REDESIGN OF TAKADA RADIO USING BOOTHROYD DEWHURST DFA METHOD

MOHAMED KADER MAIDIN B. Y.SHAHARI

BACHELOR OF ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS

JUDUL: **REDESIGN OF TAKADA RADIO USING BOOTHROYD DEWHURST DFA METHOD**

SESI PENGAJIAN: 2009/2010

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REDESIGN OF TAKADA RADIO USING BOOTHROYD DEWHURST DFA METHOD

MOHAMED KADER MAIDIN BIN Y.SHAHARI

Report submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2009

EXAMINERS APPROVAL DOCUMENT

UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

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Signature : ....
Name of Supervisor : HADI BIN ABDUL SALAAM
Position : LECTURER,
FACULTY OF MECHANICAL ENGINEERING.
Date : 23 NOVEMBER 2009

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ID Number : ME06052

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To my Beloved Family

Y.SHAHARI BIN YUSOF

NOORJAHAN I/K Y.SHAHARI

SEENIRISWANA BEGUM BINTI Y.SHAHARI

RIAS FATHIMA JAHAN BINTI Y.SHAHARI

KATHER SHARIFA BINTI Y.SHAHARI

ACKNOWLEDGEMENT

I wish to express my sincere appreciation to my main thesis supervisor, Mr. Hadi Abdul Salaam, for encouragement, guidance, critics and advise, with his continuous support and interest, I would not have been able to complete this final year project successfully.

I am also indebted to Universiti Malaysia Pahang(UMP) for providing internet facility. Other than that, appreciation to the mechanical faculty's staff that gives important guidance throughout the project. Librarians at UMP, also deserve special thanks for their assistance in supplying the relevant literatures. Their views and tips are useful indeed. I am grateful to all my family members and friends for their continuous support and encouragement for me to do my best in this course.

ABSTRACT

The present paper discusses the Boothroyd Dewhurst DFA method that been used to evaluate a radio named Takada radio based on assembly efficiency. A survey conducted by distributing questionnaire about Takada radio to the university students and manufacturing company workers. Original design of Takada radio is analyzed and redesign of Takada radio is created based on improved assembly efficiency. Main thing evaluated in this project on Takada radio is the total assembly time and cost, and percentage of design efficiency. ALGOR software analysis is used to evaluate the reliability of the integral fasteners that have been designed in the redesign of Takada radio. The integral fasteners are analyzed on whether it will break or failure under range of forces acted on the integral fasteners. The redesign of Takada radio with the higher percentage value of design efficiency is selected as the best design in term of its assembly efficiency.

ABSTRAK

Kertas projek ini membincangkan cara Boothroyd Dewhurst DFA yang telah digunakan untuk menganalisis radio yang bernama radio Takada dari aspek pemasangan komponen radio tersebut dengan efisien. Satu survey telah dibuat dengan mengagih soalan-soalan tentang radio Takada kepada pelajar universiti dan pekerja di kilang pembuatan. Rekaan asal dan rekaan baru radio Takada dianalisis dari segi pemasangan komponen dengan efisien yang lebih baik. Perkara utama yang dambil kira dan dianalisis dalam projek ini adalah jumlah masa dan kos untuk memasang radio dan pemasangan komponen efisien dalam nilai peratus. Analisis daripada perisian ALGOR telah digunakan untuk menilai tahap ketahanan pengetat yang telah dimasukkan dalam rekaan baru radio Takada. Pengetat dianalisis dari segi sama ada ia patah or bengkok apabila dikenakan daya dalam had tertentu. Rekaan baru radio Takada dengan nilai pemasangan komponen efisien yang tinggi dipilih sebagai rekaan terbaik dari segi pemasangan komponen efisien.

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LIST OF SYMBOLS

E_{ma}	Design efficiency
Nmin	Theoretical minimum number of parts
Ta	Total assembly time
Tma	Estimated time to complete the assembly of the product
E	Assemblability evaluation score ratio
K	Assembly cost ratio
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

NM	Theoretical minimum number of parts
TM	Total assembly time
DFA	Design for Assembly
DFM	Design for Manufacture
DFMA	Design for Manufacture and Assembly
AEM	Assemblability Evaluation Method
HR	Handling ratio

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter discussed about the project background such as problem statement, objectives and scope of the project. All this information is important to give a starting point for the progress in this project. This project is focused on improving a Takada radio based on the assemble efficiency using a Boothroyd-Dewhurst DFA approach.

