at the University of Massachusetts, Amherst in cooperation with Salford University Of England.

Boothroyd-Dewhurst DFA evaluation focuses on establishing the cost of handling and inserting component parts. Regardless of the assembly system, parts of the assembly are evaluated in terms of ease of handling, ease of insertion and an investigation of parts reduction. The Boothroyd and Dewhurst DFA is an effective approach to improve the design efficiency of the product. Boothroyd and Dewhurst DFA methodology has been recognized as a very useful tool in increasing competitiveness by reducing the part number of components, simplifying the product design structure and improving product design reliability. The guidelines for analyzing product for manual assembly Boothroyd and Dewhurst method are adopted and are suggested by (Joneja, 2005) as below:

i. To get the design details, engineering drawings, three dimensional models (3D), physical prototype or the own product need to be analyzed.
ii. To disassembly the product and observe the sequence and how each part is disassembled.
iii. To start the product re-assembly from the major part to the minor part, record and write the assemble time.
iv. To calculate the design efficiency.

v. Analyze the new design by repeating step 1 through 4 and gage improvements by comparing design efficiencies between current and modified design. Iterate until satisfied.

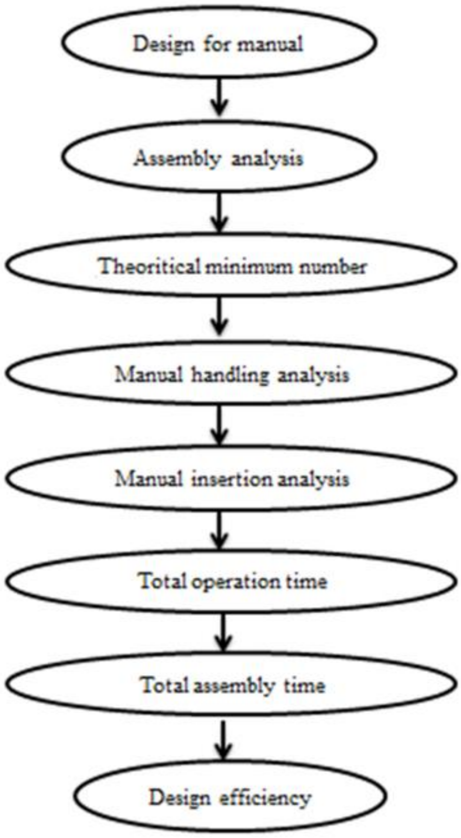


Figure 2.7: Boothroyd and Dewhurst DFA Analysis

Source: Boothroyd et al. (2002)

After evaluation of the design efficiency of a product, the necessary criteria in eliminating components of a product are done by examining the product.

Boothroyd Dewhurst DFA method is providing 3 criteria to give guidance to the designer in reducing the part count, if the part does not satisfy at least one of the 3 criteria then the part is considered to be eliminated in the product. The 3 criteria (Boothroyd, 2002) which are:

i. Does this part move relative to another?
ii. Do the mating parts have to be made of different materials?
iii. Do the parts have to be separate to allow servicing before or after assembly?

If the answer “YES” to at least one of the following three questions above for a part, the part is compulsory, it can’t be eliminated. Otherwise, if the answer “NO” the part can be eliminated and combined.

The next task is to estimate the assembly time for the design and establish its efficiency rating in terms of assembly difficulty. This analysis is first to define the estimated time for handling the part according the weight, thickness, size, how it will be grasped and orientation of each part. Secondly, is the manual insertion analysis that used to estimate the insertion time for each part according the resistance and alignment during insertion and how the part is secured such as the part secured using snap fit or others.

Next, calculated the total operation time and the total of assembly time. The formula as shown below:

Total operation time in second = N $(T_h + T_i)$

Where;

T_h = handling time

T_i = insertion time

N = Number of operations

Total assembly time (sec) = ∑ total operation time of each part.

The last step calculates the design efficiency. The design efficiency is obtained by using the formula below (Boothroyd et al, 2002)

Design efficiency, $E_{ma} = \dfrac{N_{min} \times t_a}{t_{ma}}$

Where;

$N_{\min}$ = theoretical minimum number of parts

t_a = basic assembly time = 3 seconds

t_{ma} = Estimated time to complete the assembly of the product

2.7 Previous Research

2.7.1 Electric Wok

Robert B.S. et al. (2004) had carried out a study on electric wok using Boothroyd Dewhurst DFA method and conceptual DFA analysis. Both methods also show a decrease of part count of the existing product and reduce assembly time. Analysis by using Boothroyd Dewhurst DFA method leads to part count reduce from 33 to 19, original design efficiency is 24.41% while revised design efficiency is 45.28%. Analysis of conceptual DFA method lead to the reduction of total 20parts, total assembly time 91 seconds only compare to the original assembly time 233.48 seconds.

2.7.2 Nail Puncher

According to journal entitled "Research on Collaborative Concept Design Integrating the Application of Virtual Reality and DFMA", the researcher used method of Boothroyd Dewhurst DFA method to improve he design efficiency of the corresponding nail puncher from 0.179 to 0.401. Total operation time has reduced from 134.25s to 59.12s. This case study has proved to save assembly time by 75.13s, which is 22.2% more efficient than the original design. And, in addition to cost reduction, the number of parts is also reduced from 15 to 10. (Justin J.Y. Lin, 2008)

2.7.3 Pressure Vessel

To obtain a shorter product development cycle time for a pressure vessel through reduction in manufacturing and assembly time, research has been conducted by using Boothroyd-Dewhurst DFMA method and has come out with positive results. The pressure vessel design was obtained from one of the oil and gas companies in Malaysia. Without considering the guideline of design for manufacture and assembly, the existing pressure vessel component quantity is 127, and the new design has just 108 components due to reduction of the skirt vent number from 3 to 2. The percentage of quantity reduction from the existing design is 14.96%. Even though the reduction of component is small, but it still can give impact on assembly time, material cost and material handling costs.

The orientation time has a 6.06% reduction, welding time 9.48% reduction, insertion time is 3.27% reduction, total manual handling time is 9.43% reduction and total operation time is 9.42% reduction. With all of it, it can reduce the component assembly time and eventually can shorten the development time of the pressure vessel. The design assembly efficiency for existing vessel is 0.020 %. Improve vessel design efficiency is 0.022%. The implementation of this approach has improved the company's performance and return of investment (Ismail et al., 2009)

2.7.4 Bicycle

A study of cost reduction for bicycle by using DFA methodology. According to journal entitled "Cost Reduction Study of Bicycle By Using DFMA Method", the researcher used method of Boothroyd Dewhurst DFA method to improve he design efficiency of the corresponding bicycle from 26.97% to 29.24% A reduction assembly time from original design is 367.03seconds to 338.58 seconds and assembly cost reduction from RM 0.57 to RM 0.53 per product. The project is carried out by Ho Ka Hui (2012)

2.7.5 Price tagger

The researcher of this project has used Boothroyd analysis in his project to determine the price tagger design efficiency after the current design has been evaluated using DFMA method. The existing product design efficiency is 26.62% and the new propose design is 41.26%. The labor cost reduces RM0.1940 per product. In his study, the overall cost reduction for DFMA is RM0.19 per product which is RM1.50 reduce to RM1.31, the percentage of reduction is 12.67%. And, in addition the total assembly time has reduced from 247.97 seconds to 172.4 seconds.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discussed about the method to conduct this final year project which using Boothroyd-Dewhurst DFMA method. The flow chart of this project started with product selection, project proposal, literature review and methodology. Methodology is included the gathering of product information and product disassemble. The function of disassembling is to know the details of part functioning relative to each other.

3.2 Design of Project Study

Firstly, the product selection is carried out by surveying the current computer chassis. Survey the products in the market shows the same compartment are used in the casing of the computer desktop chassis The most common design of computer chassis is selected to be the specimen to study through DFMA method. Once the product is selected the proposal which included project background, objective, scopes and problem statement.

Then, a literature review is carried out on this area. Among common keywords used in searching and browsing are like Boothroud-Dewhurst, DFMA, concurrent engineering, DFMA guidelines and product design improvement. At the same time, meetings and DFMA class session from the DFMA curriculum syllabus subject are beneficial to this study. There are 3 types of DFA method which are Boothroyd Dewhurst method, Lucas- Hull DFA method and Hitachi Assemblability Evaluation Method (AEM). The Boothroyd Dewhurst DFA method is chosen as the method in this final year project.

After that, this study proceeds to design of the framework and project methodology. In this section, the overview of methods that had been used in completing the study is reviewed in general. Here, the manual calculation method is used to determine assemblies handling and insertion code. Besides that, identify the minimum theoretical parts of Boothroyd – Dewhurst DFA are reviewed before the method for selecting the best alternative design is being discussed. From the manual calculation and minimum theoretical part, total assembly time and design efficiency can be calculated. Apart from that DFA Boothroyd software is also used to determine the DFA index and total assembly cost.

The study progress is carried on with design investigation for existing parts, for example determining the alpha and beta orientation, size and thickness and operation characteristics. In this section, the data gathered from each part are presented. The evaluations is proceed by calculate the design efficiency of existing design. Then the analysis is continued by selection of new proposed product design. Both design then are compared in sum of total operation time for each component in the product along with design efficiency.

After generating the new design, the other step is DFM analysis based on the material and manufacturing process, refer to the DFM capabilities of a range of manufacturing process, shape generation capabilities of processes and manufacturing process and material selection table. After that, a test on the sustainability of the old design and the new design is done using Solid Work simulation; the best result for the environment is discussed and chosen. The cost of the material and the assembly time are compared with the existing and the new design. Finally, a simulation test such as static load on the redesign part by using Solid Work or Algor Software.

