PRODUCT IMPROVEMENT BY USING DESIGN FOR ASSEMBLY: A CASE STUDY ON HEAVY DUTY STAPLE GUN

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PRODUCT IMPROVEMENT BY USING DESIGN FOR ASSEBLY: A CASE STUDY ON HEAVY DUTY STAPLE GUN

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Report submitted in partial fulfillment of the requirements
for the award of the degree of
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Dedicated to my beloved parents for their everlasting love, guidance and support in the whole journey of my life.

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ABSTRACT

This paper shows a detailed study to analyse the efficiency of Boothroyd Dewhurst Design for Assembly (DFA) method that was applied to improve the product design process. In today competitive world, companies try to cut down the manufacturing cost and at the same time increase their profit. In order to be a competent player in the market, the product should arrive into market within a short time and reasonable price. Assembly cost is one of the major operations in manufacturing but always ignored during designing stage. In this study, comparative analysis was done between original and alternative design. The design was done by using CATIA V5 software and analysed by using DFA software analysis to get the efficiency of original design. Then, by applying Boothroyd Dewhurst DFA method guideline, alternative design was generated and analysed using the same method to compare the effectiveness of this new alternative design. From the study, it was found that the design efficiency increased from 48.4% to 68.2% when Boothroyd Dewhurst DFA method was applied. The time of assemble also decreased from 248.83 seconds to 175.17 seconds per product. From the result, it was proven that this Boothroyd Dewhurst DFA method was able to improve the design in terms of design efficiency, product assemble time and labor cost. This method can be applied in manufacturing company in order to improve their design effectiveness.

ABSTRAK

Kajian ini menunjukkan tentang kajian lanjut untuk mengkaji kecekapan kaedah Boothroyd Dewhurst Rekabentuk untuk Pemasangan (DFA) yang diaplikasikan untuk menambahbaik proses pemasangan rekabentuk. Dalam persaingan dunia masa kini, syarikat-syarikat berusaha untuk mengurangkan kos pengeluaran produk dan pada masa yang sama mereka cuba untuk meningkatkan keuntungan syarikat. Untuk bersaing di pasaran dunia, produk yang dihasilkan mestilah berada dipasaran di dalam masa yang cepat dengan harga yang berpatutan. Kos pemasangan adalah salah satu operasi penting dalam bidang pembuatan tetapi selalu diketepikan semasa proses mereka bentuk. Dalam kajian ini, analisis perbandingan telah dibuat antara produk semasa dengan produk yang dicadangkan. Rekabentuk dilakukan dengan menggunakan perisian CATIA V5 dan dianalisis dengan menggunakan perisian analisis DFA untuk mendapatkan kecekapan bagi rekabentuk semasa. Kemudian, dengan mengaplikasikan panduan kaedah Boothroyd Dewhurst DFA, rekabentuk cadangan dihasilkan dan dianalisis dengan menggunakan kaedah yang sama untuk membandingkan keberhasilan rekabentuk cadangan ini. Daripada kajian, telah didapati kecekapan rekabentuk meningkat dari 48.4% kepada 68.2% apabila kaedah Boothroyd Dewhurst DFA diaplikasikan. Masa untuk pemasangan juga telah berkurang dari 242.83 saat untuk setiap produk kepada 175.17 saat untuk setiap produk. Daripada hasil kajian, telah terbukti bahawa kaedah Boothroyd Dewhurst DFA ini mampu untuk meningkatkan rekabentuk dari segi kecekapan rekabentuk, masa pemasangan produk dan juga kos tenaga kerja. Kaedah ini boleh diaplikasikan dalam syarikat pembuatan bagi meningkatkan kerberhasilan rekabentuk.

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LIST OF SYMBOLS

mm	Millimetre
s	Second
E_{ma}	Design efficiency
N_{min}	Theoretical minimum number of parts
T_a	Basic assembly time
E_d	Functional efficiency
T_{ma}	Estimated time to complete the assembly of the product
α	Rotational symmetry of a part about an axis perpendicular to its axis of insertion
β	Rotational symmetry of a part about its axis of insertion

LIST OF ABBREVIATIONS

DFA	Design for assembly
DFM	Design for Manufacture
DFMA	Design for manufacturing assembly
AEM	Assemblability evaluation method
RM	Ringgit Malaysia
NM	Total Theoretical minimum part
CM	Total assembly cost
TM	Total assembly time

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Nowadays, in the era of globalization, design for manufacture and assembly (DFMA) fairly important, according to the current issue of price increases for consumer good. In addition, the term DFMA accompanied by a combination of Design for Assembly (DFA) and design for manufacturing (DFM). The basic concept is that design engineers apply DFMA paradigm of software to analyse manufacturing and assembly problems at the initial design stage. In this way, all considerations about the factors that affect the final output as early as possible in the design cycle. Additional time is spent in the initial design stage is relatively less time will be spent on a redesign of repetitions and meanwhile, costs will be reduced.

DFA methods are considered and solve the problems as possible in the assembly process at the initial design stage can ensure parts will be fitted will be faster, lower cost and productivity. DFA method is similar to the paradigm of design, engineers are using all kinds of methods such as analysing, estimating, planning and simulation takes into account all the factors that will affect the installation process during the entire design process; construction revise assembled to meet the features and functionality of the final product and at the same time, to reduce costs as much as possible.

The purpose of the design for assembly (DFA) is to facilitate the assembly product that costs are reduced. Nevertheless, as a result of applying DFA usually include improved quality and reliability, and a reduction in the production of equipment and parts inventory. The secondary benefits often greater than the reduction in assembly costs. In addition, to reduce the number of parts or counts, variability, assembly surface, simplifies of the assembly sequence, components handling and insertion, for quicker and more reliable assembly. Furthermore, it is also to reduce the total of material costs, simplifying the selection of vendors, reducing labour and assembly, simplifies the assembly process and factory layout.

This study concentrated on re-design of a product with the Boothroyd Dewhurst DFA approach. The method utilized, as it gives a process of improving a product design for easy and low cost assembly. Moreover, it additionally concentrates on the capacity and assemblability simultaneously. Besides that, the Boothroyd Dewhurst DFA method, it analyses whether the part can be considered as a candidate for elimination or mixed with other parts in the assembly.

1.2 OBJECTIVE

The main objective of this project:

- To analyse the efficiency of product design in the aspect of the assembly.
- To improve product design by DFA methodology for reduce the assembly time and manufacturing cost by re-defines the component design.

1.3 SCOPE OF RESEARCH

This research, heavy duty staple gun TR110 as the product. By using the Boothroyd Dewhurst Design for assembly approach: a) Exploded view of the product and using CATIA V5 software as modelling, design the original product, b) Then, analyse the parts using DFA software for analysis original product and new design, c) Compare the result between original product and new development product, d) Using a fused deposition machine to produce a physical object of re-design using Rapid Prototyping process.

1.4 PROBLEM STATEMENT

A heavy duty staple gun is a manual handheld machine used to drive heavy metal staples into plastic, wood, or stone. It also used for different applications and to affix a variety of the materials, including wiring, insulation, roofing, house wrap, carpeting, craft materials and etc. However, in the era of globalization, product manufacturer need to be able to respond quickly to market demand and has shorter product development time to market their products in order to compute and winner in the global market. Today, a mostly product currently includes many of fasteners and unnecessary feature. Therefore, it leads to the increasing of time during assembly activities which later extend the time to introduce the product to the market. Late availability on the market will cause the design to be outdated and loss of competency.

As a conclusion, one of the methods in design for assembly (DFA) which known as Boothroyd Dewhurst can be utilized to overcome the problem. There are a few ways to enhance the design, which is; a) The great way possible to assembly the product by eliminating of fasteners to another kind assembly, such as press fit, snap fit, mechanical fastening and etc., b) Combine the part or eliminated the unnecessary part. By using this method, it was capable of assembly time saving; higher product quality and more products can be produced. Other than that, it likewise evaluated the design efficiency of the product and the product cost of assembling in the early stages of the design, designers could always estimate the efficiency and labour costs of their designs before the product produced. This research is aimed to enhance terms of product design and manufacturing process in a production and optimization in the assembly.

1.5 EXPECTED OUTCOMES

The end of this research, the outcome that has been expected is that the potential reduction in cost manufacturing, a shorter manufacturing time for assembly and increased quality of product. In addition, this product can reduce the quantity of parts in the assembly also ensure that parts are easy to assembly.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will describes about product development tool by using Quality Function Deployment (QFD), Design for Assembly (DFA), and Design for Manufacturing (DFM), and lastly Product Life Cycle. Other than that, it gives a brief clarification about the functions, the methodology and the principles of the DFA which is subcomponents of the DFMA itself and review on previous case studies.

2.2 PRODUCT DEVELOPMENT TOOL

In the era of globalization, development is an essential part of an association's long term development and accomplishment. Tragically, numerous manufacturers observe the product improvement procedure to be one of their most inefficient and wasteful activities. There are 4 types of the product development tool, which is Quality Function Deployment (QFD), Design for Assembly (DFA), and Design for Manufacturing (DFM), and lastly Product Life Cycle. The goal is to offer manufacturers with removing waste from their new product advancement projects and product designs

2.2.1 Quality Function Deployment (QFD)

Quality Function Deployment (QFD) has been developed in Japan by Yoji Akao in 1966s. According the Akao's, Quality Function Deployment (QFD) is a method to develop a design quality is a mechanism of developing a design quality that is intended to meet customer requirements and then translate user requests into the design targets and major quality guarantee points which will be used during the production phase. This method is one way to ensure the quality of the product design while still in the design stage. As a very important side benefit him show that, when suitable to be used, QFD has been shown to decrease the development time by one-third to one-half (Akao, 1990).

There are three main objectives in conducting QFD, namely:

i. Prioritize spoken and unspoken client needs and wants.
ii. Translate these needs into the features and the technical specifications.
iii. Develop and deliver a quality product or service by focusing everybody toward client satisfaction.

2.2.1.1 Principle of QFD

Quality Function Deployment using several of the principles of the Concurrent Engineering (CE) in which cross-functional teams are included in all phases of product development. In addition, in a QFA process have four phases, it utilizes a matrix to interpret client/customer needs from beginning arranging stages by means of generation control (Becker Associates Inc, 2000). Other than that, every stage in QFD speaks to a more particular of the product prerequisites from the customer. Every stage is assessed with the relationship between components. Just the most essential parts of every stage were conveyed into the following matrix.

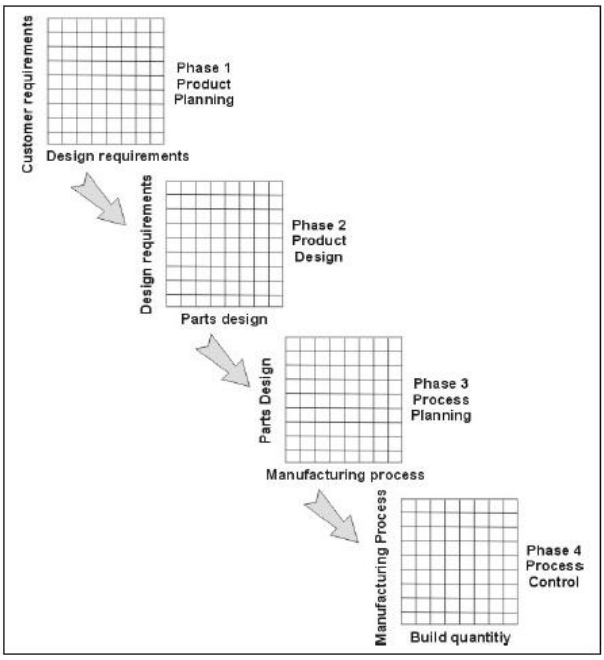


Figure 2.1: Phase in Quality Function Deployment (QFD)

Source: Reilly, 1999

i. **Product Planning (Phase 1)**

Firstly, build up the House of Quality, for example, the one demonstrated as follows (Fig. Lowe and Ridgway (2001). Other than that, phase 1 be utilized for record client requirement, guarantee information, competing product measures, and the specialized capacity of the association to meet every client requirement (Becker Associates Inc, 2000).

ii. **Product Design (Phase 2)**

For phase 2, which is headed by the engineering department. Product design requires creativity and ideas and innovative team. Additionally, product concepts are created during this phase and some documented specifications. Lastly, the parts which have been chosen to become the most important to satisfy customer needs and then sent into planning process (Becker Associates Inc., 2000).

iii. **Process Planning (Phase 3)**

In the process planning, it led by manufacturing engineering. This process including process planning, manufacturing processes must be are documented (Becker Associates Inc, 2000).

iv. **Process Control (Phase 4)**

Finally, this phase designed in place to control the production process, maintenance schedules, and skills training for operators. Similarly, in this phase of the process of selection is such that most represents danger and placed control established to avoid failure. (Becker Associates Inc, 2000).

2.2.2 Design for Assembly (DFA)

Design for Assembly was developed in 1960s. The design for assembly method must be carefully considered at all every stage of the design in the initial stages, so it can estimate the time assembly operation and cost manufacturing correctly. Designer team should provide quick results so that they are easy and convenient to use. It also should ensure that completeness and consistency in the evolution of assembility product. In addition, design for assembly method is the design of the product for ease of assembly; it is using a systematic procedure step by step to estimating assembly time and cost in the early stage. Teamwork is very important for the designer and manufacturer engineer to consider together with the structure of the product, the purpose is to make adjustments to the design or parts and they will get an immediate feedback on the effect of such change (Geng, 2004).

The purpose of design for assembly methods to guide designers to facilitate the structure through a combination of features or parts, alternative methods of obtaining. Furthermore, it also provides a tool to force designers to assist in determining the most effective method for fastening necessary interface among separate parts in the design. This is an important consideration because a separate fasteners are often the most labour intensive groups of items when considering mechanical assembly work.

Consideration fastening method is very important because 47% of the time spent on the assembly of entry and tighten the screws and nuts (Geng, 2004).

Table 2.1: Alternative choices fastening methods

Method	Assembly time (s)
Snap Fit	4.1
Press Fit	7.3
Integral Screw Fastener	11.5
Rivet (4)	36.1
Machine Screw (4)	40.5
Screw/ Washer/ Nut (4)	73.8

Source: Geng, 2004

Moreover, the other objective is when beginning to design something, the senior designer will gather all the data about the design structure and organize it appropriately for junior designer, engineer and evaluation the time of assembly process, expense and the element which will bring about the deformity. At that point they proceed with the system regulated. With the goal that overhead cost won't happen (Boothroyd. D, 2002).

2.2.2.1 Comparison of Assembly Methods

There are three major groups of the Assembly methods such as manual assembly, robotic assembly and automatic assembly. For the manual assembly, parts moved to the workbenches where workers manually assemble the product or components of a product. Moreover, hand tools are generally used to help workers. This method also is adaptable of assembly methods and the most flexible, there is usually an upper limit to the production volume, and labour costs, including benefits, cases of workers' compensation due to injury, the overhead for maintaining a clean, etc. are higher. In fixed or hard automation is characterized by a custom-built machine that assembles one and only one specific product. Certainly, this kind of machinery requires a large capital investment. With the increase in production volume, a small portion of capital investment compared to the total production cost reduction.

Indexing tables, mixers, and automatic control symbolize rigid assembly method. Sometimes, this kind of the assembly is called "Detroit-kind" assembly.

Finally, the robotic assembly incorporates the use of robotic assembly systems. This method can take the form of a single robot, or multi-station robotic assembly cell with simultaneous activities are controlled and coordinated by a PLC or computer (Vincent. C, 2005). Although this kind of assembly method can also have large capital costs, its flexibility often helps offset the expense across many different products. From the graph, the cost of the different assembly methods, as shown in Figure 2.2 show the non-linear cost for robotic assembly reflects the non-linear costs of robots. The range is suitable for every kind of assembly method shown approximately in Figure 2.3. The assembly method should be selected to avoid bottlenecks in the process, as well as lower costs.

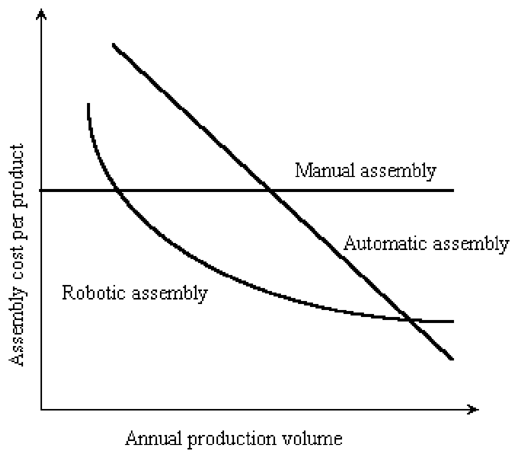


Figure 2.2: The relative cost of assembly methods vary according to the type and volume of production.

Source: Vincent. C, 2005

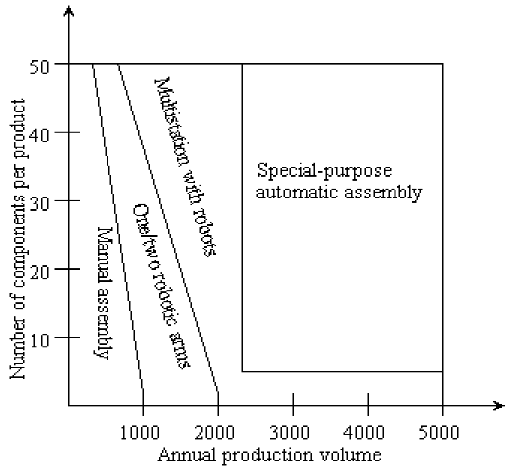
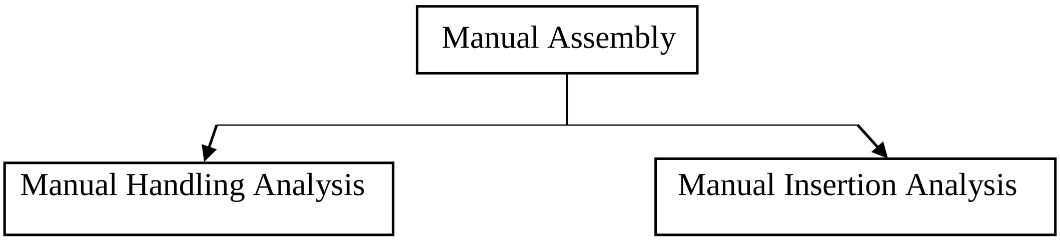


Figure 2.3: The range of production for each type of assembly methods

Source: Vincent. C, 2005

2.2.2.2 Manual Assembly

This process is divided into two separate areas such as handing and insertion (Geng, 2004; Boothroyd, 2002).



2.2.2.2.1 Handling

Handling is included acquiring, orienting and moving parts. Generally, the case of part delivery, the designers have to try:

i. Part design has end-to-end asymmetric and symmetric around the axis rotation of the insert. If this has not proved, try to design parts that have the maximum possible symmetry (see Fig. 2.4a).

ii. Design parts that, in those instances where the part cannot be made symmetric, are obviously asymmetric (see Fig. 2.4b).

iii. Give the features that will prevent jamming parts that tend to nest or stack if stored in bulk (see Fig. 2.4c).

iv. Avoid features that will enable tangled piece if stored in bulk (see Fig.2.4d).

v. Avoid parts stick together or smooth, smooth, flexible, very small or very large or dangerous to the operator (i.e., parts that are sharp, splinter easily, etc.) (See Fig. 2.5).