1.2 PROJECT BACKGROUND

Design for manufacture and assembly (DFMA) is a combination of design for assembly (DFA) and design for manufacture (DFM). The term DFMA is defined as a set of guidelines developed to ensure that a product is designed so that it can be easily and efficiently manufactured and assembled with a minimum labor effort, assemble time, and cost to manufacture the product. During a product development, DFMA method ensures that the transition from the design phase to the production phase is smooth and rapid as possible.

Generally, there are three DFA methods used to reduce the cost of the product. The main methods are Boothroyd-Dewhurst DFA method, Lucas-Hull DFA method, and Hitachi Assembly Evaluation Method (AEM). These three methods have been discussed in Chapter 2.

This project is about applying Boothroyd-Dewhurst DFA method to redesign the radio to make it better than the previous design in the aspect of assembly efficiency. This case study focused on redesigning the Takada radio and the aim of the analysis is to evaluate the redesign radio in term of the assembly efficiency.

1.3 PROBLEM STATEMENT

Radio normally consists of high number of components. In industries, the radio components are assembled together to produce final radio product. During assembly process, some intricate components are difficult to be assembled. This intricate component also need more time to be assembled and as a result, the cost to assemble the radio has been increased.

In solving the increasing cost of radio assembly, this project is done. The project also aims to minimize the difficulties encountered during assembly of the components of the radio. At the same time cost of the radio also aimed to be reduced. The radio is chosen as a product in this project because radio seems to have a lot of intricate components and also high number of components. The radio also has many areas that can be improved in term of design efficiency. Name of the radio chosen is Takada radio and it consists of 63 components that including radio parts and fasteners. Those components are chosen within the scope of the project only.

1.4 PROJECT OBJECTIVES

The objectives of this project are determined. There are three objectives have been defined to be focused on and to simplify the project as stated below:

1. To redesign the radio for improved assembly operation.
2. To analyze the original radio design and redesign based on the assembly efficiency.
3. To select the best redesign of radio based on the assembly efficiency.

1.5 SCOPE OF STUDY

The following scopes of the project are determined in order to achieve the objectives of the project:

1. The design of the original Takada radio and the redesign of the Takada radio are done using designing software which is the Solidwork 2006 software.
2. Analysis of the original design and the redesign of the Takada radio are performed using Boothroyd-Dewhurst DFA method.
3. Electrical and electronic parts in the radio such as circuit board are selected as one part because it is too complicated. The parts are assumed to be assembled as a one part.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discussed about the DFA and its guidelines. Besides that, the literature review gives a brief explanation about the functions and the principles of the DFA which is subcomponent of the DFMA itself. Some of the information in this chapter can give extra information which can be useful while doing this project.

2.2 DESIGN FOR ASSEMBLY (DFA)

Design for Assembly (DFA) is an approach to reduce the cost of the product and time of assembly by simplifying the product and process. The DFA method should be considered at all stages of the design process especially in the early stages (Boothroyd *et al*., 1994). The DFA tool needed to effectively analyze for ease of assembly of the products or subassemblies.

In the analysis of a product design for ease of assembly, it depends on whether the product is to be assembled manually, with special-purpose automation, with general purpose automation, with a general-purpose automation (robots), or a combination of these (Boothroyd *et al*., 2002). In addition, some operations have to be carried out manually and it is always necessary to use the manual assembly costs as a basis for comparison.

2.2.1 DFA Guidelines and Principles

The DFA guidelines are very useful when improving the product parts for the ease of assembly. The DFA guidelines can be summarized as below (Otto and Wood, 2001).