3.2.1 Flow Chart

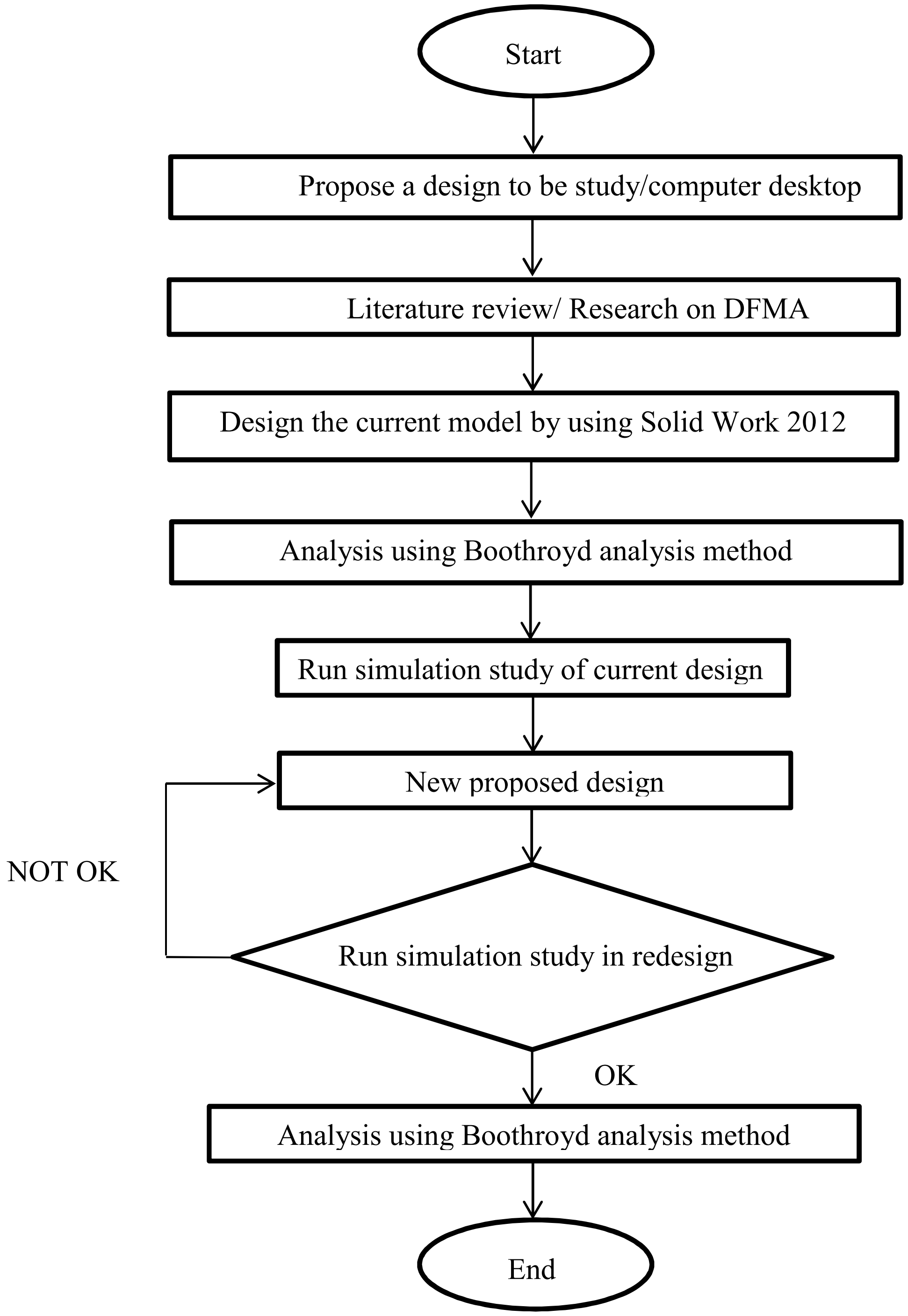


Figure 3.1: Flow Chart

3.3 Identifying and Selecting of Product

Computer desktop chassis has been chosen as the product in this project. The analysis is performed by using DFMA method. The optimization of the assembly efficiencies can be determined by Boothroyd – Dewhurst DFMA method.

Computer desktop chassis is made from many countries such as China and Taiwan. Most of the manufacturer is from China.

3.4 Parts Disassembly

To perform this study, a technical insight into the product is important to understand how the product of each part is functioning. This technique is to determine each parts orientation like alpha and beta. Apart from that dismantle technique is used to measure the size and thickness and to study the operation characteristics in more detail for be used in the manual assembly worksheet.

3.5 Current Design Review

An information gathering about the current product is collected to redesign a new product. In this project, the current product is computer desktop chassis. The product must be investigate to know how each part functioning (alpha and beta orientation ,size, thickness and operation characteristics) and to get the exact number of components like how much the number of screw and rivet.

3.6 Boothroyd – Dewhurst DFA Manual Evaluation

The criteria for reducing the parts count per assembly, establish by G. Boothroyd and P. Dewhurst involve negative answers to the following questions

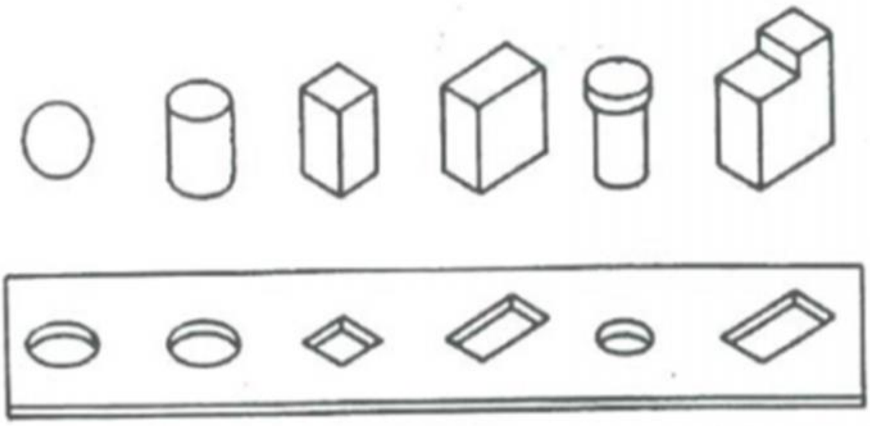
i. Does this part move relative to another?
ii. Do the mating parts have to be made of different materials?
iii. Do the parts have to be separate to allow servicing before or after assembly?

Example of DFA Manual Worksheet.

c1	c2	c3	c4	c5	c6	c7	c8	c9	Name of Assembly
Part ID	No of times the operation is carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	manual insertion time per part	Operation time c2(c4 + c6)	Operation cost 0.4 c7	Estimation for theoretical minimum parts	
Total:									**Design efficiency =**
						TM	**CM**	**NM**	*3 NM/TM* =

Figure 3.2: Worksheet for Computation of Design Efficiency

The DFA manual worksheet example will be filled with handling and insertion two digit codes and time for each part of the product. With the understanding of how part work and relate to each other in normal operating mode, the handling and insertion difficulties of the part are defined by the code obtained from Boothroyd-Dewhurst Manual handling table and Insertion table.



α	0	180	180	90	360	360
β	0	0	90	180	0	360

Figure 3.3: Alpha and Beta Rotational Symmetries for Various Parts
Source: Boothroyd (2002)

Alpha Symmetry: depends on the angle through which a part must be rotated about an axis perpendicular to the axis of insertion to repeat its orientation

Beta Symmetry: depends on the angle through which a part must be rotated about the axis of insertion to repeat orientation.

3.7 Procedure for the Analysis of Manually Assembled Products

STEP 1. The information about the computer desktop chassis is gathered like dimensions and material used. Useful items are engineering drawings or exploded 3D views.

STEP 2. The current product is being dismantled to study each part characteristics such as part orientation, size, thickness and functions.

STEP 3. A worksheet of manual assembly is set up to be filled for appropriate entries such as number of parts, theoretical part count, handling time, insertion time, assembly time, and assembly cost.

STEP 4. Each row is completed to estimate the handling times and insertion times that are obtained from Boothroyd and Dewhurst tables.

STEP 5. When all of the rows have been completed (reassembled in effect), the assembly time column is added to give a total estimated assembly time. The theoretical minimum column is also summed.

STEP 6. The design efficiency is calculated.

CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

This chapter discusses the result of design efficiency or DFA index obtained from Boothroyd-Dewhurst Software and Manual Assembly evaluation. Apart from that, discussions are made by comparing the current and new design efficiencies using both methods. In addition, a written part critiques and brief description of each part are also needed. The simulation result of stress and displacement also was discussed in this chapter.

4.1 Written Critique of Each Part

Table 4.1 shows the part critiques for each component inside the original computer desktop chassis. The table explains whether the parts is compulsory or can be eliminated based on Boothroyd criteria.

Table 4.1: Parts Critique for Each Component

Part No	Part Operation/Name	Critique	Material
1	Rivet	Theoretically necessary but could be eliminated when combining mating part or according to Boothroyd suggestion.	Steel
2	Screw	Theoretically necessary but could be eliminated according to Boothroyd suggestion.	Steel
3	Side cover	This is theoretically necessary part because it needs to be opened to allow servicing.	Galvanized steel
4	Front cover holder	This is theoretically necessary part because the mating parts with front cover are made with different material.	Galvanized steel
5	Bottom cover	This is theoretically necessary part because it is a base part for main assembly to be assembled.	Galvanized steel
6	Top cover	Since this is a base part for PC, thus it is theoretically necessary part but it could combine with both side cover.	Galvanized steel
7	CD DVD drive compartment	Theoretically necessary because it used to store drive. But it can combine with front cover holder and HDD compartment.	Galvanized steel
8	HDD right compartment	Theoretically necessary because it used to store drive.	Galvanized steel
9	HDD left compartment	Theoretically necessary because it used to store drive.	Galvanized steel
10	Back cover	This is theoretically necessary part because it is a base part for main assembly to be assembled.	Galvanized steel
11	MOBO holder	Theoretically necessary because it used to hold the PWB.	Galvanized steel
12	Front cover	This is theoretically necessary part because the mating parts with its holder are made with different material.	Plastic

4.2 Comparison between Current and New Chassis Design

Figure 4.1 and Figure 4.2 shows the current and new chassis design.