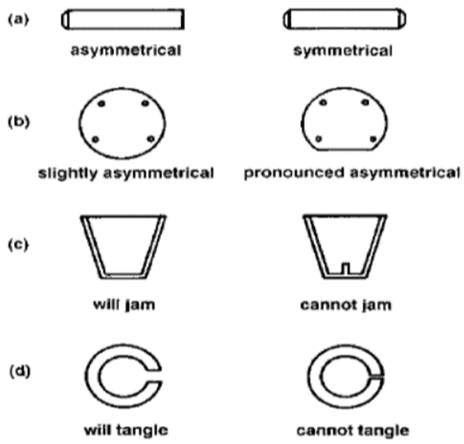


Figure 2.4: An illustration of a geometrical features influence part handing

Source: Boothroyd, 2002

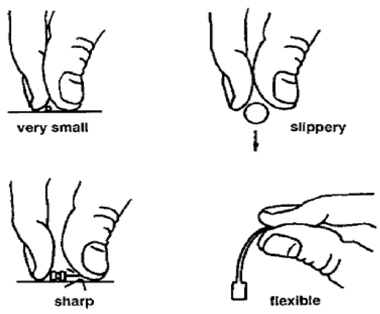
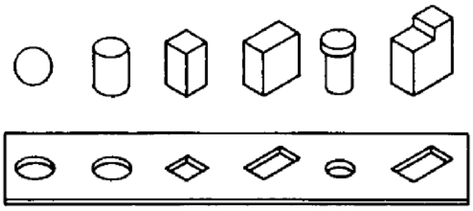


Figure 2.5: Some other features that influence part handling

Source: Boothroyd, 2002



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

Figure 2.6: An illustration of alpha and beta Rotational symmetries

Source: Boothroyd, 2002

Furthermore, identify the minimum number of the part. Boothroyd Dewhurst DFA method provides three criteria to guide the designer to reduce the number of components, if the parts do not meet at least one of three criteria, then it is considered as a potential to eliminate. There are three criteria (Boothroyd, 2002), which are: -

i. The part move relative to all other parts already assembled.
ii. The part must be a different material than or be isolated from all other parts already assemble.
iii. The part must be separated from all other parts already assembled because otherwise necessary assembly or disassembly.

2.2.2.2.2 Insertion

Insertion is a mating part to other parts. In addition, to facilitate the entry of the designer should try to (Boothroyd, 2002):

i. Designers need to provide chamfers to guide insert two mating parts. In addition, generous clearance must be provided, but care should be taken in order to prevent relief that would result in a tendency for the parts to jam or hang-up during insertion (see Figs. 2.7 to 2.9).
ii. Standardize the common parts, processes and methods in all models as well as the entire product line to allow the use of a higher number of products that usually leads to lower costs (see Fig. 2.10).

iii. Use the assembly pyramid - provides for progressive assembly about the axis of reference. Generally, it is best to assemble the top (see Fig. 2.11).

iv. A design that's part before it is released. One source of potential problems arising from the part that is placed where, due to design constraints, it must be removed before it is positively located in the hall. In this case, reliance is placed on the top of its trajectory enough to find consistently repeated (see Fig. 2.12).

v. When mechanical fasteners are commonly used following sequence shows the relative costs of different fastening process, listed in order of increasing cost of assembly manual (Fig. 2.13).

a) Snap fitting
b) Plastic bending
c) Riveting
d) Screw fastening

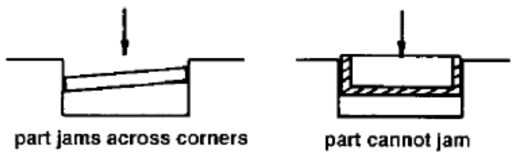


Figure 2.7: Incorrect geometry may allow some bottlenecks during insertion.

Source: Boothroyd, 2002

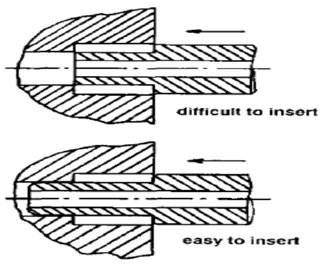


Figure 2.8: Design for facilitate the insertion - a long assembly step washers to counter bored hole.

Source: Boothroyd, 2002

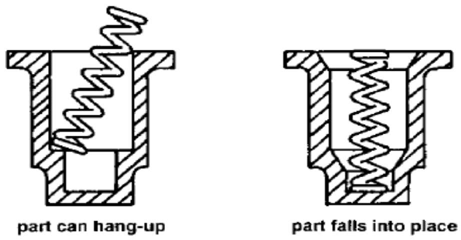


Figure 2.9: Preparation of chamfers to enable easy insertion

Source: Boothroyd, 2002

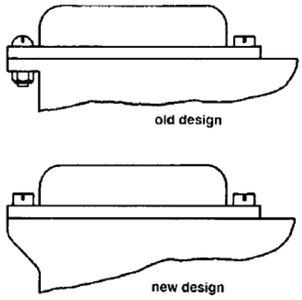


Figure 2.10: Standardize parts

Source: Boothroyd, 2002

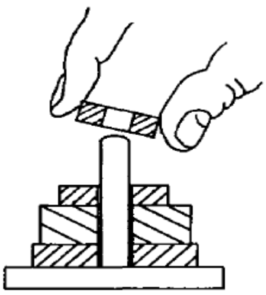


Figure 2.11: Single-axis pyramid assembly

Source: Boothroyd, 2002

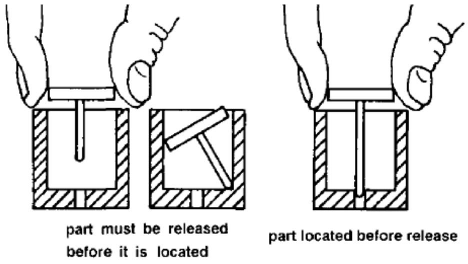


Figure 2.12: Design to help insertion

Source: Boothroyd, 2002

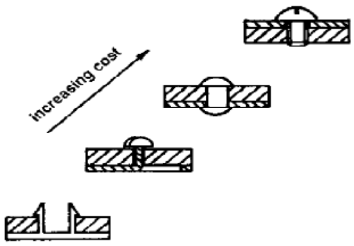


Figure 2.13: Typical fastening methods.

Source: Boothroyd, 2002

2.2.2.2.3 Guidelines of the Design for Assembly (DFA)

i. Aim for simplicity

The purpose of the simplicity is focused on reducing the number of counts, parts variation, and the surface of the assembly; facilitate sequence assembly, handling and insertion components. This is to make all the process in assembly faster and more reliable.

ii. Standardizes

The purpose of this guideline is to standardize the use of materials, components and goals of off-the-shelf components as possible to enhance inventory management, device is reduced, and the benefits of mass production although at low volume.

iii. Rationalizes product design

Rationalizes product design is to unify the materials, components and sub-assemblies across the product family to increase economies of scale and reduce the cost of equipment and tools. It also uses a modified variant introduced to allow late in order to facilitate assembly and JIT production.

iv. Use the widest possible tolerance

By using the widest possible tolerance we can reduce the tolerance on noncritical components and thus reduce operations, and process times.

v. Select the material according to the function and production processes

Avoid choose materials merely for functional features and a choice of materials also need to support the production process to ensure product reliability.

2.2.3 Design for Manufacturing (DFM)

Design for Manufacturing is the design of building components and systems as a function of the manufacturing process and design for easy to remove accumulation of parts that will make up the product after assembly (Boothroyd, 2002). Ferrer. I (2010) said that this considering design goals and manufacturing issues while the product is being designed and period for product development is reducing the quality of the product and the cost has been greatly improved. Furthermore, decision making process is very important in this method.

DFM is the method to improve the product competitiveness, the goals are to decrease manufacturing and material cost, improve the quality and flexibility. This method involving a simultaneous view of the design goals and constraints of manufacturing to identify problems manufacturing said Olivier Kerbrat (Kerbrat, 2011). DFM is a method to improve the productivity, quality and also reducing the cost. Moreover, it is also an effective method to reduce assembly time and simplify parts by using the consideration of the concurrent engineering.

Currently, The first approach (DFM) can no longer be translated into a structured method, but it's a bit can be inserted into a series of expedients, which allows the inclusion of information on manufacturing processes in product design development phase (Giudice, 2009). The reason that makes DFM is little difficulty in clearly represents the knowledge of how to use them in DFM, different sources and formats make it difficult to access the information and knowledge when needed, lack of systematic procedures to capture, organize and represent and disadvantages procedures to document and formalize the decisions made during the design process and more specifically in the preliminary design phase (Ferrer. I, 2010).

The general requirements for starting materials and the selection process is the amount of product life, the level of equipment expenses are allowed, may form part of the category and level of complexity, service or environmental requirements, the appearance and accuracy factors. All the details of the design of the part must be defined with consideration of processing. For this reason, it is important that the economic assessment of the competitive process is done while the product is still in the concept stage (Boothroyd, 2002).

2.2.3.1 DFM Techniques

Design for Manufacturing techniques including the selection process manufacturing, DFM guidelines is manufacturability analysis.

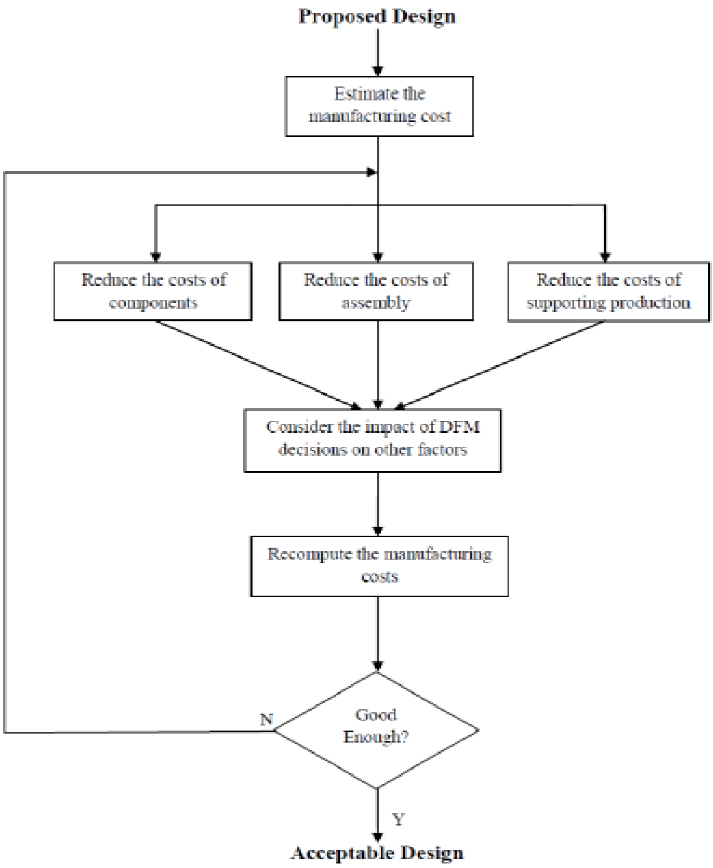


Figure 2.14: The design for manufacturing (DFM) method

Source: Syam Prasad, Tom Zacharia, J.Babu, 2014

2.2.4 The Product Life Cycle

According to Raymond Vernon, there are four phases in the product life cycle, such as the introduction, growth, maturity and decline. In addition, the length of different levels for different products, one stage of the product life cycle can last several weeks while others even decades. The product life cycle is very similar to the spread of innovation model that was developed by Everett Rogers in 1976. The life expectancy of the product and how fast it goes through the whole cycle depends on market demand and examples of how marketing instrument used (Van Vliet 2012).

2.2.4.1 Type of Phases life cycle

There are four phases in a product life cycle (Figure 2.15). In each of the four phases, the product is in an alternate state.

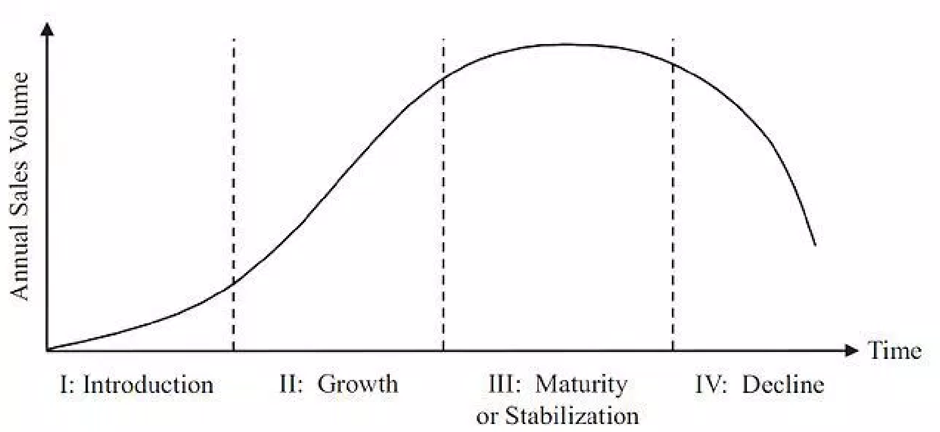


Figure 2.15: Product life cycle

Source: Malakooti, B., 2013

i. **Introduction Stage**

This function is to create demand, investment made with regard to awareness and promotion of consumer products in order to continue selling. In addition, the benefits can be reduced and there are only a few competitors. If more items of products sold, it will automatically enter the next level.

ii. **Growth Stage**

At this stage, the demand for products to boost sales. Therefore, the cost of production decreases and high profits produced. This product became known, and competitors will enter the market with their own versions of the product. Typically, they offer products at prices lower sales.

iii. **Mature Stage**

These products are widely recognized and purchased by many consumers. Competition is intense and the company will do anything to remain stable as the market leader. This is why the product is sold at a record low. Also, company would begin to look for other commercial opportunities such as the customization or innovation of product and by-product production. Marketing and promotion costs are therefore very high at this stage.

iv. **Decline Stage**

This stage in the life cycle of the product can occur due to natural, but it is also stimulated by the introduction of new and innovative products. Although a decline in sales, companies continue to offer the product as a service to their customers, so they will not be offended.

2.3 DESIGN FOR ASSEMBLY METHODOLOGIES

Nowadays, there are various method that has been used in Design for Assembly (DFA) in the industry, but each method has their advantage and disadvantage. There are three type of the design for assembly methods:

i. Boothroyd Dewhurst DFA Method
ii. Hitachi Assemblability Evaluation Method
iii. Lucas Hull DFA Method

2.3.1 Boothroyd Dewhurst DFA Method

Boothroyd Dewhurst DFA Method is methods of assessing the products based on design efficiency. If design efficiency higher, the product is better. In addition, the number of parts of products have a major impact on the efficiency of the design. If the product has a lot of parts, assembly time will be higher. Higher installation time means the design more efficient. Also, higher installation time directly means that the cost of installation is higher. Therefore, Boothroyd Dewhurst DFA proposes elimination of unnecessary parts and combine the various parts into fewer components to reduce the number of parts in products (Farid. N. M, 2007).

DFMA is a method to evaluate the manufacturability design of the part and assembly design. It is of the ways to identify the parts that are not needed in the assembly, and determine the time of manufacture and assembly costs. The steps applying DFMA methods and corresponding software are shown in Figure 2.16.

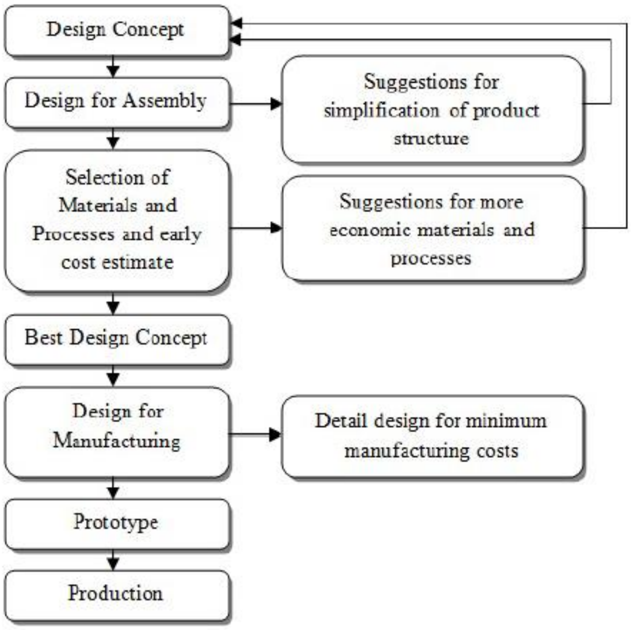


Figure 2.16: The steps applying DFMA methods

Source: Todić, V., Lukić, & Vukman, J., 2012

Boothroyd claims that the product design to manufacturing and installation can be key to the higher productivity in all manufacturing industries compared with automation. In his method, the design concept for the installation is first introduced in the conceptual design phase to ensure the best design concepts for materials and processes. Therefore, this concept has been evaluated to reduce the cost of production, which resulted in a slight increase, time in the conceptual design phase. Huge time savings will be achieved in beginning of design and detail design phase.