1. Minimize part count by incorporating multiple functions into single parts.
2. Modularize multiple parts into single subassemblies. (see Fig. 2.3)
3. Assemble in open space, not in confined spaces. Never bury important components.
4. Make parts to identify how to orient them for insertion.
5. Standardize to reduce part variety. (see Fig. 2.4)
6. Maximize part symmetry. (see Fig. 2.5 (a))
7. Design in geometric or weight polar properties if nonsymmetric.
8. Eliminate tangly parts. (see Fig. 2.5 (d))
9. Color code parts that are different but shaped similarly.
10. Prevent nesting of parts.
11. Provide orienting features on nonsymmetries.
12. Design the mating features for easy insertion. (see Fig. 2.1)
13. Provide alignment features.
14. Insert new parts into an assembly form above.
15. Insert from the same direction or very few. Never require the assembly to be turned over.
16. Eliminate fasteners.
17. Place fasteners away from obstructions.
18. Deep channels should be sufficiently wide to provide access to fastening tools. No channel is best.
19. Providing flats for uniform fastening and fastening ease.
20. Proper spacing ensures allowance for a fastening tool.

Most effective DFA guideline is to “Simplify the design by eliminating all unnecessary separate parts” (Otto and Wood, 2001)

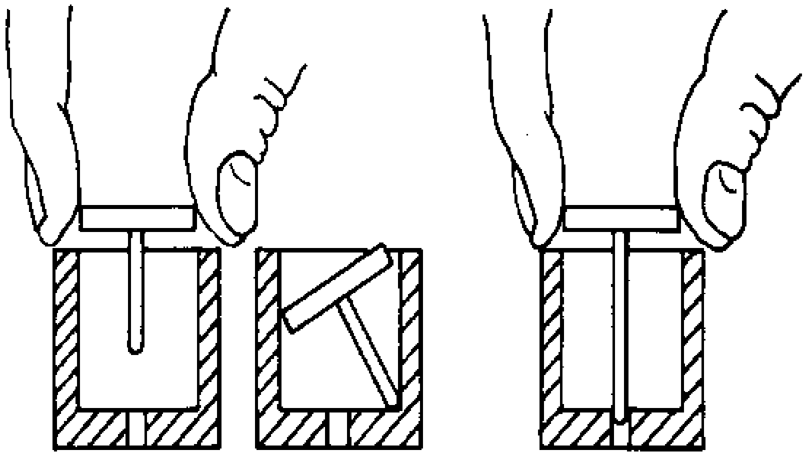


Figure 2.1: Design to aid insertion. (Boothroyd *et al*., 2002)

Source: (Boothroyd *et al*., 2002)

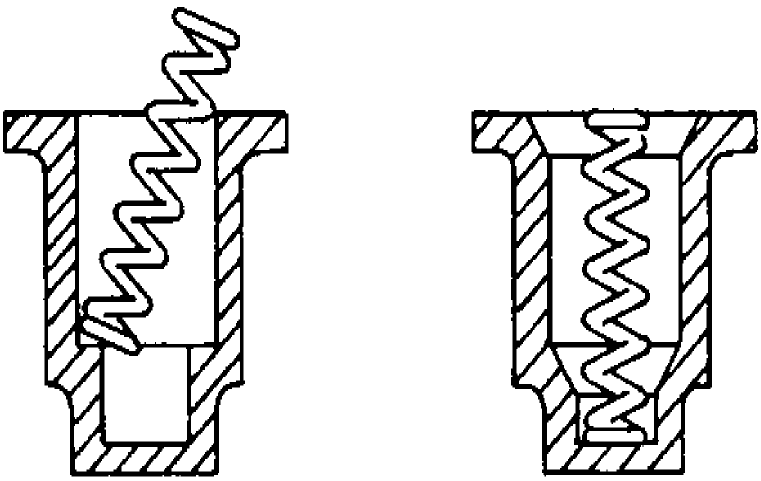


Figure 2.2: Provision of chamfers to allow insertion.

Source: (Boothroyd *et al*., 2002)