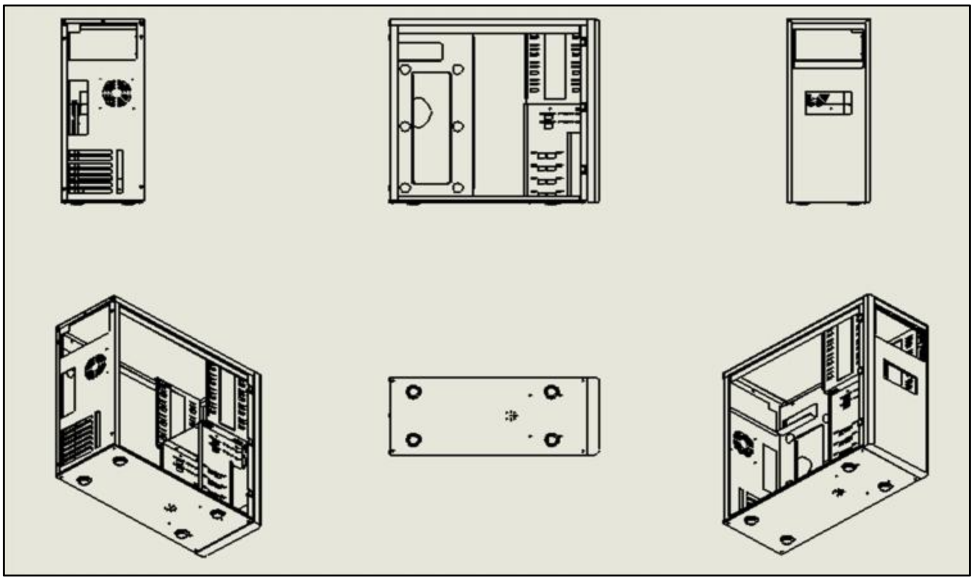


Figure 4.1: Projected View of Current Design without Side Cover on the Left Side.

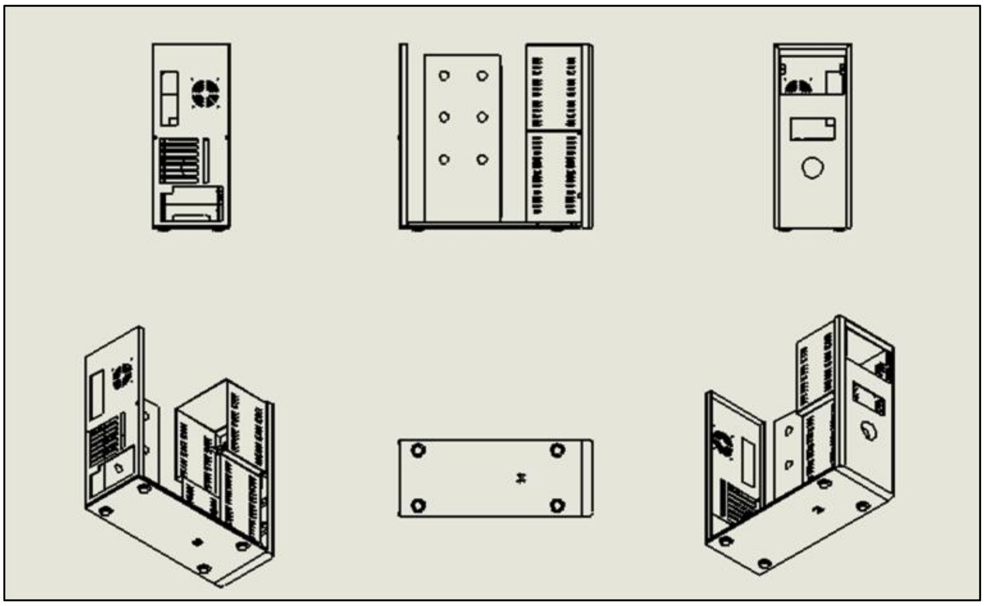


Figure 4.2: Projected View of New Design without Cover

4.3 Parts Modification

Figure 4.3 shows the designs of part before redesign and after redesign.

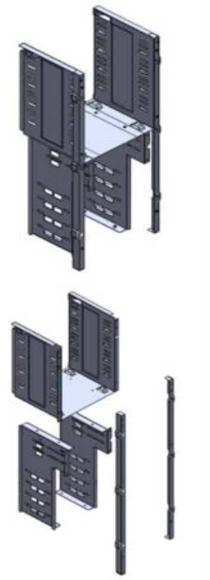
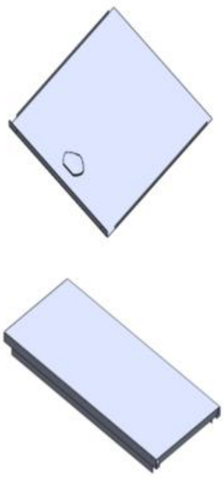
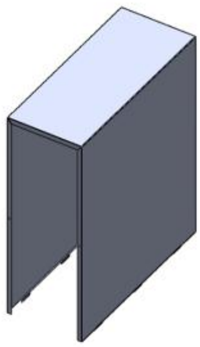
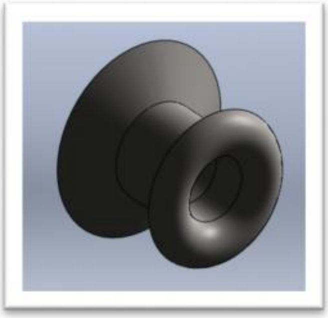
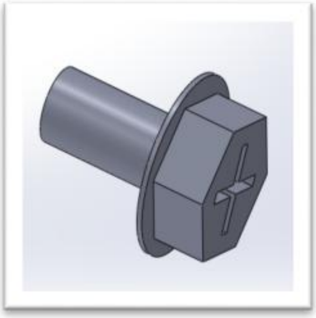
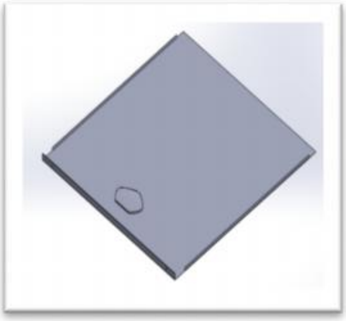
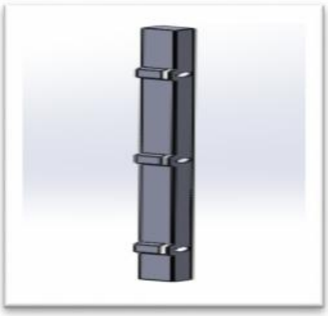
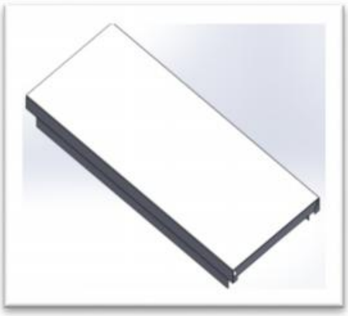
Figure		**Description**	
Before	**After**	**Before**	**After**
		An assembly of CD DVD compartment + HDD compartment + Front part. The explode view of parts that made up of 5 components. Required many rivet to assemble and take more time.	The redesign of assembled of CD DVD compartment + HDD compartment + Front part to become one part only.
Figure		**Description**	
Before	**After**	**Before**	**After**
		Consume more time of handling and insertion time for 2 side cover and top part to be assembled.	Only 2 screws needed to tighten at the back part rather than 4 screws before redesign. Eliminates all rivet used on this redesign and replace with slot fitting.

Figure 4.3: Parts Modification and Description

4.4 Parts Quantity and Specification of Old Design

Figure 4.4 shows the parts specification in old design. Each part in old computer chassis is analyzed to determine it characteristics such as repeated count, orientation (α and β), size and thickness. This is a crucial part because the information is needed to calculate the assembly time for each part from the Boothroyd handling and insertion table.

		
Quantity = 32 α= 360β= 0 Size= 4mm Thickness= 3mm $\alpha + \beta = 360$	Quantity = 4 α= 360β= 0 Size= 5mm Thickness= 3mm $\alpha + \beta = 360$	Quantity = 2 α= 360β= 360 Size = 425.74mm Thickness = 10.74mm $\alpha + \beta = 720$
		
Quantity = 2 α= 180β= 90 Size = 420mm Thickness = 10mm $\alpha + \beta = 270$	Quantity = 1 α= 360β= 360 Size = 425mm Thickness = 55mm $\alpha + \beta = 72$	Quantity = 1 α= 360β= 180 Size= 425mm Thickness= 32mm $\alpha + \beta = 540$

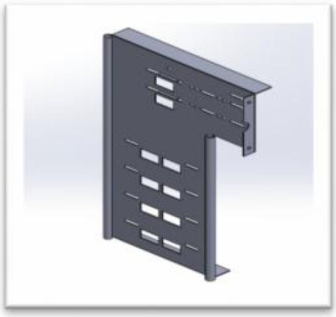
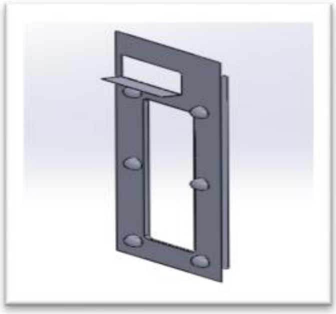
		
Quantity = 1 α= 360β= 360 Size= 194.26mm Thickness= 130mm $\alpha + \beta = 720$	Quantity = 1 α= 360β= 360 Size = 225mm Thickness = 25.74mm $\alpha + \beta = 720$	Quantity = 1 α= 360β= 360 Size= 225mm Thickness= 25.74mm $\alpha + \beta = 720$
		
Quantity = 1 α= 360β= 360 Size = 420mm Thickness = 15mm $\alpha + \beta = 720$	Quantity = 1 α= 360β= 360 Size = 400mm Thickness= 26.47mm $\alpha + \beta = 720$	Quantity = 1 α= 360β= 360 Size= 421.47mm Thickness= 35mm $\alpha + \beta = 720$

Figure 4.4: Parts Specification in Old Design

4.4.1 Current Design Manual Worksheet

Table 4.2 shows the manual worksheet of Boothroyd manual assembly of the current design.