Generally, the DFA software can be divided into three main stages (Ristic. M, 2011):

i. **Selection of work piece**

Choice the best kind of raw material or work piece as the initial phase in applying DFA depends of numerous components that influence their decision, for example;

- Mechanical and substance properties of the work piece material.
- Selection standard work piece.
- Application of near net production technology.

ii. **Selection of machining processes and systems**

In deciding the most proper machining procedures and frameworks should be taken into consideration:

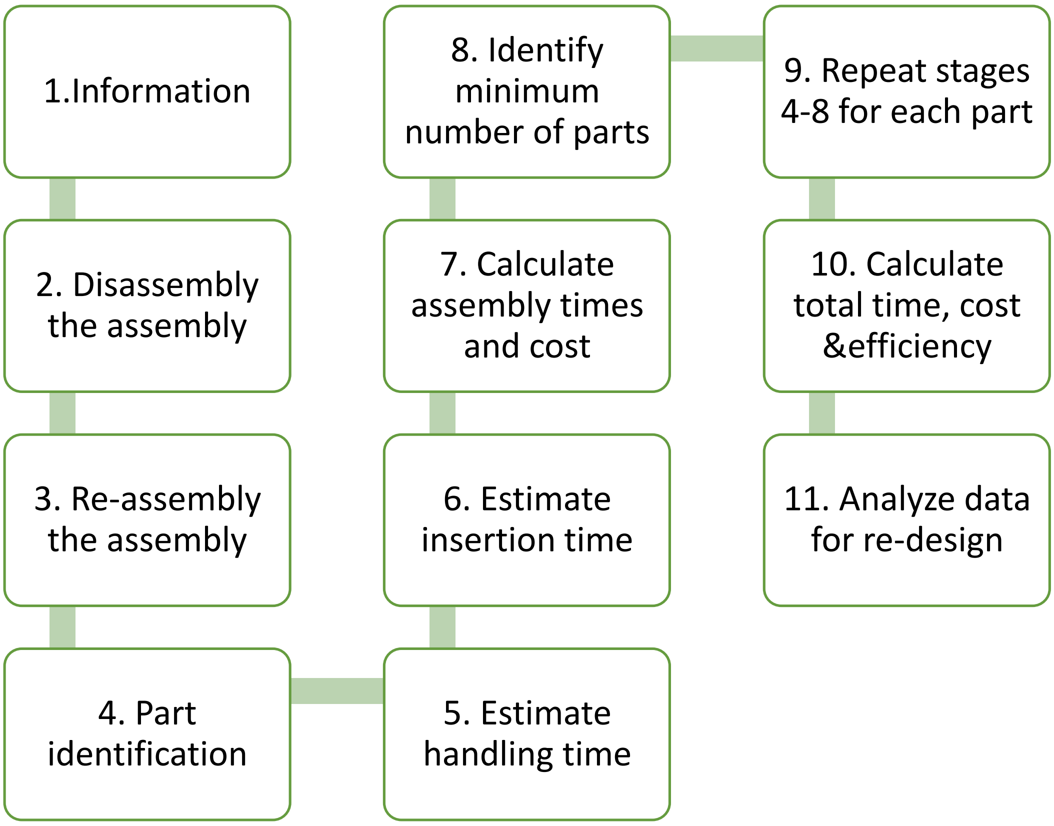
- Type of production
- Type and shape of work piece
- Economically tolerance of product
- Opportunities machining frameworks

iii. **Assembly of the product**

Assembly of the product, gives the best probability of applying DFA methods. Appropriate utilization of DFA standards allows produce a high quality product. This standards depend on:

- Reducing the quantity of parts in the gathering
- Implementation of symmetric parts when product design allows it
- Easy design of products
- Ensure self-featuring

2.3.1.1 Manual Assembly Procedure



Source: Boothroyd, 2002

The first stage of the method is getting the information of the product; find out the problem that found in the product. Then, the product was disassembly and reassembly again. To simplify this process, provided the product tree and identified the name of each part. In addition, the assembly of every component part is obtained the handling time of the part to its insertion time. Other than that, In addition, there are two key factors that affect the time required for handling during assembly manual is the thickness and size of parts.

For the handling code, alpha symmetry and beta symmetry must be considered. 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. Besides that, the beta symmetry depends on the angle through which a part must be rotated about the axis of insertion axis. Since, with such a rotation, the prism will be repeat its orientation every 180^o, it can be termed 180^o alpha symmetry. The square prism would then have to be rotated about the axis of insertion, and since the orientation of the prism about this axis would repeat every 90°, this implies 90° beta symmetry. However, of the square prism were to be inserted in a circular hole, it would have 180° alpha symmetry and 0° beta symmetry. In Figure 2.17 show about the symmetry of simple shaped parts. After complete the handling code an insertion code, assembly times and costs are calculated by using the handling time and insertion time.

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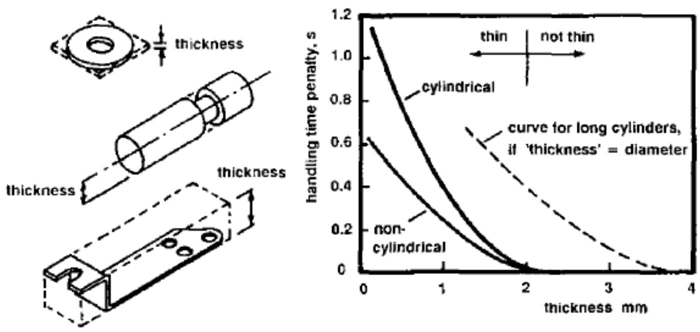


Figure 2.17: The effect of part thickness on handling time.

Source: Boothroyd, 2002

$$\text{Design efficiency, Ema} = \frac{\text{Nmin x Ta}}{\text{Tma}}$$

Where;

Nmin = Theoretical minimum number of parts

Ta = Basic assembly time (3 second)

Tma = Estimated time to complete the assembly of the product.

2.3.2 Hitachi Assemblability Evaluation Method (AEM)

Assemblability Evaluation Method has been developed in 1976 by Hitachi. The objective AEM is to better assemblability of product with enhance the design of the product. In addition, AEM can also identify weaknesses of the design early stages of the design process. This method uses two indices in the initial stages of design (Farid MN 2007), an assembly method for evaluation, E is used to assess the quality of the design and assembly difficulty assembly cost ratio, K is used to project assembly costs compared with current assembly costs. This method does not differentiate between manual, automatic assembly robot as Boothroyd Dewhurst (1992) believes there is a strong correlation relationship between's the degrees of assembly difficulty. The description of algorithmic structure for assessing suitability for assembly by Hitachi at given in Fig. show below.

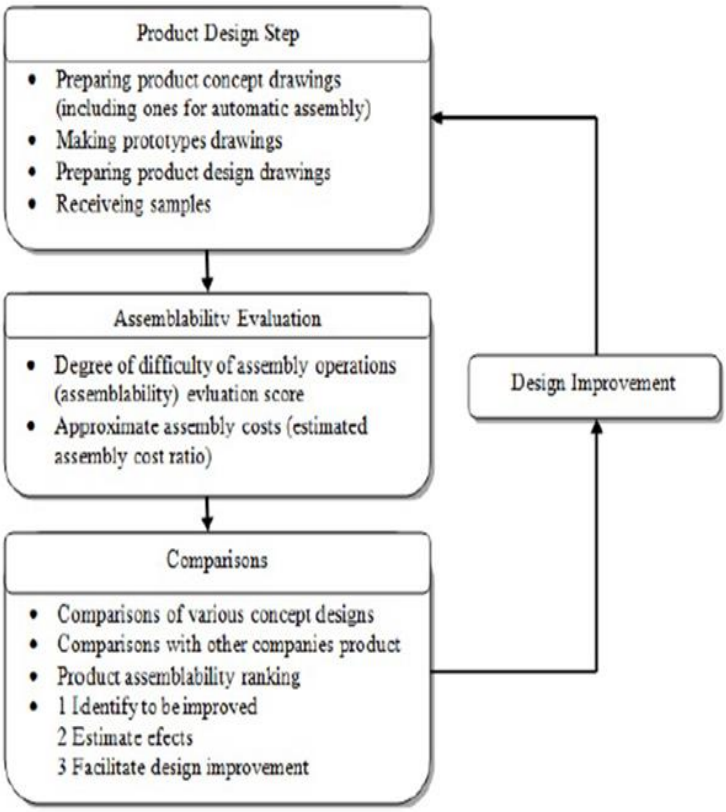


Figure 2.18: Assessment of suitability for assembly and redesign

Source: Farid M.N, 2007

2.3.2.1 Symbol in Hitachi Assemblability Method

a) Direction of motion of a part

Symbol	Penalty Point	Description of Operation
↓	0	Straight Downward
↑	30	Straight Upward
← →	20	Move Horizontally
↗ ↙	30	Move diagonally up/down
∩C	30	Turn like a screw
R	40	Turn of lift the whole assembly to insert a part

b) Fixture and forming requirement

Symbol	Penalty Point	Description of Operation
f	20	Hold a part for next one operation
F	40	Hold a part for more than next one operation
G	40	Deform a soft/flexible part (O-ring/gasket)
P	20	Bend or cut (wire)

c) Joining and processing requirements

Symbol	**Penalty Point**	**Description of Operation**
B	20	Bond with adhesive or heat or lubricate a part
W	20	Weld
S	30	Solder
M	60	Machine a part to join

d) Other symbol without penalty point

Symbol	**Penalty Point**	**Description of Operation**
—	0	Base part for assembly
│	0	Pipe to keep track of Assembly

e) An additional 15% penalty points for every operation for the second and subsequent operations:

- A powerful incentive for easy assembly activities
- It important to the automatic assembly

2.3.3 Lucas Hull DFA Method

Lucas Hull Design for Assembly (DFA) Method was developed during the late 1980's. It's different with Boothroyd Dewhurst method, where the Lucas Hull DFA Method depends on a "point scale" which gives a relative measure of get together trouble (Vincent. C, 2005).

Furthermore, those began by summarizing the reasons why, serves traditional product introduction process is recommended not capable of meeting modern requirements (Boothroyd. G, 1992):-

i. Sequential activity results in protracted lead times.
ii. Customer requirements, product design, and method of the manufacture are inextricably linked with many trades-offs; they are cannot be addressed independently by marketing, engineering and manufacturing function.
iii. Scarce design resources are wasted on interdepartmental communications, progress chasing and non-value added activities correcting designs that prove difficult to make or do not fully meet customers aspirations.
iv. Manufacturability issues are discovered too late and are the subject of quick fix solutions and compromises.
v. All design activity is pushed through a single, ill-defined activity

Categorized the part into A parts or B parts. A target is set for design efficiency which is A/B and expressed as a percentage. The aim is to exceed an arbitrary 60% target value by the elimination of category B parts through redesign.

↓

Use the boothroyd Dewhurst minimum parts criteria in a “truth” table to assist in parts count reduction to emphasize assembly cost reduction and part count reduction.

↓

Handling and feeling analysis at the size, weight, handling difficulties, and the orientation of the part. The score is summed to give the total score for the part and a handling or feeding ratio is calculated which is given by the total score divided by the number of A parts. A target of 2.5 is suggested.

↓

The fitting analysis based on the proposed assembly sequence. Each part is scored depending on whether it requires holding in a fixture, the assembly direction, alignment problems, restricted vision and the required insertion force. The total score is divided by the number of A parts to give the fitting ratio. The fitting ratio should be approach 2.5 for an acceptable design.

(Source: Boothroyd. , 2002)

The functional design efficiency can be calculated as follows:

$$\text{Ed} = \frac{\text{A}}{(\text{A}+\text{B})} \times 100\%$$

Where:

A = The number of essential components

B = The number of non- essential components

$$\text{Feeding Ratio} = \frac{\text{Total Feeding Index}}{\text{No.of essential components}}$$

Where:

Total Feeding Index = The number of essential components

No. of essential component = The number of non- essential components

2.3.4 Comparison of DFA Methods

There are three types of the Design for Assembly (DFA) method which a commonly used in the industry, which is Boothroyd Dewhurst DFA Method, Lucas Hull DFA Method, Hitachi AEM Method. These three types of method are slightly different and have advantages and disadvantages.

Table 2.2: Design for Assembly (DFA) Methods Comparison Table

DFA Methods	Advantage	Disadvantage
Boothroyd Dewhurst DFA Method	- Resign of product can be evaluated based on the design efficiency calculation - Automatic feeding and insertion	- Reduction of parts count which can result in the production and use of complex components. As the cost of assembly is usually 5% of the total cost, the end product can be easy to assemble but expensive to manufacture.
Lucas Hull DFA Method	- Evaluate part of the product by function, handling and fitting analysis and suitable in developing new products.	- Focus on the insertion and fastening process
Hitachi AEM Method	- Easy and difficulty of insertion expressed in relative terms.	- Does not take about the cost of production while making design changes, which can lead to some expensive.

Source: Razak F.B, 2010

2.3.5 Previous Research

Table 2.3: The summary of the previous researches

Author	**Methodology**	**Product Study**	**Summary**
Farhan Bin Ab Razak (2010)	DFA Method: Boothroyd Dewhurst Design for Assembly method and Hitachi Assemblability Evaluation Method (AEM)	Headlamp	In his degree thesis title "Cost Reduction Study of Automotive Part Using Design for Assembly (DFA) Method: Headlamp by Farhan Bin Ab Razak (2010)". The thesis discusses about the ability to produce a new product design with features such as a higher quality than the original product, lower cost in manufacturing is a key factor in meeting the market demand. The objectives of this thesis are to analyze existing headlamp using Boothroyd Dewhurst Design for Assembly (DFA) method and Hitachi Assemblability Evaluation Method (AEM) in terms of assembly time, assembly cost and assembly efficiency. The headlamp that has been used in this project is a Saga BLM headlamp. Finally, the original headlamp and proposed headlamp design have been compared between each other's and the best result is the proposed design which has the lowest assembly time, lowest assembly cost and highest percentage of design efficiency that is the third proposed design headlamp for each method.

T. Ariffin, M.Khairul, Kamarul A.M and M. Faizal (2010)	DFA Method: Boothroyd Dewhurst DFA method	Steam Iron	In his journal titled "Product Design improvement by design for assembly (DFA) Method: A case study on steam iron by Tajul Ariffin Bin Abdullah, M.Khairul Aizat, Kamarul A.M and M.Faizal Halim (2010)" discuss concerning improvement the design of a steam iron product with design for assembly (DFA) method. The aims of this journal are to study of the product steam iron using the Boothroyd Dewhurst DFA method. Design for Assembly offers a lot advantages including easier than installation easier of product assembly, part minimization and product efficiency. Furthermore, the original steam iron and proposed steam iron design was compared between each other's. For the result from the analysis, it potential for reduced assembly cycle times, reduced material cost and will higher product quality.
Ismail (2009)	DFMA Method	Designing Pressure Vessel	In his journal is study about effect of implement of DFMA in pressure vessel (Ismail. A.R, 2009). This analyse manage reduce the part or component and increase the design efficiency from 0.02% to 0.023%. Besides that, it also managed the reduce assembly time about 12.79% compare to existing product.

Mohan V. Tatikonda (1994)	DFA method: Boothroyd Dewhurst DFA method	Pressure recorder assembly	This paper discusses the design improvements Pressure recorder product assembly using the design for assembly (DFA) method. Moreover, DFA techniques can be applied manually or software. Many products have efficiencies as low as 20% before DFA analysis is applied, and then achieve efficiencies higher than 70%. In addition, there are several steps in the analysis: First, an initial design is developed or proposed. After that, this design alternative is assessed penalty points for each feature of the design. Third, these points are aggregated to determine the "design score" efficiency of assembly for the design. Finally, the product is "redesigned" using part and product level design rules coupled with consideration of annual volumes and existing manufacturing processes. For the results, usage DFA will reduce manufacturing costs, reduction of product development time, and increased reliability.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will describe an overview of the methodology used in carrying out this project bachelor session of 2015/2016. The methodology of a project can be defined as a sort of management and project planning from the beginning until the final stage of the project. Thus, a well-planned methodology can be avoid delay of the works and clash activities. It can also accomplish the procedures which satisfied the project objectives on time when it's being followed perfectly. In order to perform the analysis design by using Boothroyd Dewhurst DFA software a few analyzation of the original design step will conduct. This will be discussed in this chapter. This chapter described the approaches and major stages of the project undertaken.

3.2 FLOW CHART OF THE PROJECT

This project started with the selected of the product. This project, heavy duty staple gun TR110 as the product. The activities of this project started with literature reviews, selected methodology that can used and product selection. For the methodology, it included gather the information of the product, disassemble the product and capture each part of the product, understand how the parts function relative to each other and dimensioning and engineering drawing by using CATIA V5 software. Furthermore, the next step is to analyse each component from original and redesign product by using Boothroyd Dewhurst DFA software. In order to perform the analysis, Boothroyd Dewhurst DFA software is used to calculate the total assembly time, design efficiency and total manufacturing cost. Then, compare the result from the original product and redesign product based on the total assembly time, design efficiency and total manufacturing cost. Finally, fabrication process. This stage will be present with the flow fabrication process for the redesign parts using the rapid prototyping machine from starting until the end. The terminology work and planning for this project are shown in the flow chart in Figure 3.1.

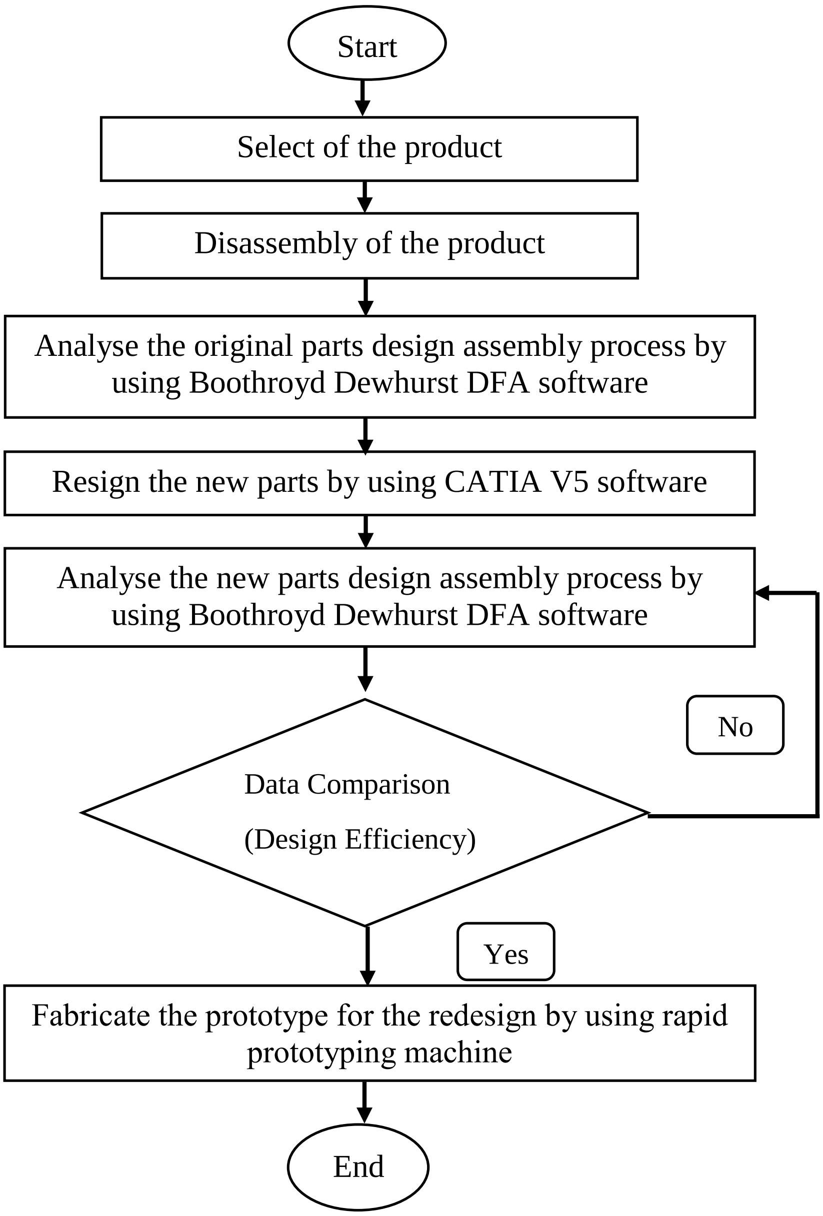


Figure 3.1: Flowchart of the project

3.3 PROCEDURE

3.3.1 Selection of Product

A heavy duty staple gun is a manual handheld machine used to drive heavy metal staples into plastic, wood, or stone. It also used for different applications and to affix a variety of the materials, including wiring, insulation, roofing, house wrap, carpeting, craft materials and etc. This project is about the reduction the cycle time for assembly process and cost reduction by using Boothroyd Dewhurst DFA method.