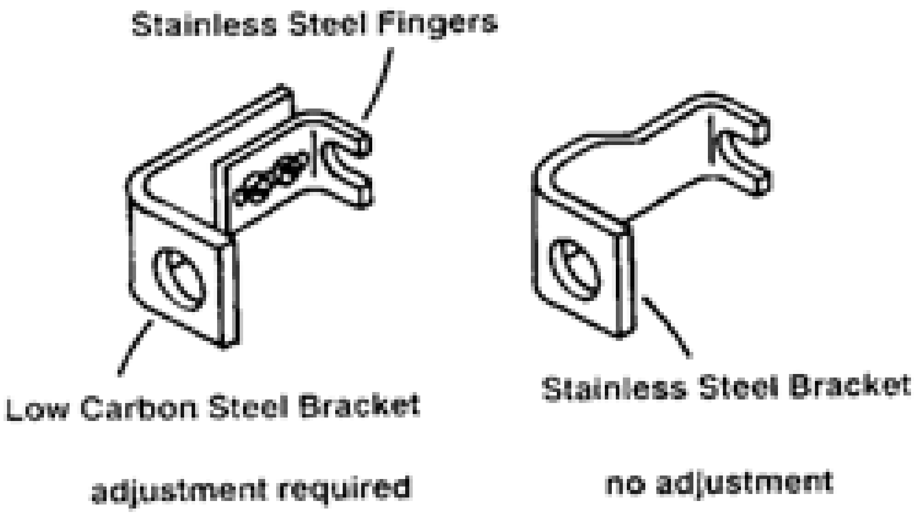


Figure 2.3: Design to avoid adjustment during insertion

Source: (Boothroyd *et al*., 2002)

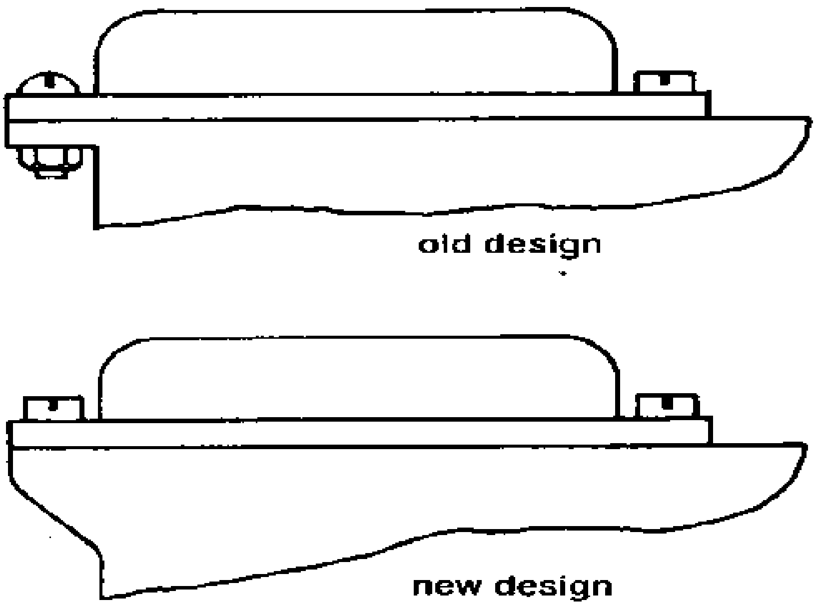


Figure 2.4: Standardize parts.assembly.

Source: (Boothroyd *et al*., 2002)

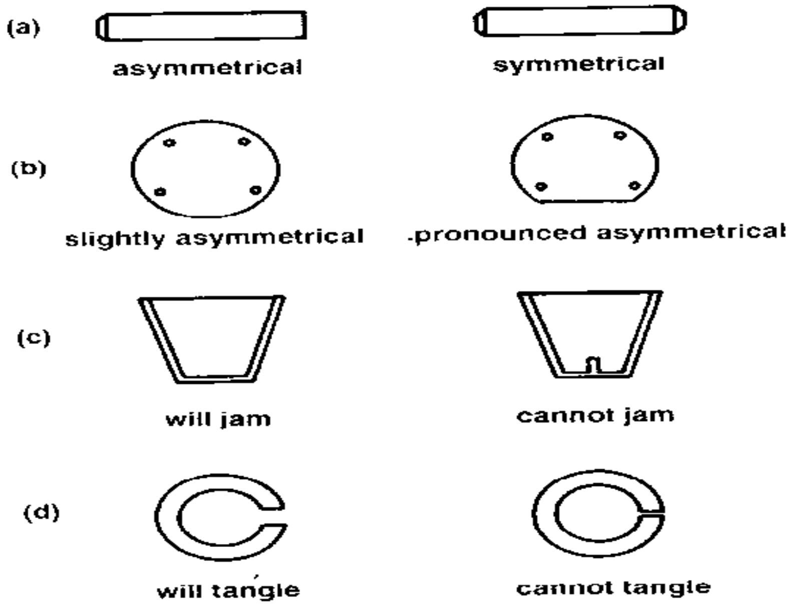


Figure 2.5: Features affecting part handling.