Table 4.2: The Manual Worksheet of Boothroyd DFA Analysis

Part No	Part Name	Number of time the operation is carried out	Manual handling code	Manual handling time (s)	Insertion code	Insertion time (s)	Assembly time (s)	Theoretical minimum no. of part
1	Rivet	32	12	2.25	36	8	328	0
2	Screw	4	12	2.25	39	8	41	0
3	Side cover	2	91	3	00	1.5	9	1
4	Front part	2	00	1.13	00	1.5	5.26	1
5	Bottom part	1	91	3	36	8	11	1
6	Top part	1	91	3	36	8	11	1
7	CD DVD drive compartment	1	30	1.95	36	8	9.95	1
8	HDD right compartment	1	30	1.95	36	8	9.95	1
9	HDD left compartment	1	30	1.95	36	8	9.95	1
10	Back cover part	1	91	3	36	8	11	1
11	MOBO holder part	1	91	3	36	8	11	1
12	Front cover part	1	91	3	30	2	5	1
	Total	48					462.11	10

4.4.2 Calculation of Total Assembly Time and Design Efficiency for Old Chassis

Total assembly time : 462.11 seconds (7.7 minutes)

Design efficiency, $E_{ma} = \frac{N_{min} \times t_a}{t_{ma}}$

Where;

N_{min} = theoretical minimum number of parts

t_a = basic assembly time = 3 seconds

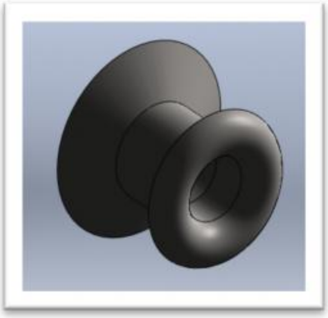
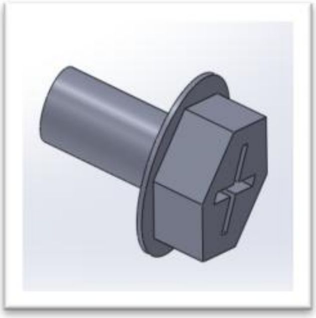
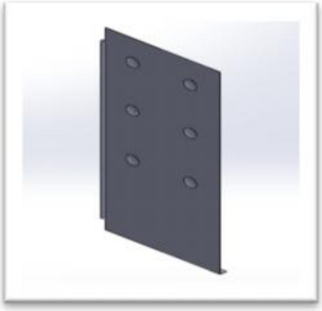
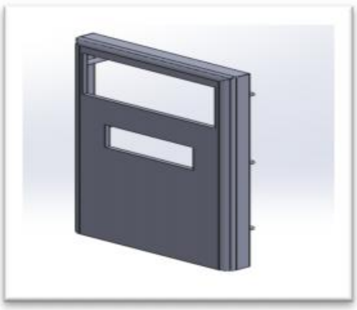
t_{ma} = Estimated time to complete the assembly of the product

Design efficiency : (3 x 10)/ 462.11

: 6.4%

4.5 Parts Quantity and Specification of New Design

Figure 4.5 shows the parts specification in new design. Each part in new design is analyzed to determine it characteristics such as repeated count, orientation (α and β), size and thickness. This is a crucial part because the information is needed to calculate the assembly time for each part from the Boothroyd handling and insertion table.

		
Quantity = 8 α= 360β= 0 Size= 4mm Thickness= 3mm α + β = 360	Quantity = 2 α= 360β= 0 Size= 5mm Thickness= 3mm α + β = 360	Quantity = 1 α= 360β= 360 Size = 424.26 Thickness = 15.74mm α + β = 720
		
Quantity = 1 α= 360 β= 360 Size = 425.74mm Thickness = 55.74mm α + β = 720	Quantity = 1 α= 360β= 360 Size = 400mm Thickness = 10.74mm α + β = 720	Quantity = 1 α= 360β= 360 Size = 425.74mm Thickness = 35mm α + β = 720

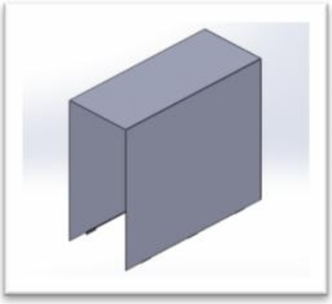
		
Quantity = 1 α= 360β= 360 Size = 400mm Thickness = 10.74mm α + β = 720	Quantity = 1 α= 360β= 360 Size = 425 mm Thickness = 178mm α + β = 720	

Figure 4.5: Parts specification in New Design

4.5.1 New Design Manual Worksheet

Table 4.3 shows the manual worksheet of Boothroyd manual assembly of the new design. From the table, the total count of part is decrease from 48 parts to 16 parts. The total assembly time per product calculates in new design using manual worksheet is 154.5s.

Table 4.3: The Manual Worksheet of Boothroyd DFA Analysis

Part No	Part Name	Number of time the operation is carried out	Manual handling code	Manual handling time (s)	Insertion code	Insertion time (s)	Assembly time (s)	Theoretical minimum no. of part
1	Rivet	8	12	2.25	36	8	82	1
2	Screw	2	12	2.25	39	8	20.5	1
3	Back part	1	91	3	36	8	11	1
4	Bottom part	1	91	3	35	7	10	1
5	Mobo part	1	91	3	36	8	11	1
6	Front cover	1	91	3	30	2	5	1
7	Disk, HDD drive compartment	1	91	3	35	7	10	1
8	Cover part	1	91	3	30	2	5	1
	Total	**16**					**154.5**	**8**

4.5.2 Calculation of Total Assembly Time and Design Efficiency for New Chassis

Total assembly time : 154.5 s (2.6minutes)

Design efficiency, $E_{ma} = \frac{N_{min} \times t_a}{t_{ma}}$

Where;

N_{min} = theoretical minimum number of parts

t_a = basic assembly time = 3 seconds

t_{ma} = Estimated time to complete the assembly of the product

Design efficiency : (3 x 8)/154.5

: 15.5%

4.6 Boothroyd-Dewhurst DFMA Software Analysis

Figure 4.6 as shown below is the product worksheet for the current computer desktop chassis. The sub-parts of computer desktop chassis is listed in the Table 4.7 such as rivet, screw, side cover, front part, bottom part, top part, CD DVD drive compartment, HDD right compartment, HDD left compartment, back cover part, Mobo holder part and front cover part. The total count of part is 48.

Design for Assembly: Product Worksheet

Boothroyd Dewhurst, Inc.

Monday, April 29, 2013 3:40 PM
CPU CASING OLD DESIGN

DFMA old edit.dfa
Product: Original

No.		Name	Part number	Type	Repeat count	Total count	Securing method	Minimum items	Minimum part criteria
1	⊟	CPU CASING OLD DESIGN		Main					
2		Rivet		Part	32	32	Rivet	0	Fastens
3		Screw		Part	4	4	Thread	0	Fastens
4		Side cover		Part	2	2	Sep. op	1	Assembly
5		Front part		Part	2	2	Sep. op	1	Assembly
6		Bottom part		Part	1	1	Sep. op	1	Assembly
7		Top part		Part	1	1	Sep. op	1	Assembly
8		CD DVD drive compartment		Part	1	1	Sep. op	1	Assembly
9		HDD right compartment		Part	1	1	Sep. op	1	Assembly
10		HDD left compartment		Part	1	1	Sep. op	1	Assembly
11		Back cover part		Part	1	1	Sep. op	1	Assembly
12		Mobo Holder Part		Part	1	1	Sep. op	1	Assembly
13		Front Cover Part		Part	1	1	Snap	1	Assembly
14	△	Totals for CPU CASING OLD DESI				**48**		**10**	

Figure 4.6: Product Worksheet for Current Design

Figure 4.7 as shown below is the product worksheet for improved design of computer desktop chassis. The sub-parts of computer desktop chassis are front cover, screw, main cover, back cover, bottom part, Mobo holder part, CD HDD compartment and rivet. The total count of parts is 16.

Design for Assembly: Product Worksheet

Boothroyd Dewhurst, Inc.

Monday, April 29, 2013 2:00 PM
CPU CASING

DFMA new edit.dfa
Product: Original

No.		Name	Part number	Type	Repeat count	Total count	Securing method	Minimum items	Minimum part criteria
1	⊟	CPU CASING		Main					
2		Front Cover		Part	1	1	Snap	1	Assembly
3		Screw		Part	2	2	Thread	1	Assembly
4		Main Cover		Part	1	1	Sep. op	1	Assembly
5		BACK COVER		Part	1	1	Sep. op	1	Assembly
6		BOTTOM PART		Part	1	1	Sep. op	1	Assembly
7		MOBO		Part	1	1	Sep. op	1	Assembly
8		CD HDD COMPARTMENT		Part	1	1	Sep. op	1	Assembly
9		Rivet		Part	8	8	Rivet	1	Assembly
10	△	Totals for CPU CASING				**16**		**8**	

Figure 4.7: Product Worksheet for Improved Design

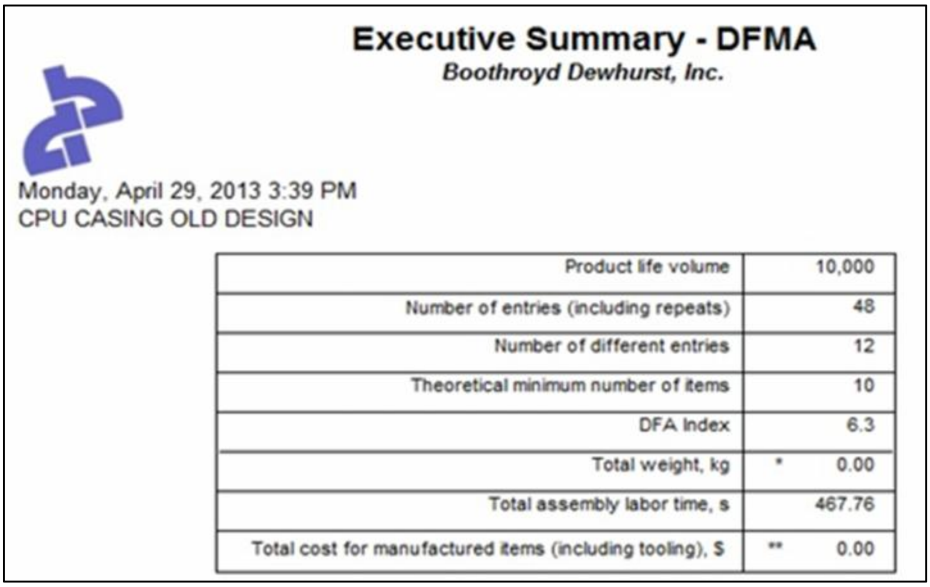
By comparison, the total counts of parts were reduced from 48 to 16 parts. The percentage of reduction was 66.67%.

Sample of calculation for reduction on total count of the number of parts

$$Percentage\ of\ reduction = \left(\frac{48-16}{48}\right) \times 100\%$$

$$= 66.67\%$$

Figure 4.8 is the executive summary for current computer desktop chassis. The total assembly time obtained from software analysis of Boothroyd-Dewhurst DFA for existing design of computer desktop chasis is 467.76 seconds. The design efficiency or DFA index obtain from the DFA software is 6.3%.



Executive Summary - DFMA

Boothroyd Dewhurst, Inc.