Figure 3.2: Original product

Table 3.1: Heavy Duty Staple Gun Specification

Product characteristics	Product Specification
Model	Heavy Duty Staple Gun TR110
Product name	Heavy Duty Staple Gun
Dimension	145.0 mm x 32 mm x 181.0 mm
Type of function	Manual
Weight	950g
Applications	Used to drive heavy metal staples into plastic, wood, or stone.
No. of parts	31

3.3.2 Parts Disassembly's

To perform this research, a technical insight into the product is important as this is where the understanding of how parts / product works and functioned. As the point of view of observer might be subjective in term of determining the best design and ease of assembly, a few exercises on other improved product or example are strongly recommended.

3.3.2.1 Part list of the original design

A heavy duty staple gun is used as a test product. Table 3.2 show the bill of the materials in the product. Basically, it has 31 part. The material of each parts also was stated.

Table 3.2: Part list of the Heavy duty staple gun

Part No.	Part Name	Quantity	Material	Theoretical Part
1.	Front casing	1	Stanley Steel	1
2.	Staple Piston Guide	1	Steel	1
3.	Left casing	1	Stanley Steel	1
4.	Tension bar upper	1	Steel	1
5.	Tension bar lower	1	Steel	1
6.	Stapler Loader	1	Steel	1
7.	Pin 34mm	1	Steel	0
8.	Staple Queue	1	Steel	1
9.	Metal handle	1	Stanley Steel	1
10.	Pin 34mm	2	Stanley Steel	0
11.	Hollow support	1	Steel	0
12.	Reload -Press	1	Steel	1
13.	Spring mount	1	Steel	1
14.	Spring	1	Steel	0
15.	Metal spring holder	1	Steel	1
16.	Right casing	1	Stanley Steel	1
17.	Circlip "E Type"	1	Steel	0
18.	Locking pin	1	Steel	0
19.	Circlip "E Type"	1	Steel	0
20.	Rivet	3	Steel	0
21.	Riveting Operation	1		0
22.	Circlip "E Type"	1	Steel	0

23.	Spring Holder	1	Steel	1
24.	Pin 25mm	1	Steel	0
25.	Rubber spring holder	1	Rubber	1
26.	Safety Storage Lock	1	Aluminium	0
27.	Pin 23mm	1	Steel	0
28.	Torsion Spring	1	Steel	1
	Total	31		15

* Theoretical minimum no. of the part

0 = Based on the 3 criteria, three of them are no, which means the part can be eliminate or combined with other part.

1= Based on the 3 criteria, three of them are yes, which means the part can't eliminate or combined with other part.

3.3.3 Software analysis

Design for Assembly 9.3 Boothroyd Dewhurst software is used identifies opportunities for substantial cost reduction in the product. Based on the literature study, analyse the each parts the original product and new design improvement by using DFA 9.3 Boothroyd Dewhurst software. It used to calculate the total assembly time, design efficiency and total cost manufacturing and then compare the result. The outcome of the analysis is more elegant products that meet both criteria are important; functions efficient and easy to install. DFA re-design also has the effect of which is included developing quality and reliability, faster development time, and require less suppliers.

In software analysis user needs to insert name of the assembly of the product. This can be seen in Figure 3.3. Other than that, user needs to set the units, time units, and cost, this also can be see Figure 3.3.

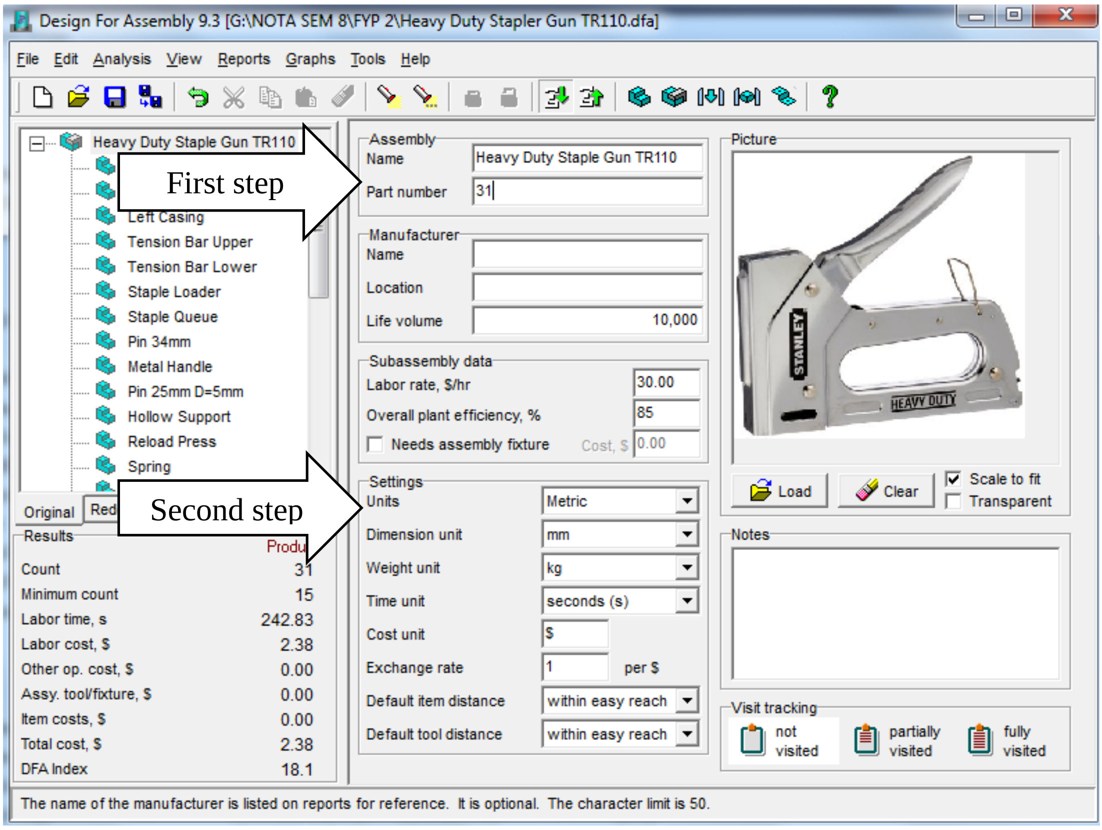


Figure 3.3: Software Analysis

After all the above information has been setting, then user needs to add part for the product. After the part has been added, the user need to decide name of the part, then user need to decided either the part is subassembly or assembly. Other than that, user need to decide the securing method of the part and decide the dimension of the parts. Lastly user needs to decide handling and insertion difficulties of the part. After all the information been submitted, user needs to continue the step for all the parts of the product. Finally user can get the DFA index of the assemblies. This step is shown in Figure 3.4. Reflex with the figure on the next page.

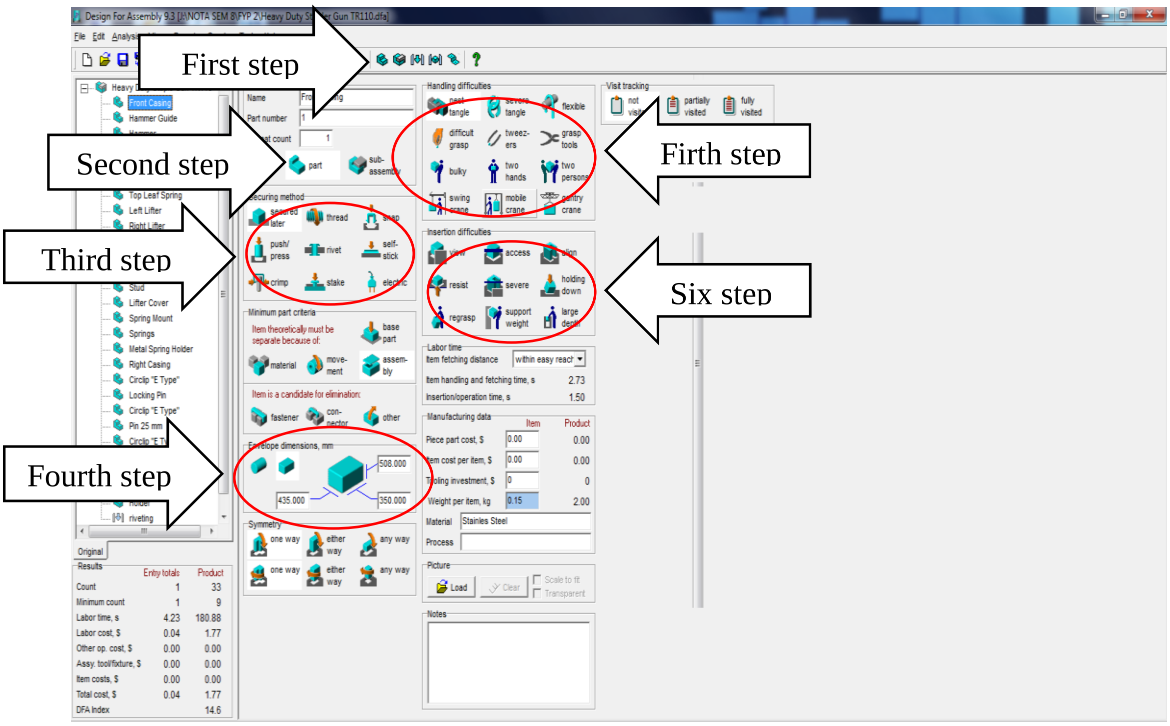


Figure 3.4: Software Analysis

3.3.4 Alternative design

After all the information has been gathered for the original design, alternative design needs to be generated according to DFA Boothroyd Dewhurst method. This alternative design needs to be more effective in term of the design efficiency, for the alternative design to be development, there are certain guidelines and suggestion from Boothroyd Dewhurst that can be followed.

3.3.4.1 Design for Assembly guideline

There are the guideline of the DFA:

a) Make parts such that it is easy to identify how they should be oriented for insertion.

b) Prefer self-locating parts.

c) Standardize to reduce part variety.

d) Maximize part symmetry

e) Eliminate tangle parts

f) Provide the alignment features

g) Eliminate fasteners

3.3.5 CATIA V5 designing of alternative product

These designs are based on the DFA guidelines for the alternative design to achieve better design efficiency compare to the original product. Every parts of the alternative design is been draw according to the detailed of the parts. This step is continue until all the parts is been drawn. After all the parts is been drawn assembly of the parts is needed. The assembly of the parts also uses by using CATIA V5 software.

3.3.6 Boothroyd Dewhurst DFA for alternative design

After all the parts of the alternative design already been drawn, analysis of the alternative design is necessary, these analysis is to make sure that the result for alternative design is better if compare to the result for original design. Every part is needed to analyse by using software analysis. All the steps are repeated for every part. If the analysis for the alternative design are better compare to the original design, so the alternative design are effective if compare the original design. If the alternative design are not good as current design that means the alternative design is not effective, so need to make the new alternative again until the alternative design is effective compare to the original design.

3.3.7 Fabrication Process

After designing and simulation, comes fabrication process. This stage is intended to fabricate the prototype for the redesign parts. Therefore, rapid prototyping machine as shown in Figure 3.6 will be build the product according the dimension. The process will be carry out at RP & Reverse Eng. Lab, Faculty of Mechanical, Universiti Malaysia Pahang.

Figure 3.5: Rapid prototyping machine

3.4 Summary

This chapter show how to implement Boothroyd Dewhurst Design for Assembly method to improve the proposed product design in term of assembly effectiveness. All the information get from the literature reviews will use in this chapter and new proposed design should be identified in this chapter.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter explains about results and discussion of this project. These included the results in the original design and proposed design of the heavy duty staple gun. The result was analysed using Boothroyd Dewhurst DFA method. In addition, this method was analysed using software and manually calculating of the design efficiency. The result from this simulation also will compare with analysis of original design and alternative design. For the recommendations for this project will be discussed in the next chapter.

4.2 Product Information

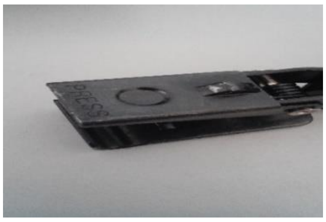
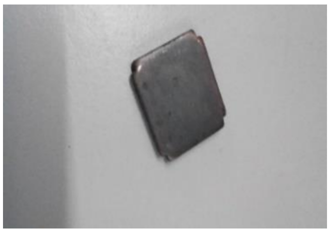
In this project, the original design of heavy duty staple gun consists of 31 components. The detail of the original part name, material, quantity and theoretical part of the product is shown in Table 4.1.

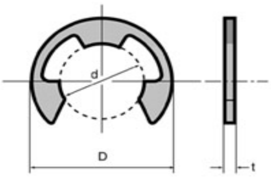
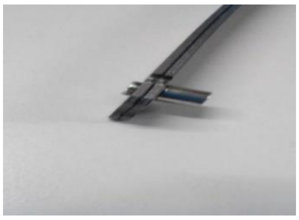
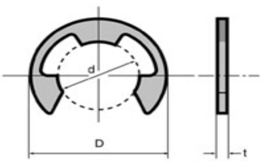
Table 4.1: The detail of the original part name, material, quantity and theoretical part of the product

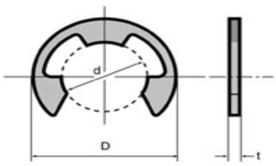
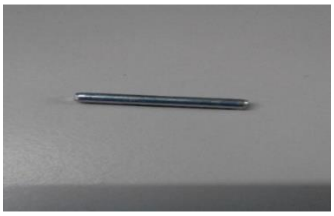
Part No.	Part Name	Quantity	Material	Theoretical Part
1.	Front casing  110mm X 29mm X 67mm	1	Stanley Steel (0.200kg)	1
2.	Staple Piston Guide  82mm X 1mm X 23mm	1	Steel (0.007kg)	1
3.	Left casing  179mm X 10mm X 111mm	1	Steel (0.15kg)	1

4.	Tension bar upper  140mm X 2mm X 17mm	1	Steel (0.050kg)	1
5.	Tension bar lower  140mm X 2mm X 17mm	1	Steel (0.050kg)	1
6.	Stapler Loader  179mm X 9mm X 18mm	1	Steel (0.041kg)	1
7.	Pin 34mm  D= 5mm, L= 34mm	1	Steel (0.01kg)	0

8.	Staple Queue  169mm X 13.2mm X 17.2mm	1	Steel (0.038kg)	1
9.	Metal handle  172mm X 17mm X 23mm	1	Steel (0.025kg)	1
10.	Pin 34mm  D= 5mm, L= 34mm	2	Steel (0.01kg)	0
11.	Hollow support  D= 8.5mm, d=5mm, L=23mm	1	Steel (0.015kg)	0

12.	Reload -Press  30mm X 14mm X 6mm	1	Steel (0.017kg)	1
13.	Spring mount  L= 43mm, D max = 20mm, D min = 10mm, D wire = 1.5mm	1	Steel (0.002kg)	1
14.	Spring  L =97mm, D wire = 0.5mm, d = 3mm	1	Steel (0.001kg)	0
15.	Metal spring holder  24.5mm X 22mm X 3mm	1	Steel (0.008kg)	1

16.	Right casing  179mm X 10mm X 111mm	1	Steel (0.15kg	1
17.	Circlip “E Type”  D =8mm, d = 3mm, t = 0.5mm	1	Steel (0.001)	0
18.	Locking pin  D = 6.5mm, d = 4.5mm	1	Steel (0.0035kg)	0
19.	Circlip “E Type”  D =8mm, d = 3mm, t = 0.5mm	1	Steel (0.001kg)	0

20.	Rivet  D = 5mm, D = 3mm	3	Steel (0.009kg)	0
21.	Riveting Operation	1		0
22.	Circlip “E Type”  D =8mm, d = 3mm, t = 0.5mm	1	Steel (0.001kg)	0
23.	Spring Holder  19.5mm X 10mm X 10.5mm	1	Steel (0.002kg)	1
24.	Pin 25mm  D = 4mm, L = 25mm	1	Steel (0.003kg)	0

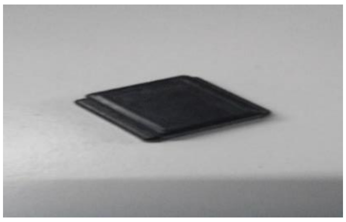
25.	Rubber spring holder  22mm X 7mm X 20mm	1	Rubber (0.002kg)	1
26.	Safety Storage Lock  D = 1.5 mm, L = 37mm	1	Aluminium (0.0015kg)	0
27.	Pin 23mm  D = 4mm, L = 23mm	1	Steel (0.0026kg)	0
28.	Torsion Spring  d = 3mm, L = 5mm , D wire = 1mm	1	Steel (0.0015kg)	1
Total		31		15

Figure 4.1 shows the views the heavy duty stapler gun TR110 product structure. By understanding the product structure, the assembly evaluation can be done more successfully. This figure also shows a heavy duty stapler gun that has been dismantled. This part has been grouping by their group regarding their assembly partner.

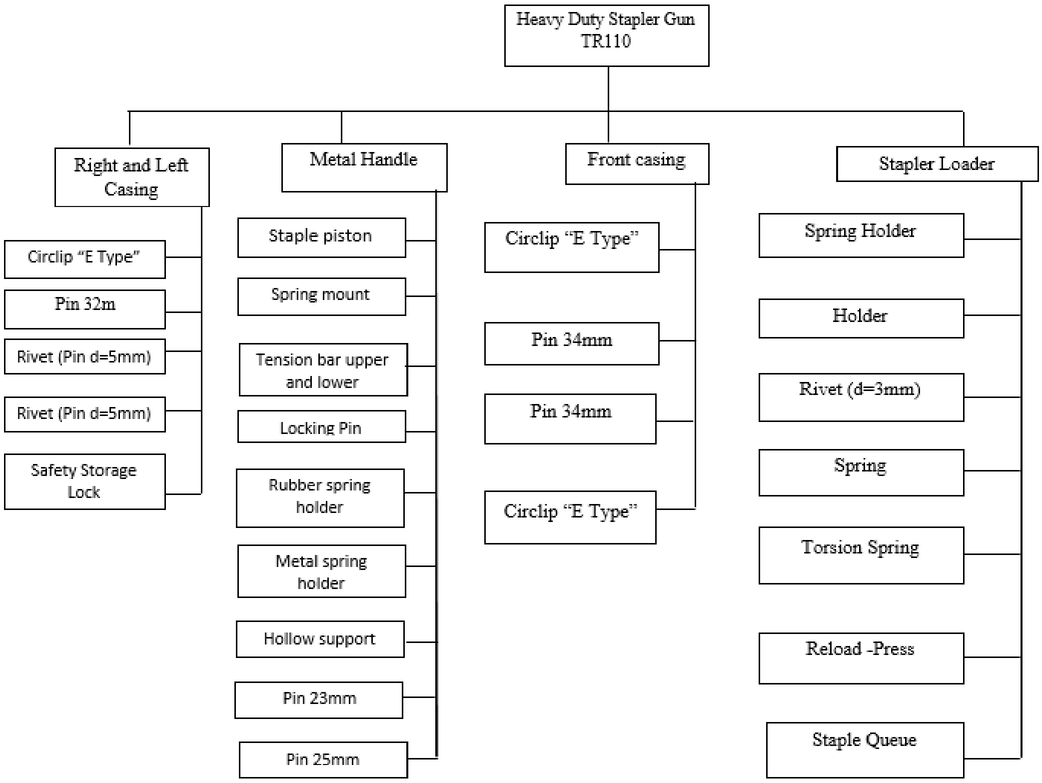


Figure 4.1: Original design of the heavy duty staple gun TR110 structure

4.3 Product Design Analysis by using Boothroyd-Dewhurst DFA

The analysis of original design is done after original heavy duty staple gun is model. The analysis is done by using Boothroyd Dewhurst DFA method design techniques. The analysis of the original design is very important because from the result, the modification design is generate. From the Table 4.2 shows the result of original design which consists of the total number of different parts, total time assembly process, total cost manufacturing and design efficiency. Other than that, the analysis shows that number of different part is 21 part and entries which including the repeat part is 31 parts. While the time of assembly is 242.83s and total cost RM2.38 for design efficiency is 43.8 percent (see Appendix B1).