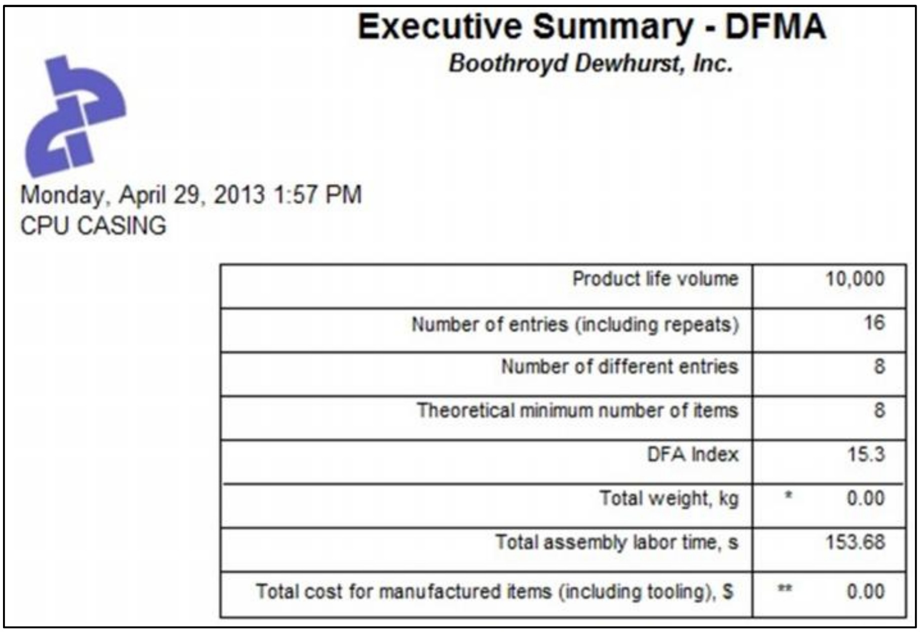
Monday, April 29, 2013 3:39 PM

CPU CASING OLD DESIGN

Product life volume	10,000
Number of entries (including repeats)	48
Number of different entries	12
Theoretical minimum number of items	10
DFA Index	6.3
Total weight, kg	* 0.00
Total assembly labor time, s	467.76
Total cost for manufactured items (including tooling), $	** 0.00

Figure 4.8: Executive Summary for Current Design of Computer Desktop Chassis

Figure 4.9 is the executive summary for new computer desktop chassis. The total assembly time obtained from software analysis of Boothroyd-Dewhurst DFA for new design of computer desktop chasis is 153.68 seconds while the DFA index obtained is 15.3%.



Executive Summary - DFMA

Boothroyd Dewhurst, Inc.

Monday, April 29, 2013 1:57 PM
CPU CASING

Product life volume	10,000
Number of entries (including repeats)	16
Number of different entries	8
Theoretical minimum number of items	8
DFA Index	15.3
Total weight, kg	* 0.00
Total assembly labor time, s	153.68
Total cost for manufactured items (including tooling), $	** 0.00

Figure 4.9: Executive Summary for New Design of Computer Desktop Chassis

4.7 Design Efficiency and Assembly Time Comparison between Old Design and Redesign

Table 4.4 shows the improvement in design efficiency and assembly time of current design and improved design in manual and software method.

Table 4.4: Comparison of Old Design and Redesign

Method	Design Efficiency (%)			Time (s)		
	Current Design	Improved Design	Improvement (%)	Current Design	Improved Design	Improvement (%)
Manual Assembly	6.4	15.5	142.18	462.11	154.5	67
Software	6.3	15.3	142.85	467.76	153.68	67

According to the results, the Boothroyd-Dewhurst manual calculation shows that the design efficiency of improved design has improved from 6.4% to 15.5%, total of 9.1 % of increment from the current design. On the other hand, the DFA software shows about 9.0 % increment in design efficiency of improved desktop design. Based on the observation, there is a small deviation in result between the DFA manual and software.

Based on table 4.4, both the manual and software method giving different efficiency. For manual calculation by using manual handling table and manual insertion table, the efficiency of the original design is 6.4%. However, the efficiency for software method is lower than the manual calculation, which is 6.3% this deflection might be due to detail input need to be classified such as how much number of snap fit for a certain part, compare to manual just classified that part is used snap fit to secure. In software detail operation characteristic is need to classify whether used auto fed, manual fed, screw driver or hand tighten to secure the screw. Apart from that, there are 3 dimension need to classified (size, thickness and width) compared to manual just only need to input the size and thickness.

With the help of manual handling table and the manual insertion table, assembly times and theoretical minimum number of parts are calculated using the assessment provided. Based on these numbers, redesigns can be developed and the resulting assembly times are compared.

For the improved design, the manual method calculation gives an efficiency of 15.5%. A total of 9.1% increment for this new design. In other words, the new design has improved 142.18% from the original design. On the other hand time assembly has reduced by 67% from the original design assembly time.

For software method, however, the efficiency has improved from 6.3% to 15.3%. There is 9% increment for this new design by using software. This means that the improved design has improved 142.85% from the original design via software method.

4.8 Cost Estimation of Current and New Design of Computer Desktop Chassis

Table 4.5 shows the reduction total count of parts and cost estimation of current design and improved design. The estimation cost of current and improved design is estimated using Boothroyd software. The labor rate that is input into the software is RM5/hour.

Costing assumptions:

- Labor cost/month = RM1000
- Working day/month = 25days
- Working hour/day = 8hours
- Labor cost/day = RM40
- Labor cost/hour = RM 5
- Labor cost/second = RM 0.0014

Table 4.5: Part Counts and Total Cost per Product

Design	Current	Improved
No. of Part Counts (n)	48	16
Total cost per product (RM)	0.65	0.21

Besides that, from Table 4.5, the chassis design has a reduction of number of part counts of 66.7%. The elimination of parts will make the chassis simpler and less time for assembly. Reduction of parts also will reduce labor time for assembly. As a result of chassis improvement, the total cost are reduce from RM0.65 to RM 0.21; a reduction 67.7% of the overall cost per product. This method of DFMA for simplicity and ease of assembly has help to eliminate waste and labor time in a production floor. This creates a more effective manufacturing and production assembly line.

Therefore, the improved design has increase the efficiency for the computer desktop chassis while reducing the number of part counts and total cost per product for the manufacturing of a CPU desktop chassis.

Figure 4.10 shows the product worksheet with cost estimation from Boothroyd DFA software with the assumption labor rate per hour is RM5 per hour.

Design for Assembly: Product Worksheet
Boothroyd Dewhurst, Inc.

Monday, June 03, 2013 10:16 AM
CPU CASING OLD DESIGN

DFMA old edit.dfa
Product: Original

No.		Name	Handling problems	Insertion problems	Ergonomic problems	Tool fetching and preparation time, s	Item handling time, s	Insertion/ operation time, s	Total labor time, s	Labor cost, RM
1	⊟	CPU CASING OLD DESIGN								
2		Rivet	X	X	X	2.90	3.38	8.20	373.46	0.52
3		Screw	X	X	X	2.90	0.00	2.30	12.10	0.02
4		Side cover	X	X	X	0.00	3.00	3.40	12.80	0.02
5		Front part	X	X	X	0.00	3.00	3.40	12.80	0.02
6		Bottom part	X	X	X	0.00	3.00	3.40	6.40	0.01
7		Top part	X	X	X	0.00	3.00	3.40	6.40	0.01
8		CD DVD drive compartment	X	X	X	0.00	3.00	3.80	6.80	0.01
9		HDD right compartment	X	X	X	0.00	3.00	3.40	6.40	0.01
10		HDD left compartment	X	X	X	0.00	3.00	3.40	6.40	0.01
11		Back cover part	X	X	X	0.00	3.00	3.40	6.40	0.01
12		Mobo Holder Part	X	X	X	0.00	3.00	3.40	6.40	0.01
13		Front Cover Part	X	X	X	0.00	3.00	8.40	11.40	0.02
14	△	Totals for CPU CASING OLD DESI							**467.76**	**0.65**

Figure 4.10: Estimation Cost for Current Design in Each parts with Total Cost per Product

The total cost per product is estimated to be RM0.65. The total cost is only for total assembly labor cost while the other cost is not included in this estimation. Total assembly labor cost is a cost based on labor rate and total assembly time for a part itself.

Example calculation of estimated cost per part in Figure 4.10

Labor rate: RM5/hour is equivalent to RM 0.001389/s

Total assembly time for rivet is 373.46s

Therefore: 373.46s × RM0.001389/s: RM0.51

Total assembly cost per product = Σ cost for each parts

Design for Assembly: Product Worksheet

Boothroyd Dewhurst, Inc.

Monday, June 03, 2013 10:24 AM
CPU CASING

DFMA new edit.dfa
Product: Original

No.		Name	Handling problems	Insertion problems	Ergonomic problems	Tool fetching and preparation time, s	Item handling time, s	Insertion/ operation time, s	Total labor time, s	Labor cost, RM
1	⊟	CPU CASING								
2		Front Cover	X	X	X	0.00	3.00	9.90	12.90	0.02
3		Screw	X	X	X	2.90	3.87	10.59	31.82	0.04
4		Main Cover	X	X	X	0.00	3.00	5.30	8.30	0.01
5		BACK COVER	X	X	X	0.00	3.00	3.40	6.40	0.01
6		BOTTOM PART	X	X	X	0.00	3.00	3.40	6.40	0.01
7		MOBO	X	X	X	0.00	3.00	3.40	6.40	0.01
8		CD HDD COMPARTMENT	X	X	X	0.00	3.00	3.80	6.80	0.01
9		Rivet	X	X	X	2.90	3.87	5.10	74.66	0.10
10	△	Totals for CPU CASING							**153.68**	**0.21**

Figure 4.11: Estimation Cost for New Design in Each parts with Total Cost per Product

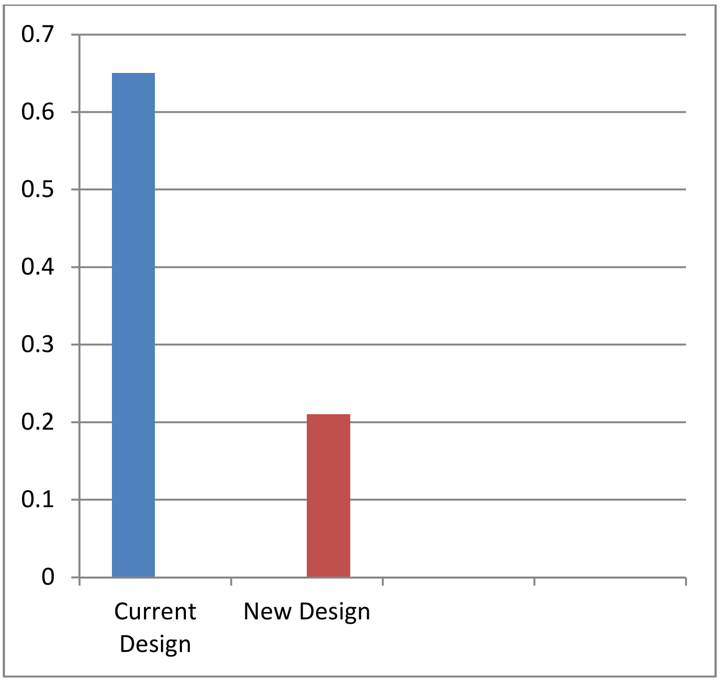


Figure 4.12: Current and New Design Cost Estimation

4.9 Simulation Analysis of Stress and Displacement

The old compartment design is compared with the redesign compartment in term of stress and displacement. The analysis is done using SolidWork 2012 software. Pressure are applied to the holder of CD drive and HDD drive. The result of stress and displacement of the both design is compared. The applied force is about 8.829N (F=mg) then the applied pressure on the surface is about 9375 N/m² ($P = \frac{F}{A}$). A linear static analysis is used to investigate the design. Linear Static analysis calculates displacements, strains, stresses, and reaction forces under the effect of applied loads. Linear static analysis makes the static assumption. In static assumption all loads are applied slowly and gradually until they reach their full magnitudes. After reaching their full magnitudes, loads remains constant (time-invariant).The simulation is carried out to make sure the improve design meet the reliability standard that is below the yield and tensile strength and the deflection is same or better than the current design. This material of the CPU is choosing to be the galvanized steel. The material properties of the galvanized steel are shown in the table below.

Table 4.6: Material Properties of Galvanized Steel
Source: Autodesk Solidwork Software (2013)

Parameters	Value
Yield strength	2.03943e+008N/m² (203.9MPa)
Tensile strength	3.56901e+008 N/m²
Elastic modulus	2e+011 N/m²
Poisson's ratio	0.29
Mass density	7870 kg/m³

Sample of calculation for force and pressure:

Force = $m \times g$

Force = 0.9kg x 9.81m/s = 9N

Area = (0.012mm × 0.005mm) × 4 = $2.4 \times 10^{-4} mm$

Pressure = $\frac{F}{A} = \frac{9}{2.4 \times 10^{-4}}$ *=37500N/m²*

Pressure applied to each of drive holder 37500/4 = 9375 N/m²

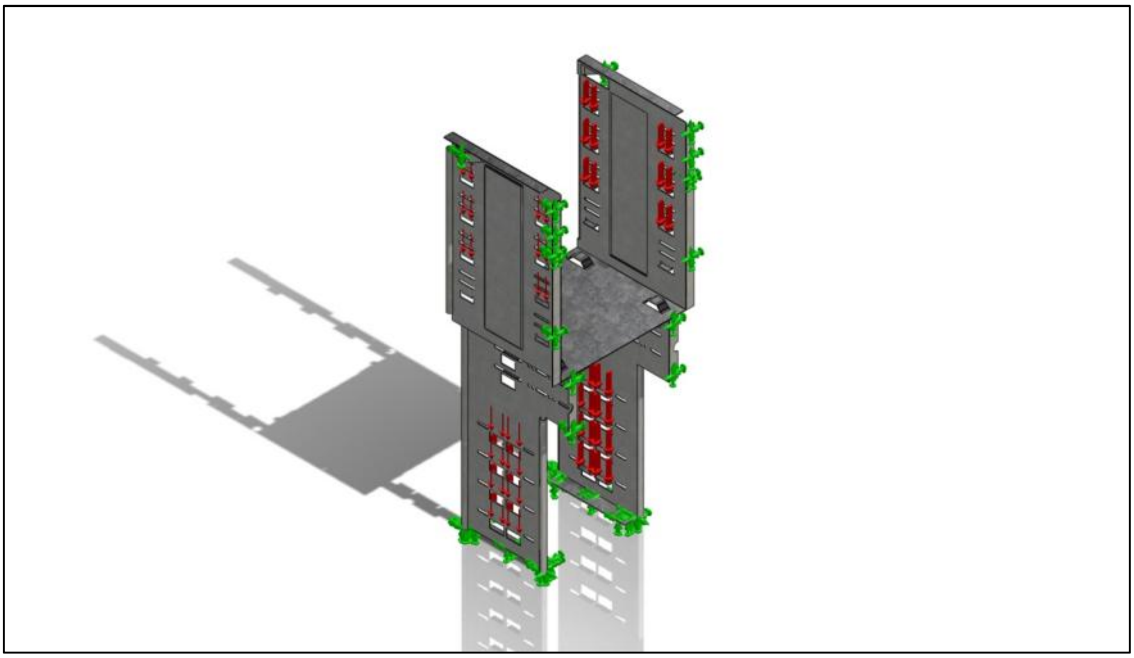


Figure 4.13: The Pressure and Fixture Applied on the Current Design Model

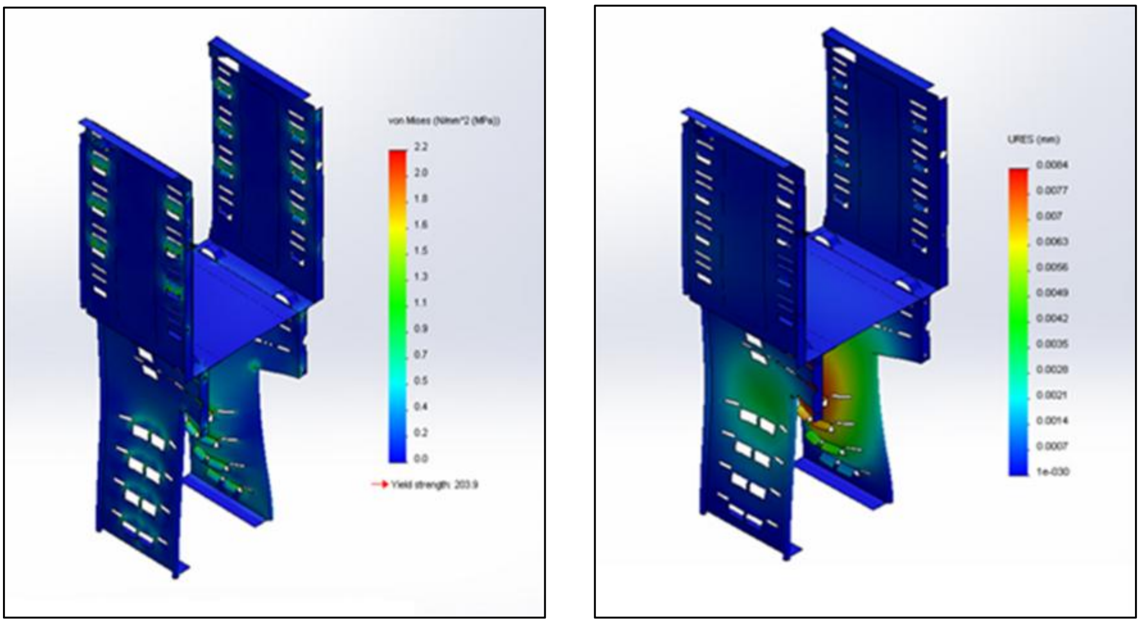


Figure 4.14: The Stress and Displacement Simulation of the Old Design

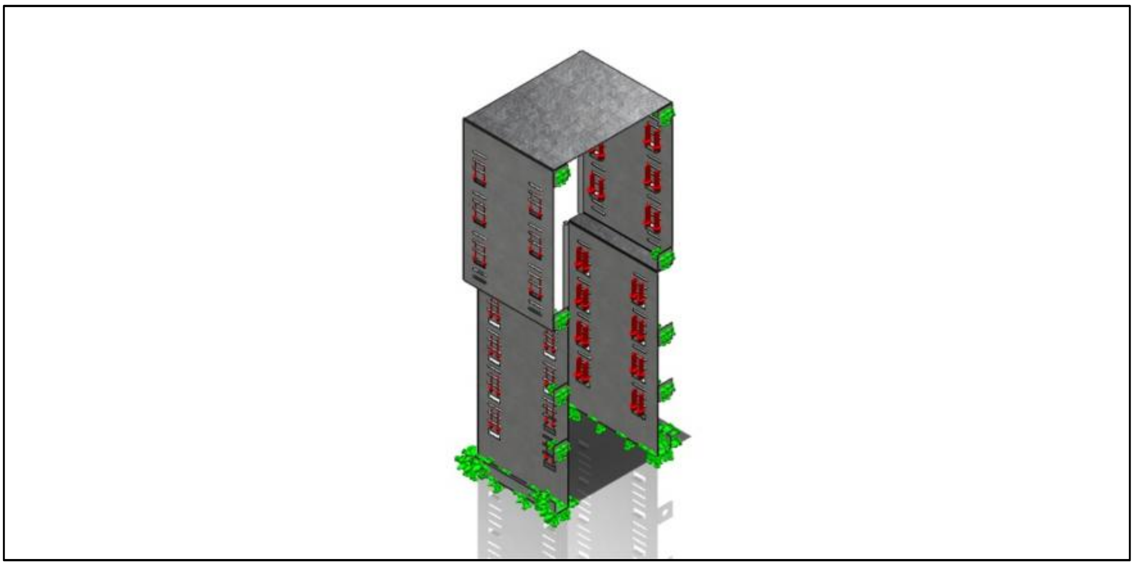


Figure 4.15: The Pressure and Fixture Applied on the New Design Model

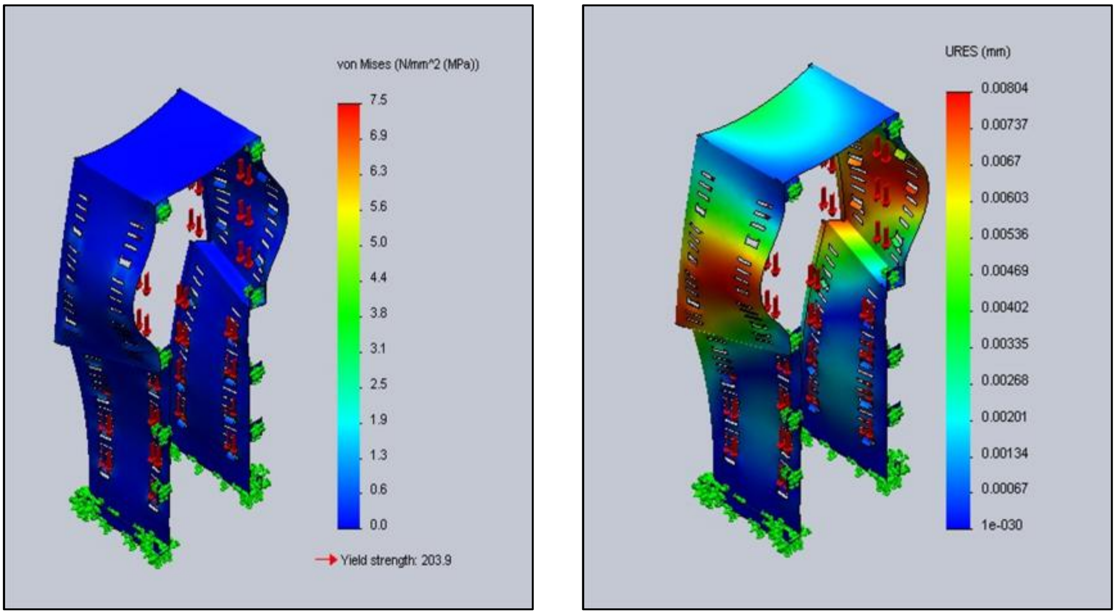


Figure 4.16: The Stress and Displacement Simulation of the New Design

The weight of hard disk is around 900g. Then the force exerted by the hard disk is 9N. The pressure applied on each of the surface part is 9375N/m².

Table 4.7: The Result of Simulation of Displacement and Stress Study

Old Design		New Design	
Stress N/mm² (MPa)	**Displacement** (mm)	**Stress** N/mm² (MPa)	**Displacement** (mm)
Max: 2.19116 Min: 0	Max: 0.00840163 Min: 0	Max: 6.62113 Min: 0	Max: 0.00801447 Min: 0

Table 4.7 shows the stress and displacement of the old design and the new design of computer desktop chassis (Disk compartment). From the mechanical properties of the material the yield strength of the galvanized steel is 203.9MPa and the tensile strength is 350MPa. The stress of the old design is 2.2MPa compare to new design is 6.6MPa. Both values are less than the yield strength which is 203.9MPa and tensile strength which is 350MPa. For the displacement study the old design deflects about 0.00840163mm compare with the new design which is 0.00801447mm. The displacement is about similar with the current design. For the stress and displacement simulation, the result still can be acceptable because of the stress on the part still low than the yield and tensile strength of the material and the value of displacement can be ignored because of small value. The modification can be accepted for this project.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.0 Conclusion

As a conclusion, the project shows considerable part count reduction by implementing Boothroyd-Dewhurst DFA method. The method leads to part count reduction after a redesign exercise on the existing product. The Boothroyd-Dewhurst DFA method, no matter in manual or software form, is proved as a useful tool in improving the design efficiency of current products. According to the results, the Boothroyd-Dewhurst manual calculation shows that the design efficiency of modified computer chassis has improved from 6.4% to 15.5%. On the other hand, the DFA software shows that DFA index increased from 6.3% to 15.3%.Based on the observation, there is a deviation in result between the DFA manual and software. Practically, this deviation is caused by different of calculating process. For example, in Boothroyd-Dewhurst manual calculation, the handling and insertion time are fixed accordant to the part dimension and symmetrical angle. But for software, more detailed information is required for certain securing or process operation, such as number of revolution, handling and insertion difficulty, tools involved, part elimination factor, and etc. For the stress and displacement simulation, the result still can be acceptable because of the stress on the part still low than the yield strength and tensile strength of the material and the value of displacement can be ignored because of small in different values. The modification can be accepted for this project.

5.1 Recommendations

The overall project can be held more easily and precisely by using Boothroyd-Dewhurst DFA software. In DFA software, engineers can easily get the result of DFA index by simply choosing the picture of handling difficulties and insertion difficulties rather than manual to check each column and row to get the assembly time for each part. Apart from that DFA software also provide the early cost profile of product designs to the engineers. On the other hand, DFA software is more detail in specified the characteristic of operation.

Secondly, the simulation also can be done by using Autodesk Simulation Multiphysics, Algor or Ansys rather than Solidwork.Each software has their pro and contra. For example in Solidwork, the simulation is easy to use for beginner but in Ansys more detail information need to be put in the setup to run the simulation.

Thirdly, the DFA study should be carried out together with the design team of a certain company. The product selection from the beginning of the project that has being improved should give some benefit to the company. The student indirectly has contributed something to the company. The project should be acknowledged by the company.

Next, when conducting a DFA research, the suggestion of having more than one student in a group is encouraged. This is due to the best idea and brainstorming that will come out for better improvement of certain product. A member of two persons is enough in a group to give a better idea in term of product design and analysis of DFMA methods. For a better job specification one student carry out a Boothroyd analysis while the other student doing Hitachi or Lucas analysis.

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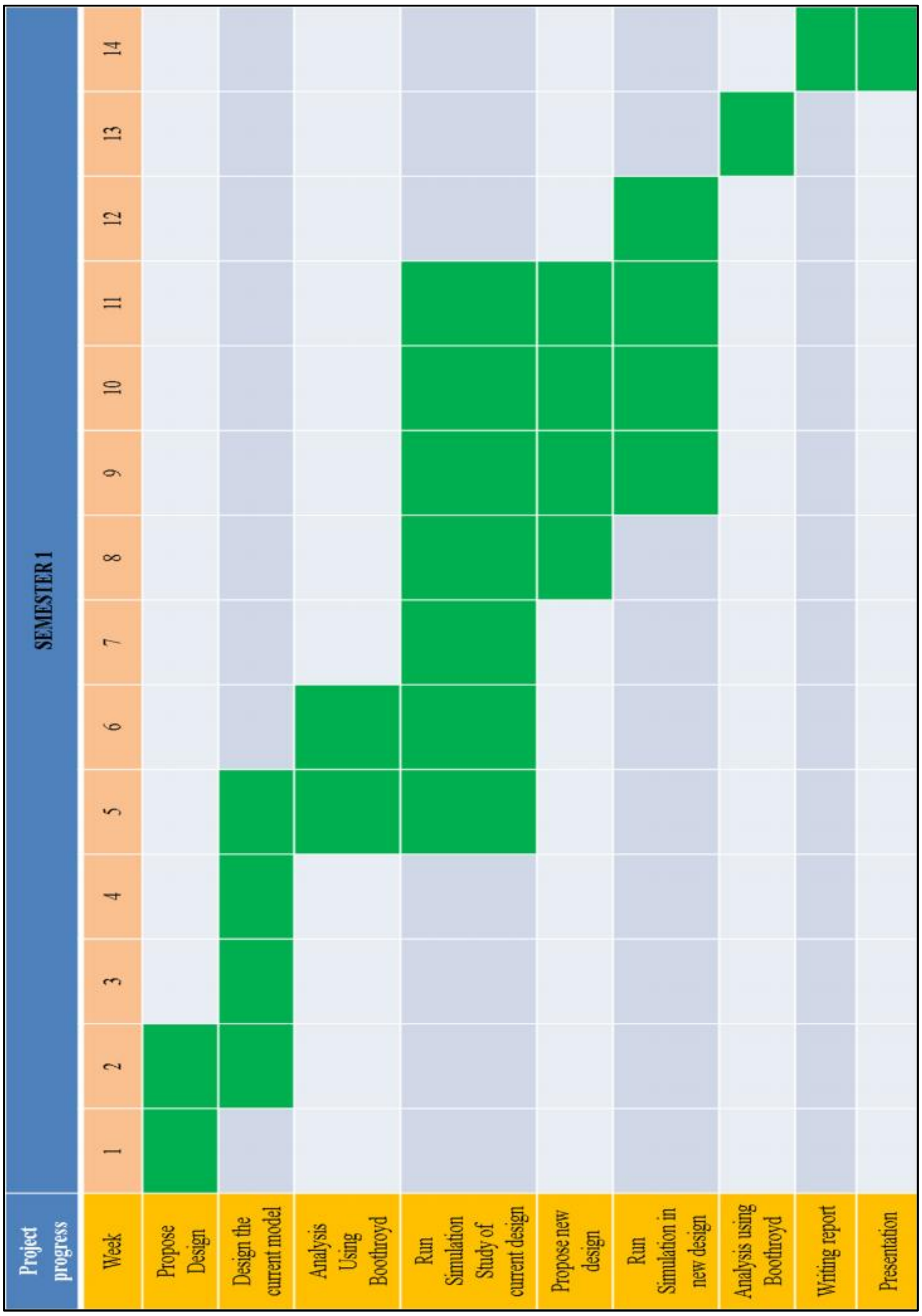
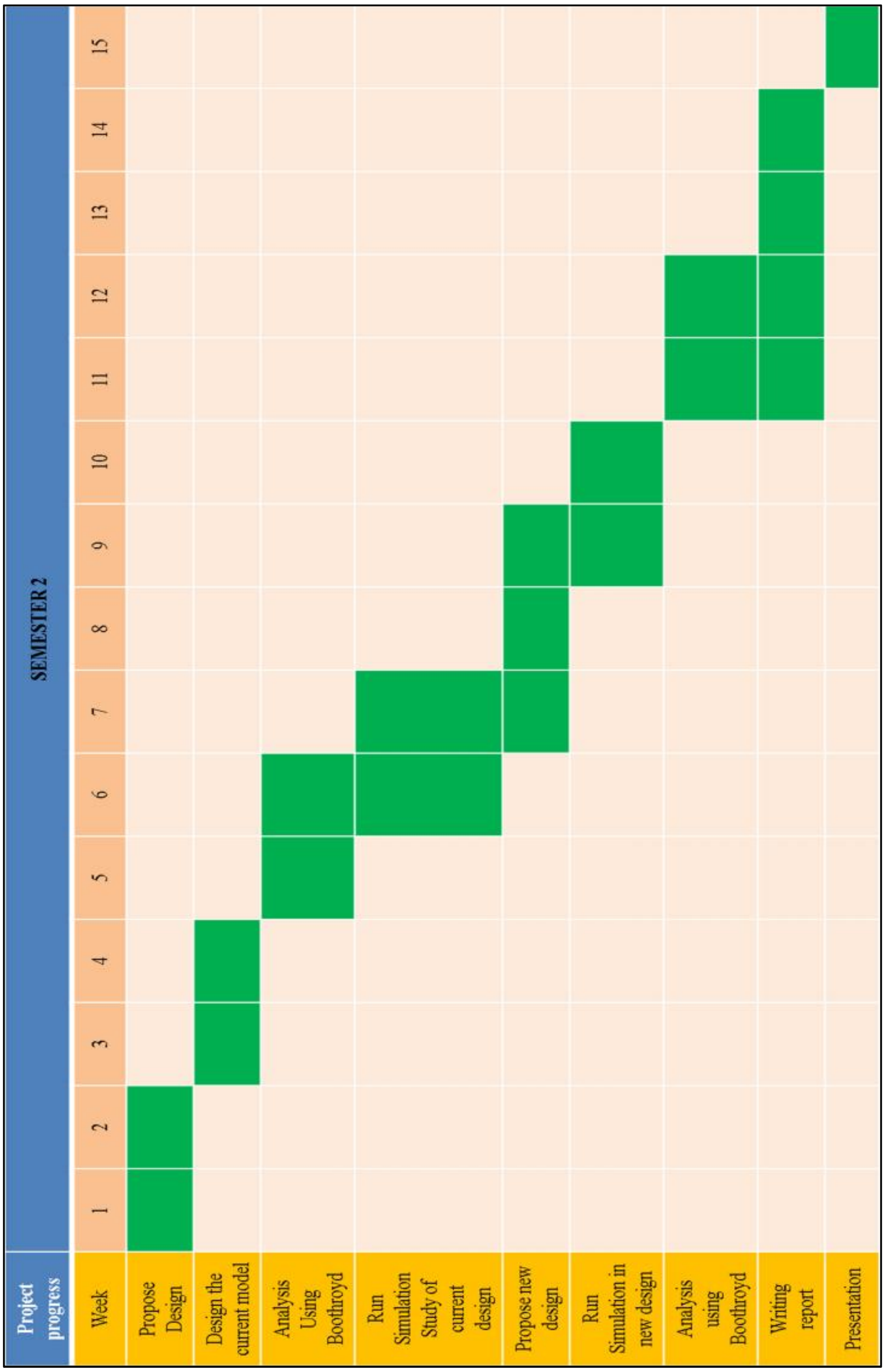
APPENDICES