Table 4.2: Total number of different parts, total time assembly process, total cost manufacturing and design efficiency for original design.

Per Product Data	Entries (Includes repeat)	No. of different part	Times, s	Labor Cost. RM
Necessary	15	13	94.34	0.72
Fasteners	10	6	115.91	1.14
Unnecessary	6	3	32.58	0.52
Total	31	21	242.83	2.38
DFA Index	18.1			

4.3.1 Original Design Calculations

Calculation design efficiency of original product design

$$\text{Design efficiency, Ema} = \frac{\text{Nmin x Ta}}{\text{Tma}}$$

$$\text{Ema} = \frac{15(\frac{242.83}{31})}{242.83} \text{ x } 100 = 48.4\ \%$$

Where;

Nmin = Theoretical minimum number of parts

Ta = Basic assembly time

Tma = Estimated time to complete the assembly of the product.

4.3.2 Selection of part for redesign

Based on the design guidelines DFA method, there are have parts to be redesign stage, it focuses on eliminating the fasteners as many as possible and reduces the parts by combining it with other parts. Separate fasteners such as pin with Circlip “E Type” are always the high prior candidate for elimination. The suggestion analysis from Boothroyd Dewhurst DFA software is shown in Table 4.3 and 4.4 (see Appendix D1 for detail suggestion of redesign).

Table 4.3 suggest with based on the result for original design, by reducing the pin for Circlip “E Type” in original design, time saving for new development design is 115.91 seconds for assembly and percentage of reduction is 36.94 percent.

Table 4.3: Suggestion of reduction for fasteners

Parent Assembly	Home	Quantity	Time saving, s	Percent reduction
Heavy duty staple gun	Pin 34mm	2	19.86	8.18
	Pin 25mm	1	9.93	4.09
	Circlip "E Type"	3	13.10	5.39
	Locking Pin	1	9.23	3.80
	Rivet 5mm	2	24.56	10.11
	Rivet 3mm	1	13.03	5.37
Total			115.91	36.94

In the Table 4.4 show, it suggested that by eliminating the parts or combining the parts with other will reduce the time of assembly process by 45 second and increase 29.56 percent of reduction.

Table 4.4: Suggestion of reduction for eliminating the parts or combining the parts with other

Parent Assembly	Home	Quantity	Time saving, s	Percent reduction
	Pin 23mm	1	7.04	2.90
Heavy duty staple gun	Pin 25mm	1	7.04	2.90
	Right casing	1	2.20	0.91
	Left Casing	1	2.20	0.91
	Tension bar upper	1	0.83	0.34
	Tension bar lower	1	0.83	0.34
	Locking pin	1	0.78	0.32
Total			20.92	8.62

4.3.3 Critics of the all parts for redesign

In design for assembly process it is important to critic each parts in the product. This information is important to improve the product. The critic is referred to all parts. In addition, some suggestion and recommendation has been including between the critics. Table 4.5 shows the critics and recommendation each parts in the product.

Table 4.5: The critics and recommendation each parts.

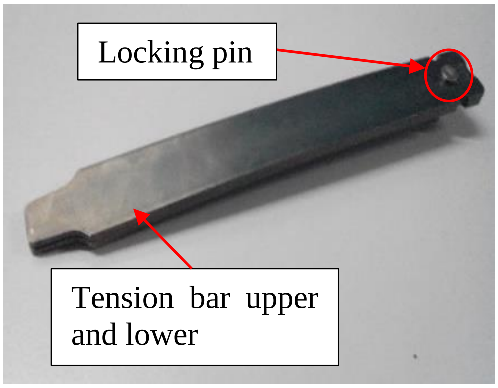
No	Name	Critics
1	Front casing	No
2	Staple Piston Guide	This part suggested to make the hole diameter 6mm for hold the spiral spring.
3	Left casing	This part use the pin 23mm for the hold the spring mount. Modification using snap fit is made this part.
4	Tension bar upper	Suggested for eliminated and replace with spiral spring
5	Tension bar lower	Suggested for eliminated and replace with spiral spring
6	Pin 34mm	No
7	Staple Queue	No
8	Metal handle	No
9	Pin 34mm	Suggested for eliminated
10	Hollow support	Make the fillet for the diameter 2mm at both side.
11	Reload -Press	No
12	Spring mount	No
13	Spring	No
14	Metal spring holder	Suggested for eliminated
15	Right casing	This part use the pin 23mm for the hold the spring mount. Modification using snap fit is made this part.
16	Rivet 3pcs	No
17	Circlip “E Type”	Suggested for eliminated
18	Safety Storage Lock	Suggested for eliminated
19	Pin 23mm	Suggested for eliminated
20	Torsion Spring	No
21	Circlip “E Type”	No

22	Locking pin	Suggested for eliminated and replace with spiral spring
23	Spring Holder	No
24	Rubber spring holder	Suggested for eliminated
25	Circlip “E Type”	Suggested for eliminated
26	Riveting Operation	No
27	Pin 25mm	Suggested for eliminated
28	Stapler Loader	No

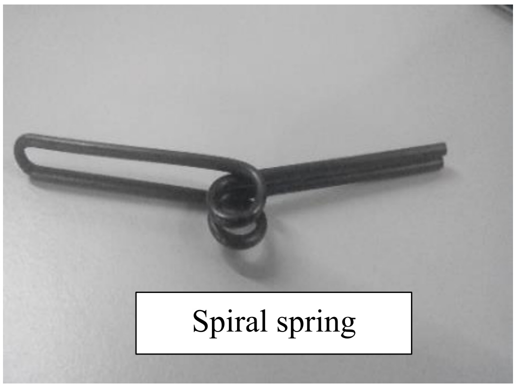
4.4 Product Redesign Evaluation

New purpose of the heavy duty stapler gun TR110 is generated. Table 4.6 to 4.9 shows the 3D of the part for redesign, modification and description of the part. For detail drawing of redesign, (see Appendix E1)

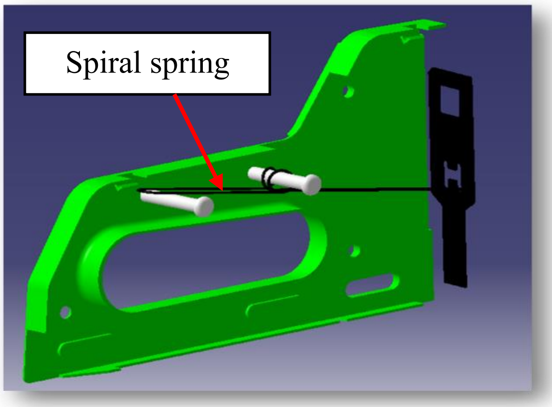
4.4.1 Generate New Design



(i)



(ii)

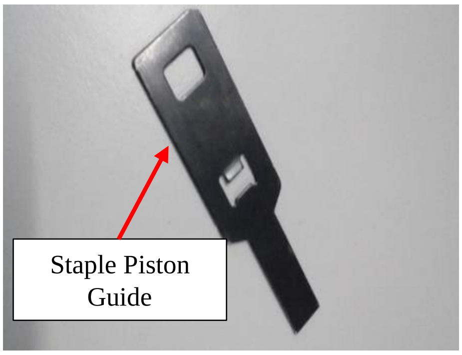


(iii)

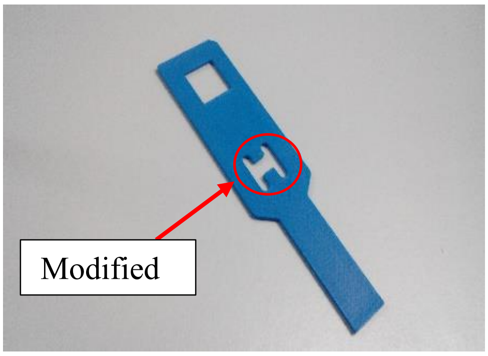
Figure 4.2: (i) Original part of the locking pin, tension bar upper and lower
(ii) New development of spiral spring
(iii) Location of spiral spring

Table 4.6: Description and Modification of locking pin, tension bar upper and lower

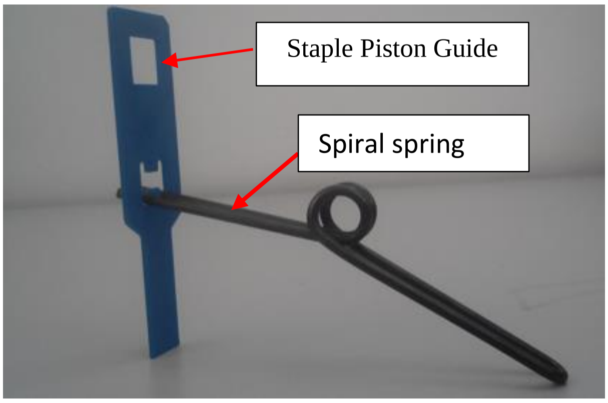
No.	Description	Modification
1.	- Reduced the total of the part and cost of manufacturing. - It take the time for the assembly.	- Locking pin, tension bar upper and lower eliminated and make the spiral spring of new development. - For diameter of spiral spring is 6mm.



(i)



(ii)



(iii)

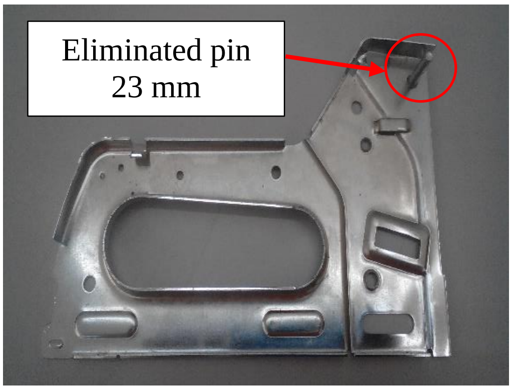
Figure 4.3: (i) Original part of staple piston guide

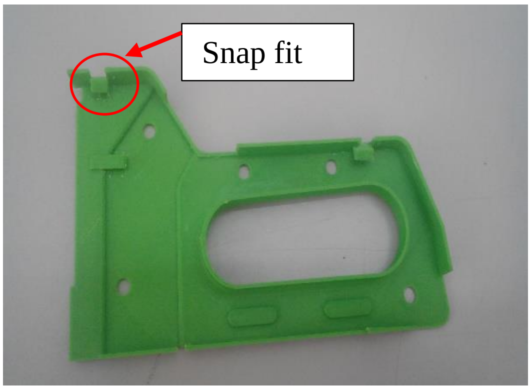
(ii) New development of the part

(iii) Assembly part with staple piston guide and spiral spring

Table 4.7: Description and Modification of staple piston guide

No.	Description	Modification
2.	- When use the spiral spring, the staple piston guide must be make the modified.	- For the new development, it make the hole for the diameter 6mm. - It can easy to insert and support the spiral spring at the staple piston guide.





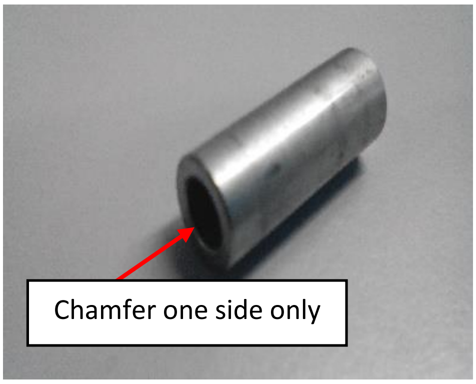
(i) (ii)

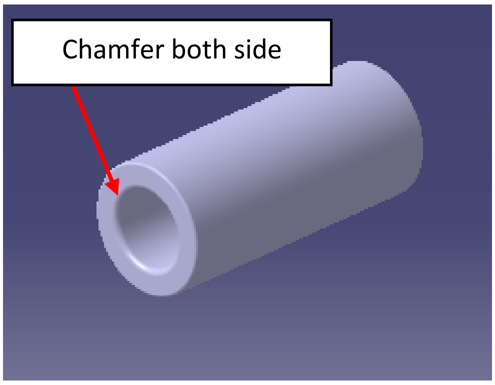
Figure 4.4: (i) Original part of right and left casing

(ii) New development of right and left casing

Table 4.8: Description and Modification of right and left casing

No.	**Description**	**Modification**
3.	- Eliminated pin 23 mm for reduced the cost manufacturing and time of assembly process	- For the new development, pin 23mm replaced the snap fit at the right and left casing.





(i) (ii)

Figure 4.5: (i) Original part of hollow support

(ii) New development of the part

Table 4.9: Description and Modification of hollow support

No.	Description	Modification
4.	- Difficult to insert pin 32mm. It can take long to assembly of this part.	- For the new development, it make the fillet for the diameter 2mm. - It can easy to insert pin 32mm.

4.4.2 Alternative of the Original Design using Boothroyd Dewhurst DFA

In this research an alternative design are develop. The modification is based on Boothroyd Dewhurst DFA method. The model are illustrated in Figure 4.6 and 4.7.

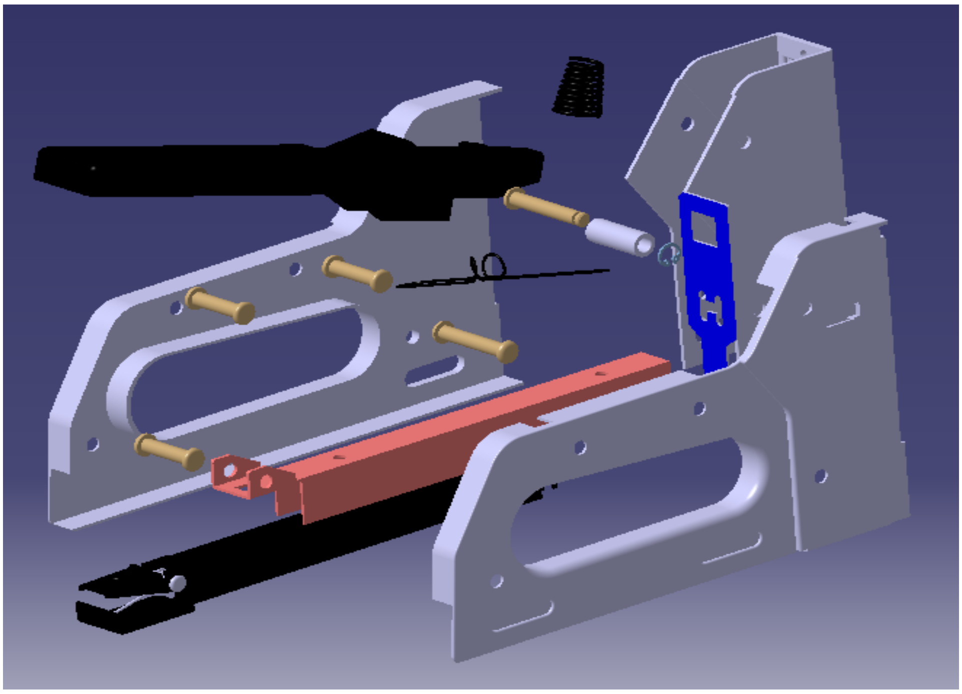


Figure 4.6: Exploded view of the alternative design

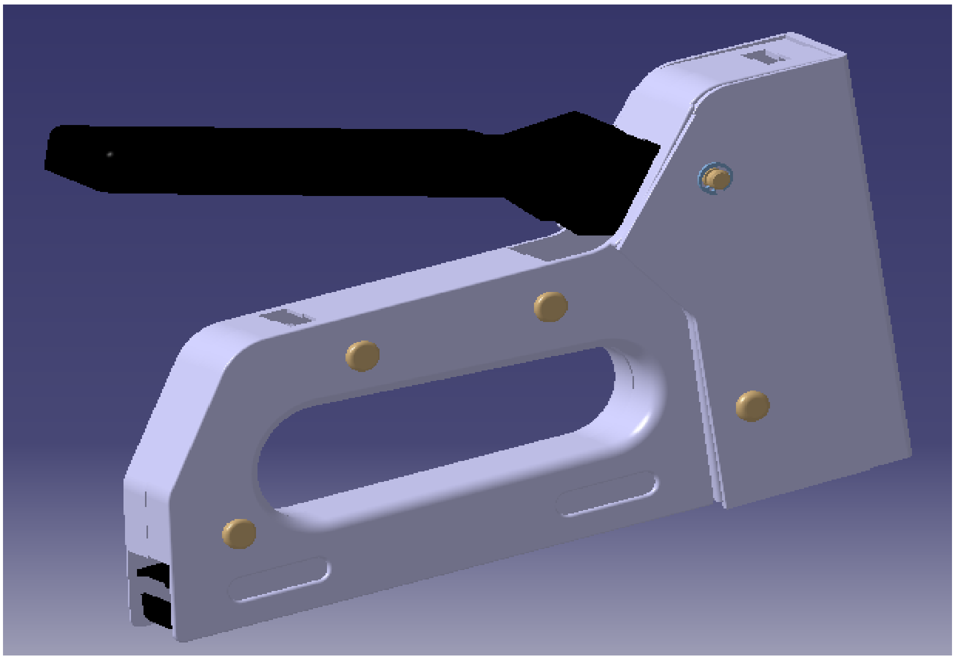


Figure 4.7: Isometric view of the alternative design

4.4.3 Alternative Design Analysis

Table 4.10: Total number of different parts, total time assembly process, total cost1.

Per Product Data	**Entries (Includes repeat)**	**No. of different part**	**Times, s**	**Labor Cost. RM**
Necessary	14	13	84.08	0.82
Fasteners	7	0	91.09	0.9
Unnecessary	0	0	0	0
Total	22	13	175.17	1.72
DFA Index	15.1			

The analysis is done by using Boothroyd Dewhurst DFA method design techniques. From the Table 4.9 shows the result of alterative design which consists of the total number of different parts, total time assembly process, total cost manufacturing and design efficiency. Other than that, the analysis shows that number of different part is 13 part and entries which including the repeat part is 22 parts. While the time of assembly is 175.17s and total cost RM1.72 for design efficiency is 68.8 percent (see Appendix B2).

4.4.4 Alternative Design Calculations

Calculation design efficiency of alternative product design

$$\text{Design efficiency, Ema} = \frac{\text{Nmin x Ta}}{\text{Tma}}$$

$$\text{Ema} = \frac{9(\frac{175.17}{22})}{175.17} \text{ x100} = 68.2\ \%$$

Where;

Nmin = Theoretical minimum number of parts

Ta = Basic assembly time

Tma = Estimated time to complete the assembly of the product.

4.5 Comparison between original and alternative product

After the analysis between the original and alternative product, design in term design efficiency was compared by using Boothroyd Dewhurst DFA method. Table 4.11 shows comparison original product and alternative product.

Table 4.11: The comparison original product and alternative product.

	Original Product	**New Development Product**
Number of parts (including repeats)	31	22
Theoretical minimum number of items	15	9
DFA Index	18.1	15.1
Total assembly labor time, s	242.83	175.17
Total assembly labor cost, $	2.38	1.72

From Table 4.11 shows the result of comparison original product and alternative product. In the table included total number of parts, theoretical minimum, DFA index, total assembly time and total assembly cost.

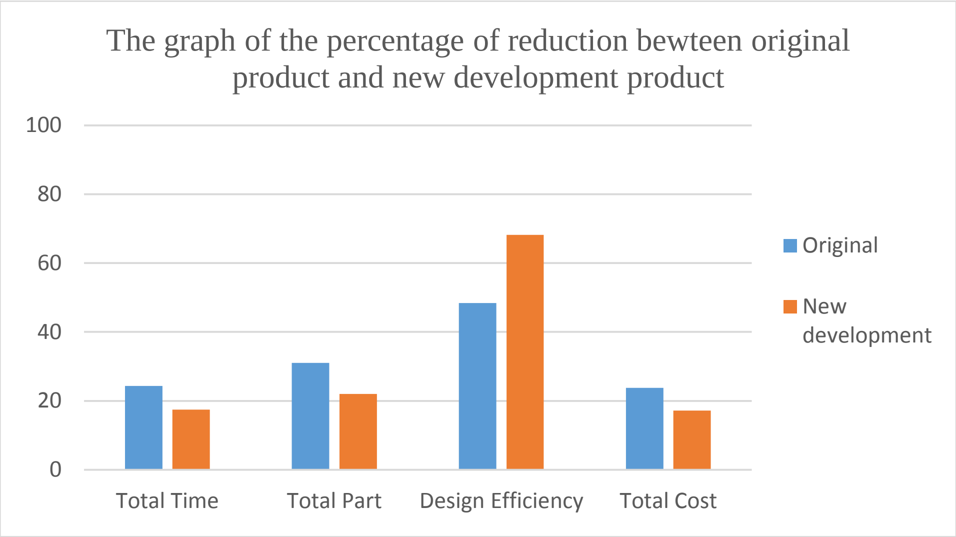


Figure 4.8: Reduction using Boothroyd Dewhurst DFA analysis.

The Figure 4.8 shows the graph of the percentage of reduction between original product and new development product due to total time for assembly process, total parts, design efficiency and estimated total cost for this process. By referring the graph above, the objective of this project was achieved by reduced the fasteners and combining items. It is due the fasteners having the insertion difficulties and difficult to align, and reduced the fasteners and combining other parts together, the total time for the assembly process decreases from 242.84 second per product to 175.17 second per product while the percentage of the design efficiency for the new development increases from 48.4% to 68.2%. The increment is 19.8% is because the Boothroyd Dewhurst Design for Assembly method is applied. Other than that, the total parts count for new development decrease or reduce from 31 parts to 22 parts. Labor cost to produce per product also decrease from RM2.83 to RM1.72.

4.6 Summary

As for the summary of this chapter, the result shows that the total of the part is being reduced and ease assembly can be done on the new product design. The design concept is carried out between the original and the new product development of the heavy duty stapler gun TR110.

In addition, the higher design efficiency for the new development of the heavy duty stapler gun proves that the Boothroyd Dewhurst DFA method gives more benefit to the manufacturing especially in the assembly process. As the result of this experiment, all, the purpose of this research was achieved as the new product development of the heavy duty stapler gun TR110 was proposed.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter mainly describes discuss about the conclusion that will be summarized by the overall results obtained for this project. Also included here are some other suggestions for the project for further improvement in the future.

5.2 CONCLUSION

For this research, the heavy duty staple gun TR110 is selected as the main product for analysis by using Boothroyd Dewhurst Design for Assembly method. The main objective to analyse the efficiency of product design in the aspect of the assembly and to improve product design by DFA methodology for reduce the assembly time and manufacturing cost by re-defines the component design. By using the CATIA V5 software, the entire components design and the 3D view of redesigned parts are clearly show.

From the analysis in chapter 4, the new design of existing design product is observed to be more user-friendly compared to the original existing design. The improvement of this new design can be divided into 3 categories, which include combining and reducing internal material and reducing number of fasteners. From the result shows, the design efficiency increases from 48.4% to 68.2%. The increment is 19.8% is because the Boothroyd Dewhurst Design for Assembly method is applied, time to assemble also decreases from 242.84 second per product to 175.17 second per product. In addition, the labor cost for each product to assemble also decrease when the Boothroyd Dewhurst Design for Assembly method is applied. It decreases from RM 2.38 per product to RM 1.72 per product to assemble. The decrement in labor cost per products occurs because the new design is more efficient that the existing design which has led to direct influence to the labor cost. From the case studies, this Boothroyd Dewhurst Design for Assembly method is able to improve the design in term of the design efficiency, product time and labor cost.

5.3 RECOMMENDATIONS

Recommendations should be implemented to improve the project. These are several recommendations regarding:

a) There are so many things in terms of facilities can be improved, especially software DFA Boothyrod Dewhurst. This is because FKP laboratory do not have of these software.

b) Other extensive analysis like stress-strain distribution and failure mode analysis by using Computer Aided Engineering (CAE) software like FEMPRO, ALGOR and advance software like NASTRAN and PATRAN depending on the product being evaluated are also suggested.

c) The labor cost and production cost can be defined by collaboration with industry which means the price of the product can be determine before and after the modification.

d) For the further research in the redesign part, design guideline, material selection and manufacturing process should be properly considered or else the design will be a failure. The redesign part is also very important for the enhancement of the design efficiency and the reduction in labor cost per product.

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APPENDICES

APPENDIX A1

Gantt chart Final Project Year 1

No.	Project Progress		Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Literature studies for product improvement method	Planning														
		Actual														
2	Literature studies DFA methodolgy	Planning														
		Actual														
3	Literature review including type of product improvement method, type of DFA method and comparison the DFA method	Planning														
		Actual														
4	Finding the problem statement, objective and scope of the project	Planning														
		actual														
5	Surveying the product to redesign and short listed	Planning														
		actual														
6	Learn the Boothroyd Dewhurst method	Planning														
		Actual														
7	Exploded view for the product including understand how the parts function relative to each other	Planning														
		Actual														
8	Draw the original parts using CATIA V5 Software	Planning														
		Actual														
9	Learn the Boothroyd Dewhurst DFA Software	Planning														
		Actual														

Proposed progress

Actual progress

APPENDIX A2

Gantt chart Final Project Year 2

No.	Project Progress		Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Analyse original parts design assembly process by using BD DFA software	Planning														
		Actual														
2	Redesign the new parts by using CATIA V5 software	Planning														
		Actual														
3	Analyse the new parts design assembly process by using BD DFA Software	Planning														
		Actual														
4	Calculate total assembly time and design efficiency	Planning														
		actual														
5	Comparison between original and alternative product	Planning														
		Actual														
6	Fabricate the prototype for the redesign by using Rapid Prototyping machine	Planning														
		Actual														

Proposed progress

Actual progress

APPENDIX B1

Executive Summary of Boothroyd Dewhurst DFA

Executive Summary - DFA

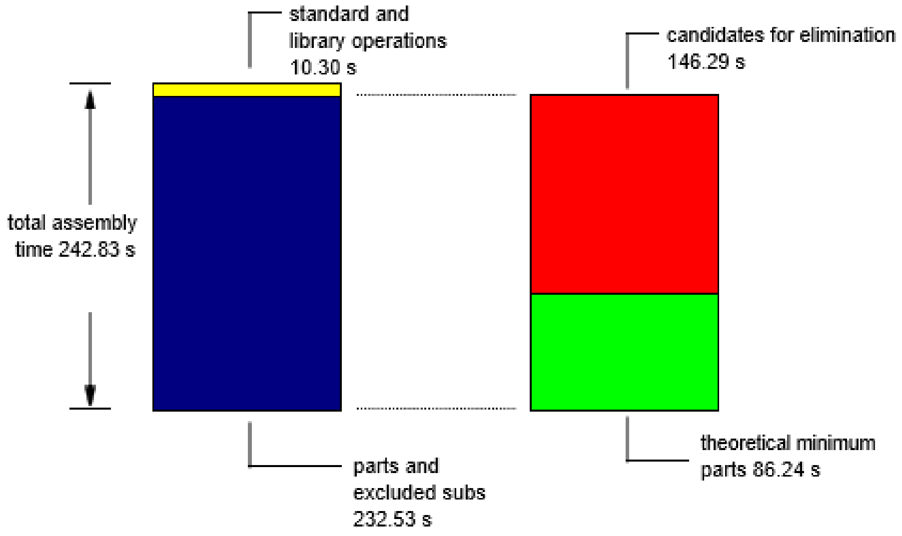
Boothroyd Dewhurst, Inc.

Wednesday, 20 April, 2016 3:13 PM
Heavy Duty Staple Gun TR110

Heavy Duty Stapler Gun TR110.dfa
Product: Original

Per Product data	Entries (including repeats)	Labor Time, s	Labor Cost, $
Component parts	30	232.53	2.28
Subassemblies partially or fully analyzed	0	0.00	0.00
Subassemblies not to be analyzed (excluded)	0	0.00	0.00
Standard and library operations	1	10.30	0.10
Totals	**31**	**242.83**	**2.38**

The chart shows a breakdown of time per product



APPENDIX B2

Executive Summary of Boothroyd Dewhurst DFA

Executive Summary - DFA

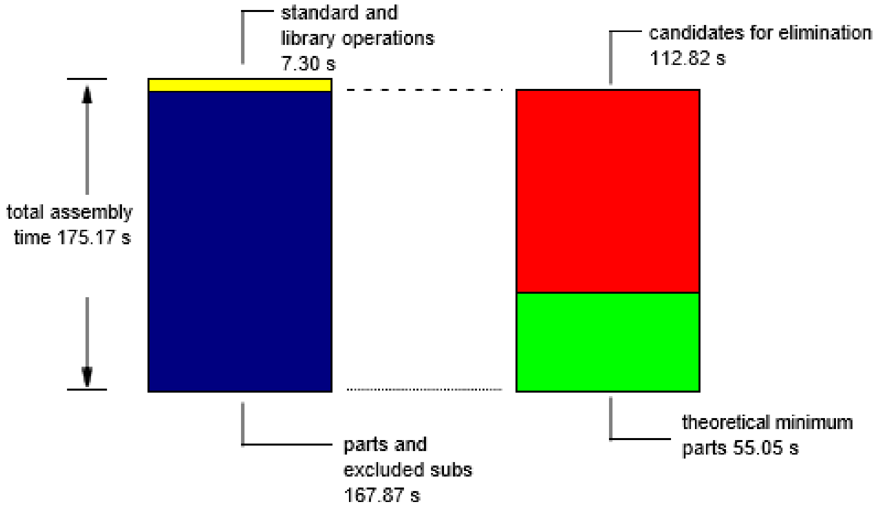
Boothroyd Dewhurst, Inc.

Thursday, 5 May, 2016 10:37 AM
Heavy Duty Staple Gun TR110

Heavy Duty Stapler Gun TR110.dfa
Product: Redesign

Per Product data	Entries (including repeats)	Labor Time, s	Labor Cost, $
Component parts	21	167.87	1.65
Subassemblies partially or fully analyzed	0	0.00	0.00
Subassemblies not to be analyzed (excluded)	0	0.00	0.00
Standard and library operations	1	7.30	0.07
Totals	**22**	**175.17**	**1.72**

The chart shows a breakdown of time per product



APPENDIX C1

Structure Chart of Original

Design for Assembly: Structure Chart

Boothroyd Dewhurst, Inc.

Wednesday, 20 April, 2016 3:15 PM
Heavy Duty Staple Gun TR110

Heavy Duty Stapler Gun TR110.dfa
Product: Original

- Heavy Duty Staple Gun TR110
  - Front Casing
  - Staple Piston Guide
  - Left Casing
  - Tension Bar Upper
  - Tension Bar Lower
  - Staple Loader
  - Staple Queue
  - Pin 34mm
  - Metal Handle
  - Pin 25mm D=5mm
  - Hollow Support
  - Reload Press
  - Spring
  - Metal Spring Holder
  - Spring Mount
  - Right Casing
  - Circlip "E Type"
  - Locking Pin
  - Circlip "E Type"
  - Spring Holder
  - Circlip "E Type"
  - Pin 25mm
  - Rubber Sppring Holder
  - Safety Storage Lock
  - Pin 23mm
  - Torsion Spring
  - riveting
  - Rivet 5mm
  - Rivet 3mm

APPENDIX C2

Structure Chart of Redesign

Design for Assembly: Structure Chart

Boothroyd Dewhurst, Inc.

Thursday, 5 May, 2016 10:40 AM
Heavy Duty Staple Gun TR110

Heavy Duty Stapler Gun TR110.dfa
Product: Redesign

- Heavy Duty Staple Gun TR110
  - Front Casing
  - Staple Piston Guide
  - Left Casing
  - Right Casing
  - Staple Loader
  - Staple Queue
  - Pin 34mm
  - Circlip "E Type"
  - Torsion Spring
  - Reload Press
  - Metal Handle
  - Spring
  - Spring Mount
  - Spring Holder
  - Spiral Spring
  - Hollow Support
  - riveting
  - Rivet 5mm
  - Rivet 3mm
  - Rivet (L=22mm)
  - Rivet (L=30mm)

APPENDIX D1

Suggestions for Redesign

Design for Assembly: Suggestions for Redesign

Boothroyd Dewhurst, Inc.

Wednesday, 20 April, 2016 3:17 PM
Heavy Duty Staple Gun TR110

Heavy Duty Stapler Gun TR110.dfa
Product: Original

Incorporate integral fastening elements into functional parts, or change the securing methods, in order to eliminate as many as possible of the following separate fastening elements.

Parent assembly	Name	Part number	Quantity	Time savings, s	Percentage reduction
Heavy Duty Staple Gun TR110	Pin 34mm	8	2	19.86	8.18
	Pin 25mm D=5mm	10	1	9.93	4.09
	Circlip "E Type"	17	1	13.10	5.39
	Locking Pin	19	1	9.23	3.80
	Circlip "E Type"	18	1	13.10	5.39
	Rivet 5mm	28	2	24.56	10.11
	Rivet 3mm	29	1	13.03	5.37
Totals				102.81	42.34

Combine connected items or attempt to rearrange the structure of the product in order to eliminate the following items whose function is solely to make connections.

Parent assembly	Name	Part number	Quantity	Time savings, s	Percentage reduction
Heavy Duty Staple Gun TR110	Hollow Support	11	1	5.25	2.16
	Spring	14	1	4.01	1.65
	Circlip "E Type"	20	1	13.10	5.39
	Pin 25mm	22	1	7.04	2.90
Totals				29.40	12.11

Reduce the number of items in the assembly by combining with others or eliminating the following parts or subassemblies. Note that combining an item with another may eliminate further items such as fasteners or operations, resulting in much larger time reductions than those indicated.

Parent assembly	Name	Part number	Quantity	Time savings, s	Percentage reduction
Heavy Duty Staple Gun TR110	Safety Storage Lock	24	1	7.04	2.90
	Pin 23mm	25	1	7.04	2.90
Totals				14.08	5.80

Design for Assembly: Suggestions for Redesign

Boothroyd Dewhurst, Inc.

Wednesday, 20 April, 2016 3:17 PM
Heavy Duty Staple Gun TR110

Heavy Duty Stapler Gun TR110.dfa
Product: Original

Reduce separate operation times where possible. Try to improve or eliminate any which do not add value to the product and yet contribute significantly to assembly time.

Parent assembly	Name	Part number	Quantity	Time savings, s	Percentage reduction
Heavy Duty Staple Gun TR110	riveting	27	1	10.30	4.24
Totals				10.30	4.24

Add assembly features such as chamfers, lips, leads, etc., to make the following items self-aligning.

Parent assembly	Name	Part number	Quantity	Time savings, s	Percentage reduction
Heavy Duty Staple Gun TR110	Hollow Support	11	1	1.50	0.62
	Metal Spring Holder	15	1	1.50	0.62
	Locking Pin	19	1	1.50	0.62
	Rubber Sppring Holder	23	1	1.50	0.62
Totals				6.00	2.47

Redesign the assembly where possible to allow adequate access and unrestricted vision for placement or insertion of the following items.

Parent assembly	Name	Part number	Quantity	Time savings, s	Percentage reduction
Heavy Duty Staple Gun TR110	Front Casing	1	1	2.20	0.91
	Left Casing	3	1	2.20	0.91
	Staple Loader	6	1	2.20	0.91
	Pin 34mm	8	2	4.40	1.81
	Metal Handle	9	1	2.20	0.91
	Pin 25mm D=5mm	10	1	2.20	0.91
	Reload Press	12	1	2.20	0.91
	Spring Mount	13	1	2.20	0.91

Design for Assembly: Suggestions for Redesign

Boothroyd Dewhurst, Inc.

Wednesday, 20 April, 2016 3:17 PM
Heavy Duty Staple Gun TR110

Heavy Duty Stapler Gun TR110.dfa
Product: Original

	Circlip "E Type"	17	1	2.20	0.91
	Circlip "E Type"	20	1	2.20	0.91
	Spring Holder	21	1	2.20	0.91
	Circlip "E Type"	18	1	2.20	0.91
	Pin 25mm	22	1	2.20	0.91
	Safety Storage Lock	24	1	2.20	0.91
	Pin 23mm	25	1	2.20	0.91
	Torsion Spring	26	1	2.20	0.91
	riveting	27	1	3.00	1.24
	Rivet 5mm	28	2	6.00	2.47
	Rivet 3mm	29	1	3.00	1.24
Totals				49.40	20.34

The individual assembly items listed below nest or tangle and/or are difficult to grasp. Consider redesign of the items to eliminate or reduce their handling difficulties.

Parent assembly	Name	Part number	Quantity	Time savings, s	Percentage reduction
Heavy Duty Staple Gun TR110	Front Casing	1	1	0.78	0.32
	Staple Piston Guide	2	1	0.83	0.34
	Left Casing	3	1	0.78	0.32
	Tension Bar Upper	4	1	0.83	0.34
	Tension Bar Lower	5	1	0.83	0.34
	Staple Queue	7	1	0.78	0.32
	Pin 34mm	8	2	1.56	0.64
	Metal Handle	9	1	0.78	0.32
	Pin 25mm D=5mm	10	1	0.78	0.32

Design for Assembly: Suggestions for Redesign

Boothroyd Dewhurst, Inc.