Appendix A – Gantt chart for semester 1



Appendix B – Gantt chart for semester 2



Appendix C – Manual handling time table

Key:

ONE HAND

parts can be grasped and manipulated by one hand without the aid of grasping tools		parts are easy to grasp and manipulate; thickness > 2 mm; size > 15 mm	parts are easy to grasp and manipulate; thickness > 2 mm; 6 mm ≤ size ≤ 15 mm	parts are easy to grasp and manipulate; thickness > 2 mm; size < 6 mm	parts are easy to grasp and manipulate; thickness ≤ 2 mm; size > 6 mm	parts are easy to grasp and manipulate; thickness ≤ 2 mm; size ≤ 6 mm	parts present handling difficulties (1); thickness > 2 mm; size > 15 mm	parts present handling difficulties (1); thickness > 2 mm; 6 mm ≤ size ≤ 15 mm	parts present handling difficulties (1); thickness > 2 mm; size < 6 mm	parts present handling difficulties (1); thickness ≤ 2 mm; size > 6 mm	parts present handling difficulties (1); thickness ≤ 2 mm; size ≤ 6 mm
		0	1	2	3	4	5	6	7	8	9
$(\alpha+\beta) < 360°$	0	1.13	1.43	1.88	1.69	2.18	1.84	2.17	2.65	2.45	2.98
$360° \leq (\alpha+\beta) < 540°$	1	1.5	1.8	2.25	2.06	2.55	2.25	2.57	3.06	3	3.38
$540° \leq (\alpha+\beta) < 720°$	2	1.8	2.1	2.55	2.36	2.85	2.57	2.9	3.38	3.18	3.7
$(\alpha+\beta) = 720°$	3	1.95	2.25	2.7	2.51	3	2.73	3.06	3.55	3.34	4

ONE HAND with GRASPING AIDS

parts can be grasped and manipulated by one hand but only with the use of grasping tools		parts need tweezers for grasping and manipulation; parts can be manipulated without optical magnification; parts are easy to grasp and manipulate; thickness > 0.25 mm	…; thickness ≤ 0.25 mm	parts can be manipulated without optical magnification; parts present handling difficulties (1); thickness > 0.25 mm	…; thickness ≤ 0.25 mm	parts require optical magnification for manipulation; parts are easy to grasp and manipulate; thickness > 0.25 mm	…; thickness ≤ 0.25 mm	parts require optical magnification for manipulation; parts present handling difficulties (1); thickness > 0.25 mm	…; thickness ≤ 0.25 mm	parts need standard tools other than tweezers	parts need special tools for grasping and manipulation
		0	1	2	3	4	5	6	7	8	9
$\alpha \leq 180°$, $0 \leq \beta \leq 180°$	4	3.6	6.85	4.35	7.6	5.6	8.35	6.35	8.6	7	7
$\alpha \leq 180°$, $\beta = 360°$	5	4	7.25	4.75	8	6	8.75	6.75	9	8	8
$\alpha = 360°$, $0 \leq \beta \leq 180°$	6	4.8	8.05	5.55	8.8	6.8	9.55	7.55	9.8	8	9
$\alpha = 360°$, $\beta = 360°$	7	5.1	8.35	5.85	9.1	7.1	9.55	7.85	10.1	9	10

TWO HANDS for MANIPULATION

		parts present no additional handling difficulties; $\alpha \leq 180°$; size > 15 mm	…; $\alpha \leq 180°$; 6 mm ≤ size ≤ 15 mm	…; $\alpha \leq 180°$; size < 6 mm	…; $\alpha = 360°$; size > 6 mm	…; $\alpha = 360°$; size ≤ 6 mm	parts present additional handling difficulties (e.g. sticky, delicate, slippery, etc.) (1); $\alpha \leq 180°$; size > 15 mm	…; $\alpha \leq 180°$; 6 mm ≤ size ≤ 15 mm	…; $\alpha \leq 180°$; size < 6 mm	…; $\alpha = 360°$; size > 6 mm	…; $\alpha = 360°$; size ≤ 6 mm
		0	1	2	3	4	5	6	7	8	9
parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary) (2)	8	4.1	4.5	5.1	5.6	6.75	5	5.25	5.85	6.35	7

TWO HANDS or assistance required for LARGE SIZE

		parts can be handled by one person without mechanical assistance; parts do not severely nest or tangle and are not flexible; part weight < 10 lb; parts are easy to grasp and manipulate; $\alpha \leq 180°$	…; part weight < 10 lb; parts are easy to grasp and manipulate; $\alpha = 360°$	…; part weight < 10 lb; parts present other handling difficulties (1); $\alpha \leq 180°$	…; part weight < 10 lb; parts present other handling difficulties (1); $\alpha = 360°$	…; parts are heavy (> 10 lb); parts are easy to grasp and manipulate; $\alpha \leq 180°$	…; parts are heavy (> 10 lb); parts are easy to grasp and manipulate; $\alpha = 360°$	…; parts are heavy (> 10 lb); parts present other handling difficulties (1); $\alpha \leq 180°$	…; parts are heavy (> 10 lb); parts present other handling difficulties (1); $\alpha = 360°$	parts severely nest or tangle or are flexible (2)	two persons or mechanical assistance required for parts manipulation
		0	1	2	3	4	5	6	7	8	9
two hands, two persons or mechanical assistance required for grasping and transporting parts	9	2	3	2	3	3	4	4	5	7	9

Appendix D - Manual insertion time table

Key: PART ADDED but NOT SECURED

			after assembly no holding down required to maintain orientation and location (3)				holding down required during subsequent processes to maintain orientation or location (3)			
			easy to align and position during assembly (4)		not easy to align or position during assembly		easy to align and position during assembly (4)		not easy to align or position during assembly	
			no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)
			0	1	2	3	6	7	8	9
addition of any part (1) where neither the part itself nor any other part is finally secured immediately	part and associated tool (including hands) can easily reach the desired location	0	1.5	2.5	2.5	3.5	5.5	6.5	6.5	7.5
	part and associated tool (including hands) cannot easily reach the desired location: due to obstructed-access or restricted vision (2)	1	4	5	5	6	8	9	9	10
	part and associated tool (including hands) cannot easily reach the desired location: due to obstructed access and restricted vision (2)	2	5.5	6.5	6.5	7.5	9.5	10.5	10.5	11.5

PART SECURED IMMEDIATELY

			no screwing operation or plastic deformation immediately after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion						screw tightening immediately after insertion	
					plastic bending or torsion			riveting or similar operation				
			easy to align and position with no resistance to insertion (4)	not easy to align or position during assembly and/or resistance to insertion (5)	easy to align and position during assembly (4)	not easy to align or position during assembly: no resistance to insertion	not easy to align or position during assembly: resistance to insertion (5)	easy to align and position during assembly (4)	not easy to align or position during assembly: no resistance to insertion	not easy to align or position during assembly: resistance to insertion (5)	easy to align and position with no torsional resistance (4)	not easy to align or position and/or torsional resistance (5)
			0	1	2	3	4	5	6	7	8	9
addition of any part (1) where the part itself and/or other parts are being finally secured immediately	part and associated tool (including hands) can easily reach the desired location and the tool can be operated easily	3	2	5	4	5	6	7	8	9	6	8
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily: due to obstructed access or restricted vision (2)	4	4.5	7.5	6.5	7.5	8.5	9.5	10.5	11.5	8.5	10.5
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily: due to obstructed access and restricted vision (2)	5	6	9	8	9	10	11	12	13	10	12

SEPARATE OPERATION

		mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-fastening processes	
		none or localized plastic deformation				metallurgical processes					
							additional material required				
		bending or similar processes	rivetting or similar processes	screw tightening or other processes	bulk plastic deformation (large proportion of part is plastically deformed during fastening)	no additional material required (e.g. resistance, friction welding, etc.)	soldering processes	weld/braze processes	chemical processes (e.g. adhesive bonding, etc.)	manipulation of parts or sub-assembly (e.g. orienting, fitting or adjustment of part(s), etc.)	other processes (e.g. liquid insertion, etc.)
		0	1	2	3	4	5	6	7	8	9
assembly processes where all solid parts are in place	9	4	7	5	12	7	8	12	12	9	12