Wednesday, 20 April, 2016 3:17 PM
Heavy Duty Staple Gun TR110

Heavy Duty Stapler Gun TR110.dfa
Product: Original

	Hollow Support	11	1	0.75	0.31
	Reload Press	12	1	0.78	0.32
	Metal Spring Holder	15	1	0.78	0.32
	Spring Mount	13	1	0.78	0.32
	Right Casing	16	1	0.78	0.32
	Locking Pin	19	1	0.78	0.32
	Spring Holder	21	1	0.78	0.32
	Pin 25mm	22	1	0.83	0.34
	Rubber Sppring Holder	23	1	0.78	0.32
	Safety Storage Lock	24	1	0.83	0.34
	Pin 23mm	25	1	0.83	0.34
	Torsion Spring	26	1	0.87	0.36
	Rivet 5mm	28	2	1.56	0.64
	Rivet 3mm	29	1	0.78	0.32
Totals				19.86	8.18

Consider redesign of the individual assembly items listed below to eliminate the need for grasping tools.

Parent assembly	Name	Part number	Quantity	Time savings, s	Percentage reduction
Heavy Duty Staple Gun TR110	Circlip "E Type"	17	1	6.06	2.50
	Circlip "E Type"	20	1	6.06	2.50
	Circlip "E Type"	18	1	6.06	2.50
Totals				18.18	7.49

Design for Assembly: Suggestions for Redesign

Boothroyd Dewhurst, Inc.

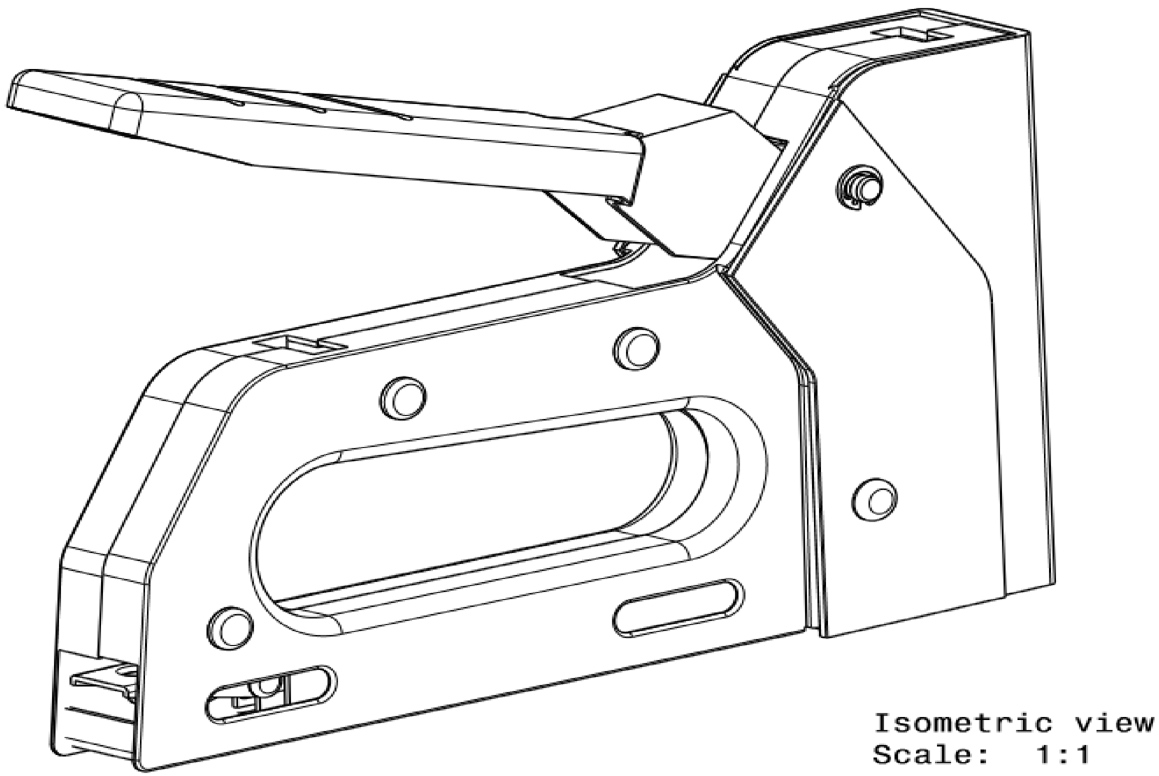
Wednesday, 20 April, 2016 3:17 PM
Heavy Duty Staple Gun TR110

Heavy Duty Stapler Gun TR110.dfa
Product: Original

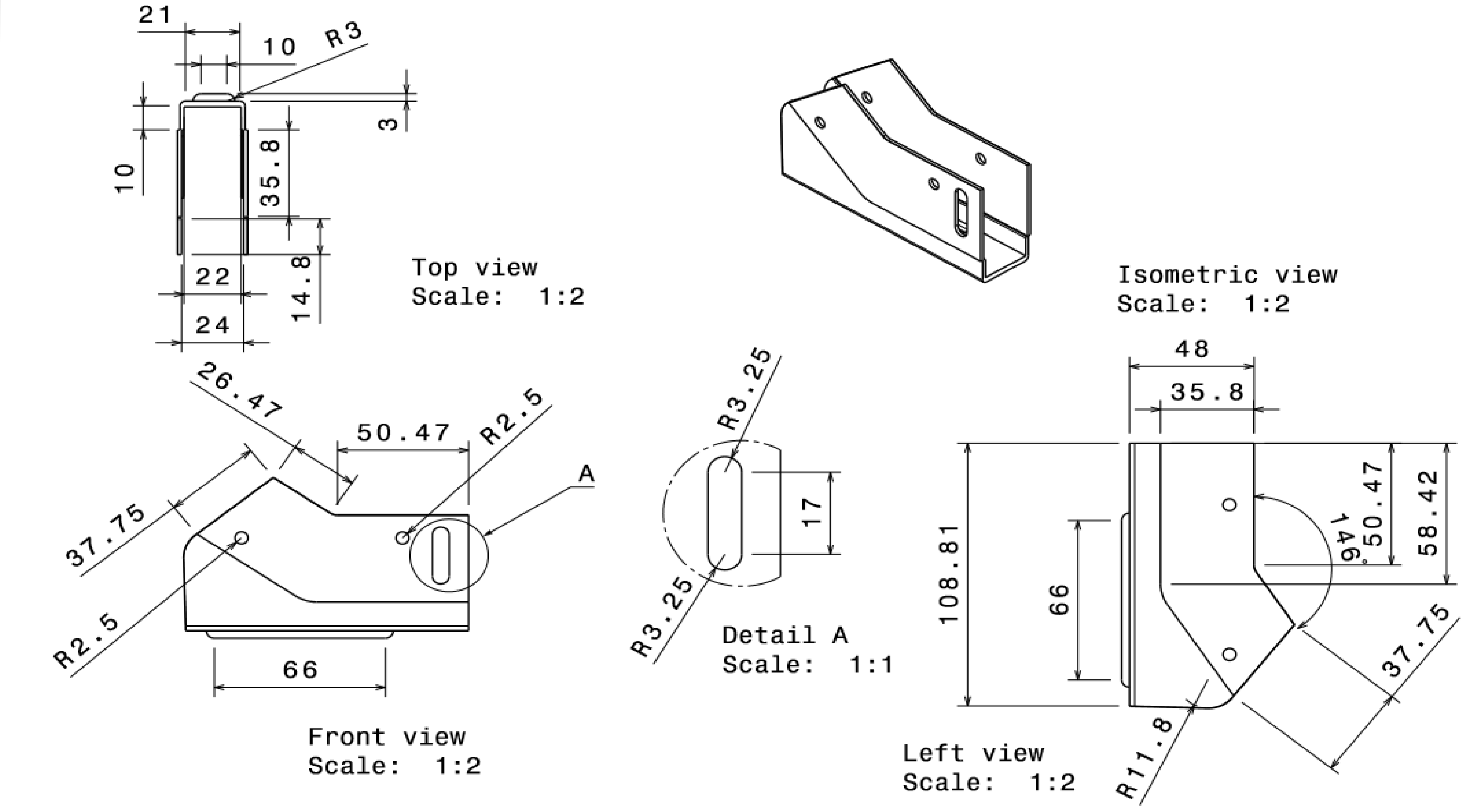
Review the following items and operations that may cause ergonomic difficulties for the assembly worker.

Parent assembly	Name	Part number	Quantity
Heavy Duty Staple Gun TR110	Front Casing	1	1
	Left Casing	3	1
	Staple Loader	6	1
	Pin 34mm	8	2
	Metal Handle	9	1
	Pin 25mm D=5mm	10	1
	Reload Press	12	1
	Spring Mount	13	1
	Circlip "E Type"	17	1
	Circlip "E Type"	20	1
	Spring Holder	21	1
	Circlip "E Type"	18	1
	Pin 25mm	22	1
	Safety Storage Lock	24	1
	Pin 23mm	25	1
	Torsion Spring	26	1
	riveting	27	1
	Rivet 5mm	28	2
	Rivet 3mm	29	1

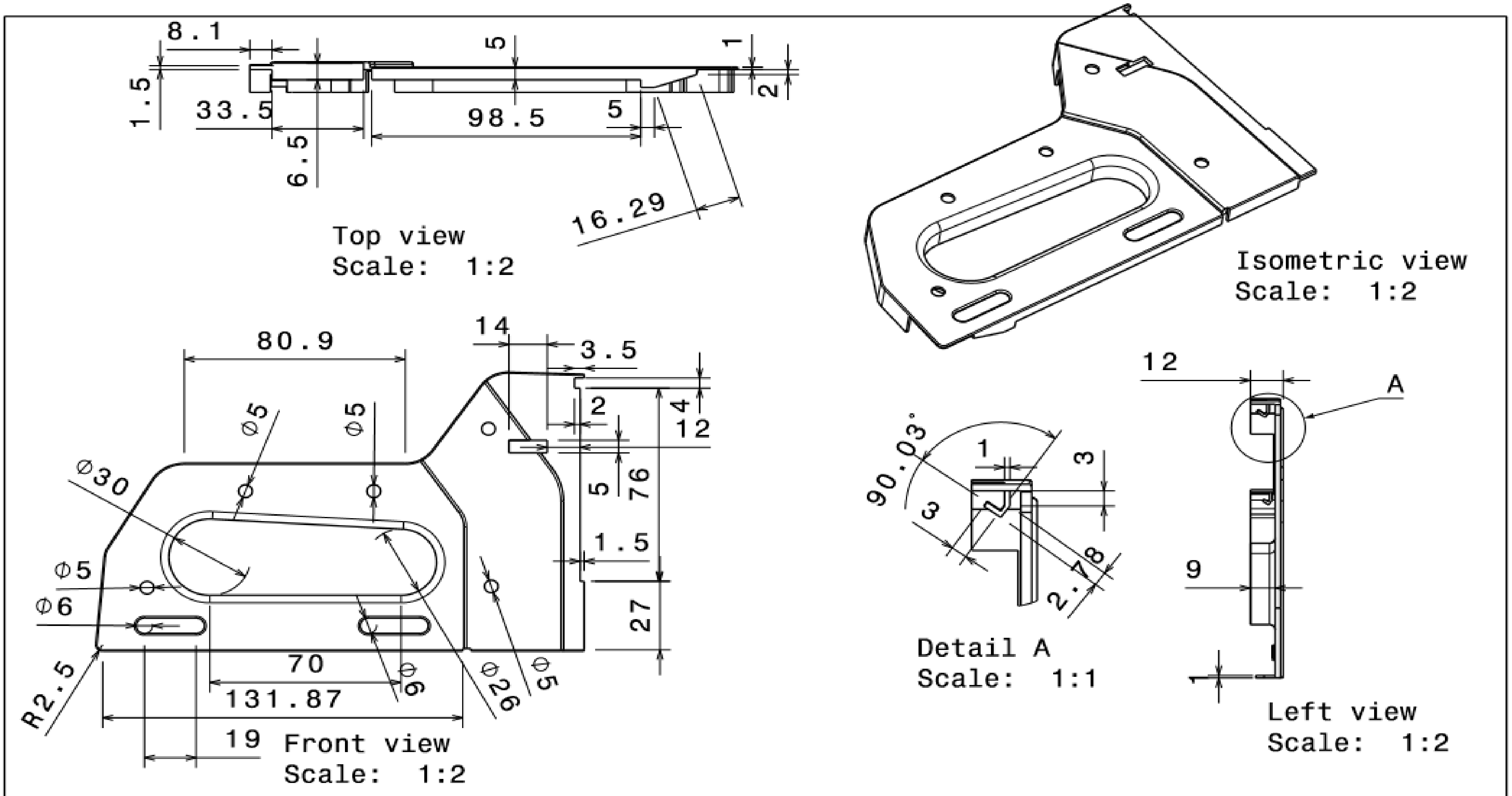
APPENDIX E1: Drawing of Redesign



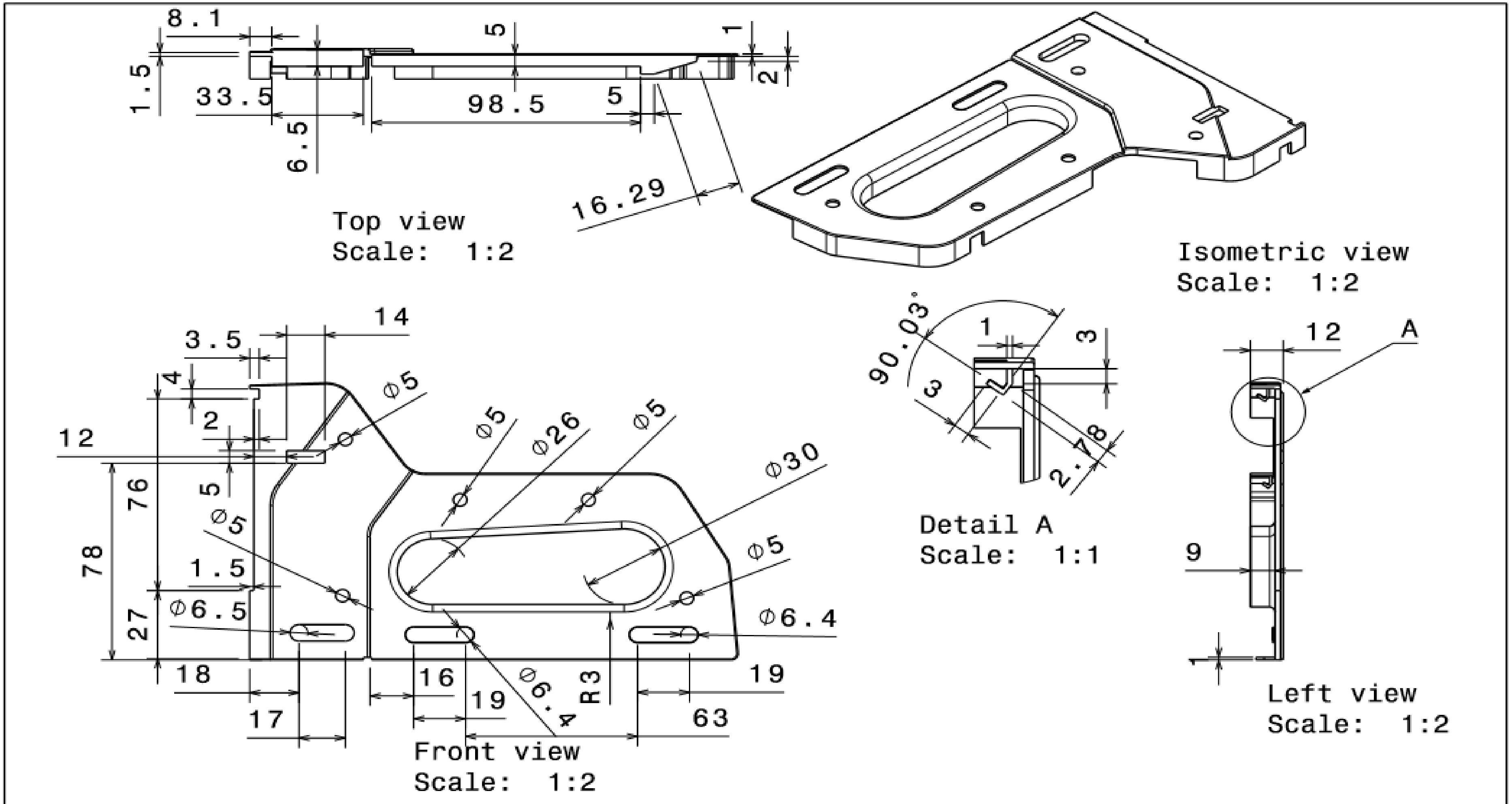
Designer by:	MUHAMAD FAIZ BIN A RAZAK	
ID No. :	FA12064	Part Name: HEAVY DUTY STAPLE GUN TR110
Date :	19/5/2016	Unit: mm



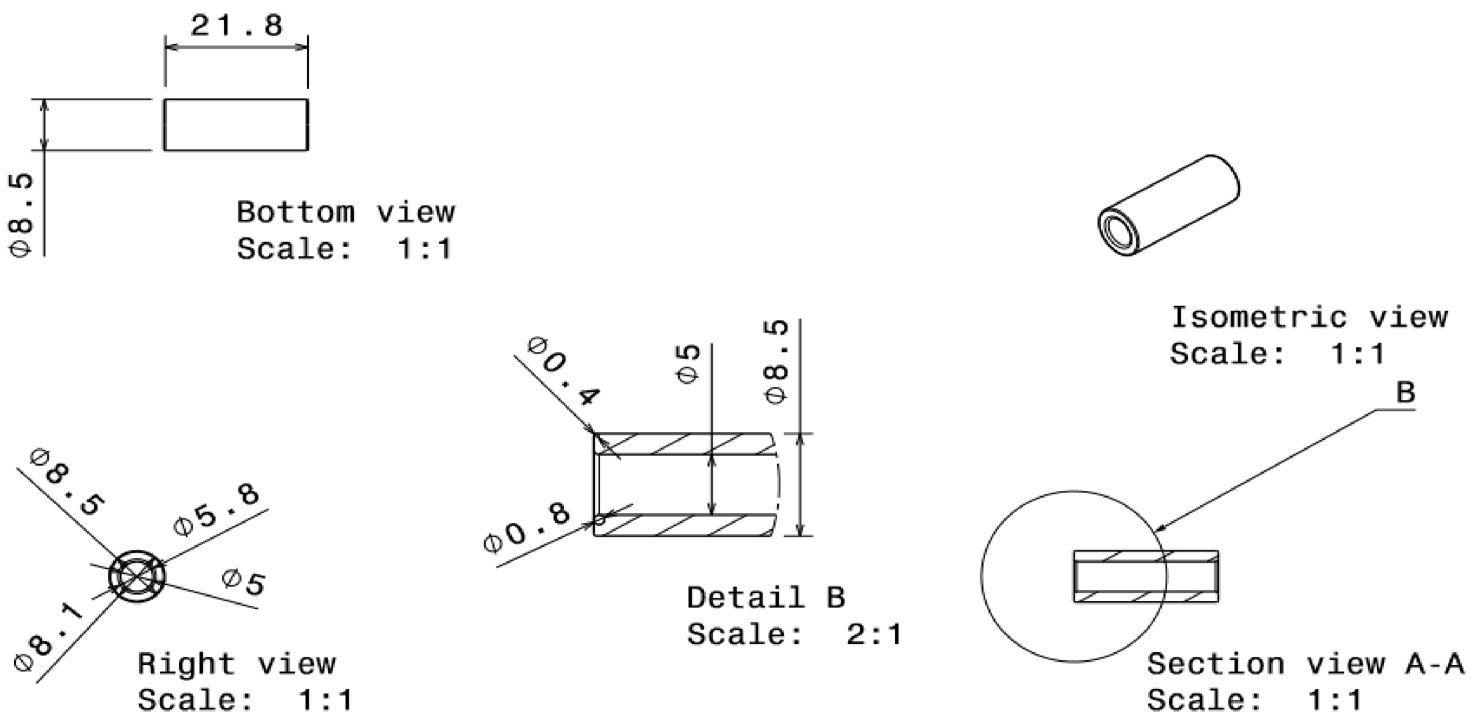
Designer by: MUHAMAD FAIZ BIN A RAZAK	
ID No. : FA12064	Part Name : Front Casing
Date: 20/5/2016	Unit : mm



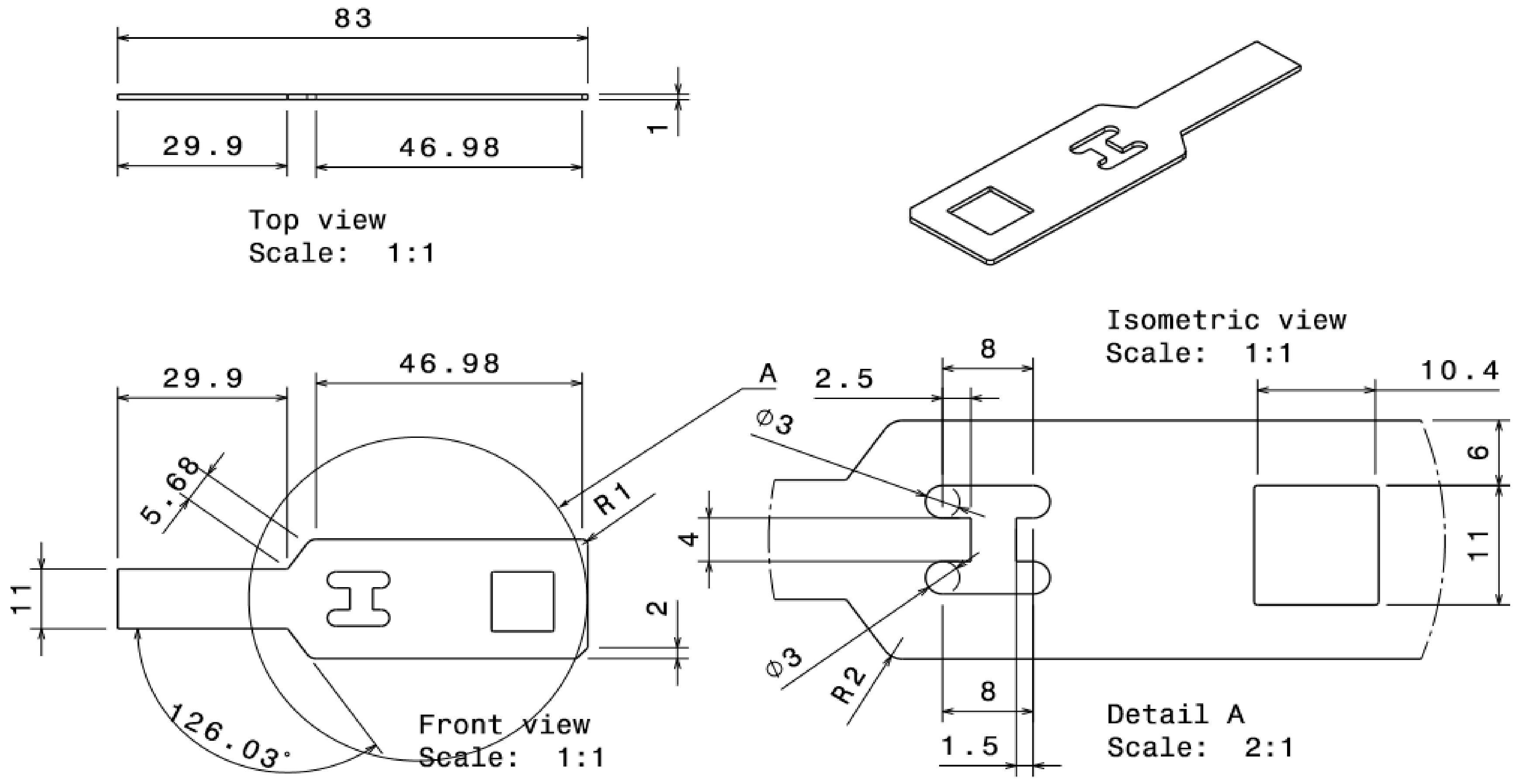
Designer by : MUHAMAD FAIZ BIN A RAZAK	
ID No. : FA12064	Part Name : Right Casing
Date : 22/5/2016	Unit : mm



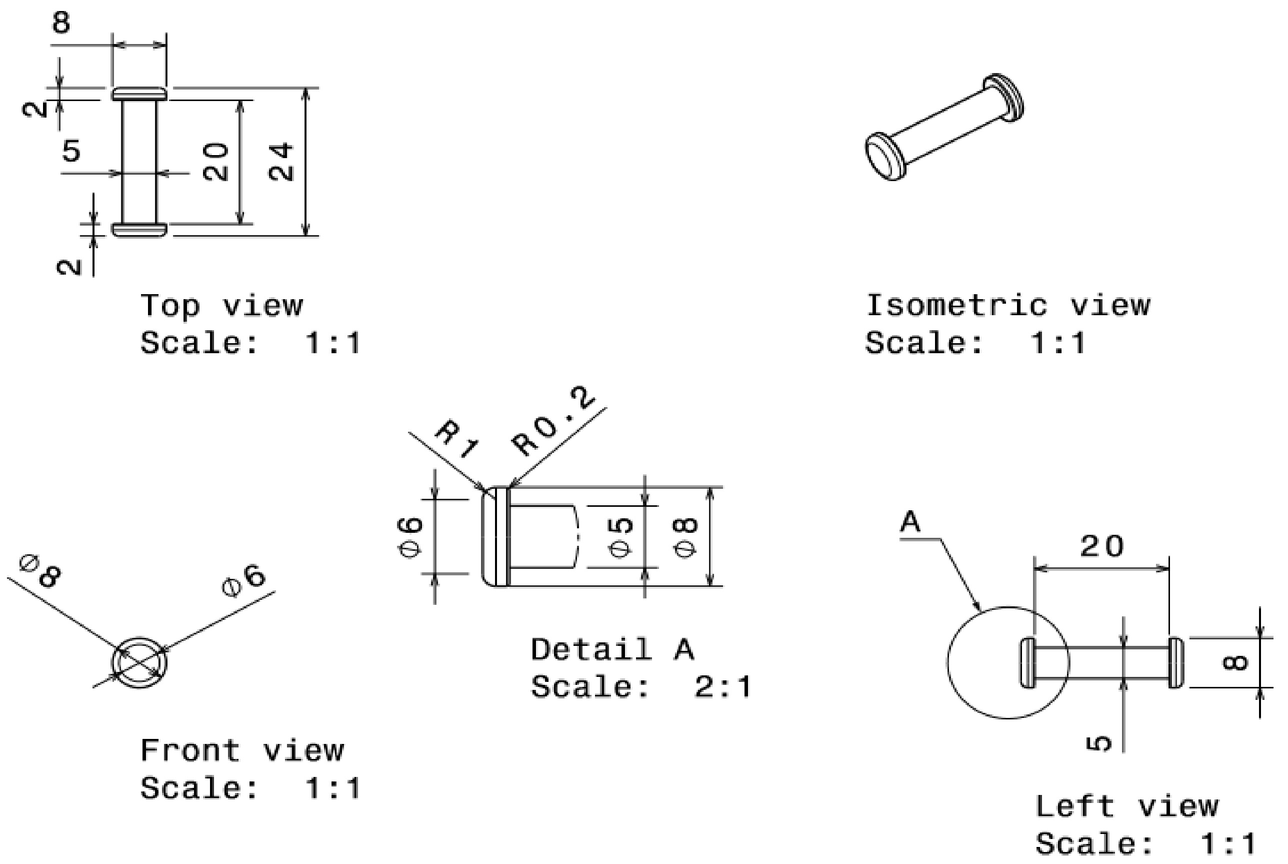
Designer by : MUHAMAD FAIZ BIN A RAZAK	
ID No. : FA12064	Part Name : Left Casing
Date : 22/5/2016	Unit : mm



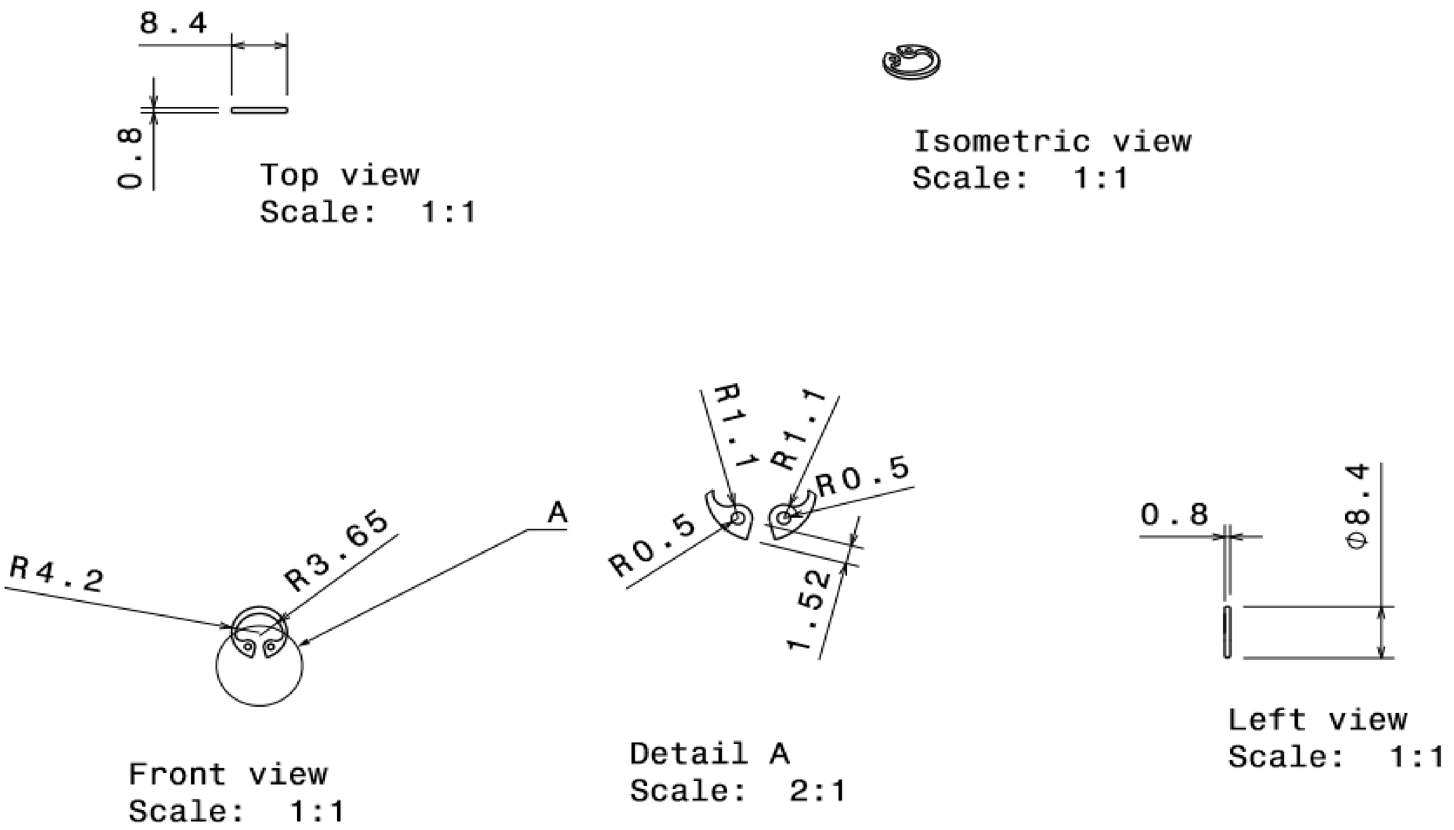
Designer by:	MUHAMAD FAIZ BIN A RAZAK		
ID.No:	FA12064	Part Name:	Hollow Support
Date:	19/5/2016	Unit: mm	



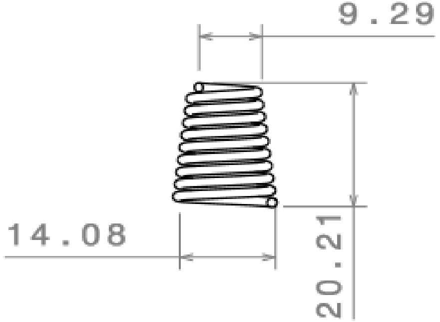
Designer by:	MUHAMAD FAIZ BIN A RAZAK		
ID No:	FA12064	Part Name : Staple Piston Guide	
Date:	19/5/2016	Unit:	mm



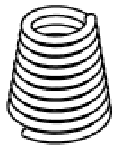
Designer by : MUHAMAD FAIZ BIN A RAZAK	
ID No : FA12064	Part Name : Rivet 20mm
Date : 21/5/2016	Unit : mm



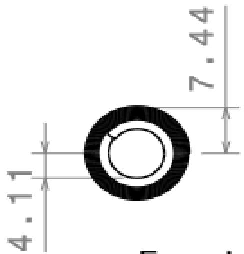
Designer by:	MUHAMAD FAIZ BIN A RAZAK		
ID No. :	FA12064	Part Name:	Circlip "E" Type
DATE:	20/5/2016	Unit :	mm



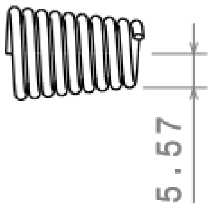
Top view
Scale: 1:1



Isometric view
Scale: 1:1

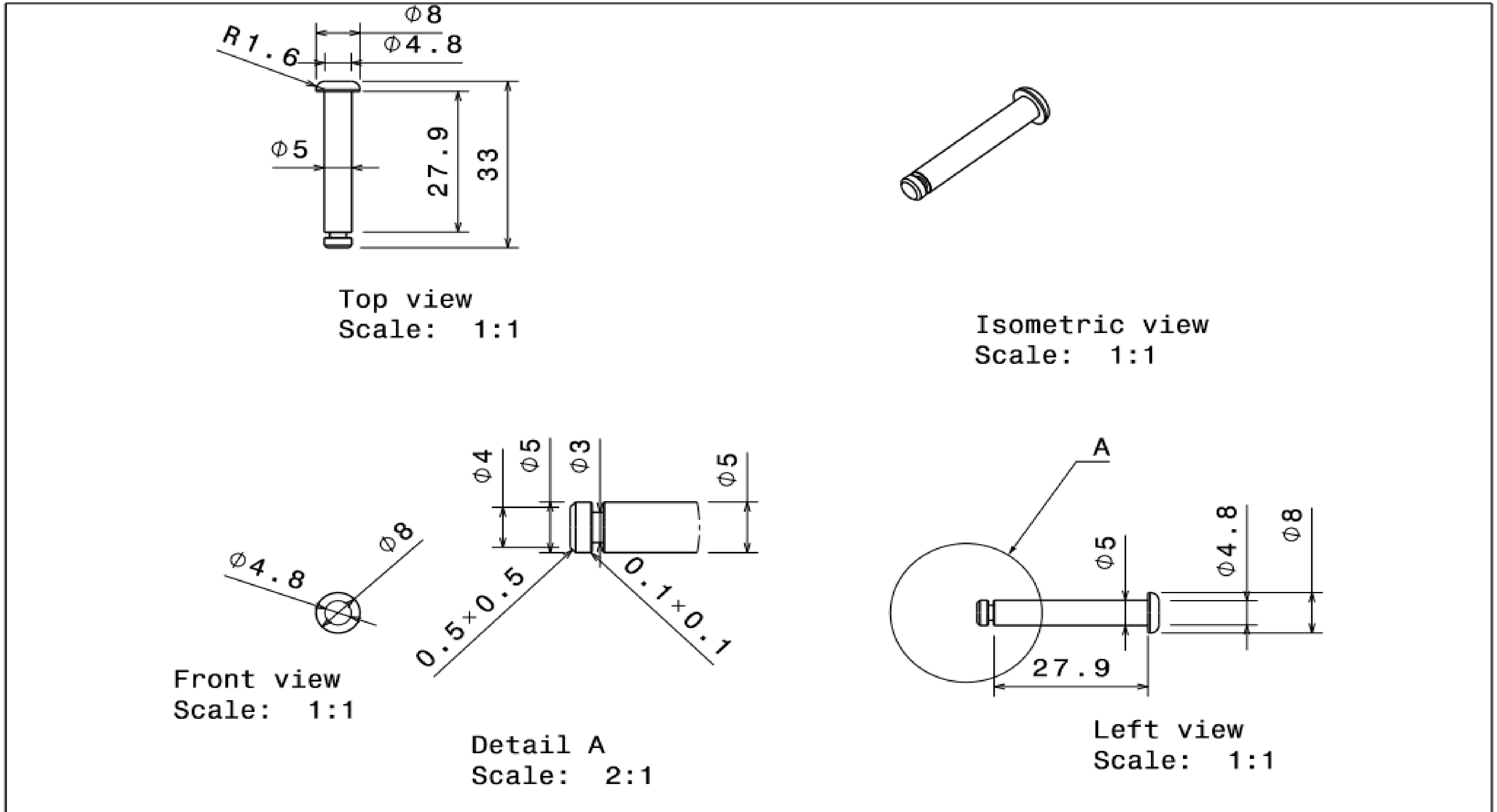


Front view
Scale: 1:1



Left view
Scale: 1:1

Designer by : MUHAMAD FAIZ BIN A RAZAK	
ID No. : FA12064	Part Name : Spring Mount
Date : 21/5/2016	Unit : mm



Designer by : MUHAMAD FAIZ BIN A RAZAK	
ID No. : FA12064	Part Name : Rivet Circlip 34mm
Date : 22/5/2016	Unit : mm