Source: (Boothroyd *et al.*, 2002)

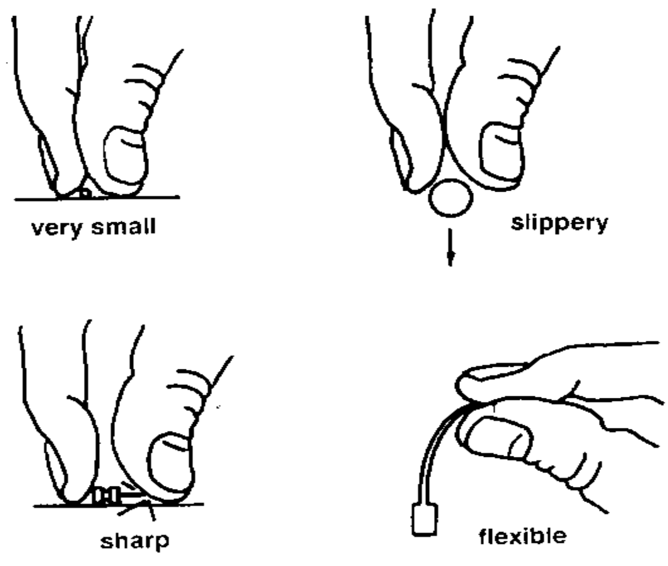


Figure 2.6: Geometrical features affecting part handling.

Source: (Boothroyd *et al.*, 2002)

The DFA guidelines are differ from the various source and it is insufficient for a number of reasons as stated below:

1. The guidelines will not provide any means to evaluate a design quantitatively for its ease of assembly.
2. No relative ranking of all the guidelines that can be used to indicate which guidelines result in the greatest improvements in handling and assembly.
3. These guidelines are simply a set of rules which provide the designer with suitable background information to be used to develop a design that will be more easily assembled than a design developed without such a background.

If a product contains fewer parts, it will take less time to be assembled, thereby reducing assembly costs. In addition, if the parts are easier to grasp, move, orient and insert, the parts can reduce the assembly time and assembly costs. The reduction of the number of parts in an assembly has benefit and generally reducing the total cost of parts in the assembly. This is usually where the major cost benefits of the application of design for assembly occur.

2.3 DESIGN FOR ASSEMBLY METHOD

There are three DFA methods being used in industry nowadays which is:

1. The DFA method exploited by Boothroyd-Dewhurst Inc., USA.
2. The Hitachi Assemblability Evaluation Method (AEM) by Hitachi Ltd, Japan.
3. The Lucas Design for Assembly Methodology by Lucas-Hull, UK.

2.3.1 Boothroyd-Dewhurst DFA Method

Geoffrey Boothroyd and Peter Dewhurst developed a computerized version of the DFA method which allowed its implementation in a broad range of companies in 1981. In many companies, DFA is a corporate requirement and DFA software is continually being adopted by companies attempting to obtain greater control over their manufacturing costs.

In this method, the manual assembly process can be divided into two separate areas which are handling (acquiring, orienting and moving the parts) and insertion and fastening (mating a part to another part or group of parts). Application of the manual method is straightforward using the subassembly worksheet and two pages of manual handling and manual insertion chart. The worksheet will be completed for each subassembly and for the final assembly.

For manual handling, the information that should be known and considered is listed down below. (Boothroyd *et al*., 2002).

1. Alpha (α) - It is the rotational symmetry of a part about an axis perpendicular to its axis of insertion.
2. Beta (β) - It is the rotational symmetry of a part about its axis of insertion.
3. Thickness-It is the length of the shortest side of the smallest rectangular prism that encloses the part.
4. Size-It is the length of the longest side of the smallest rectangular prism that can enclose the part.

For manual insertion, below are the some of the knowledge that have to be known (Boothroyd *et al*., 2002).

1. Holding down required - It means that the part will require gripping, realignment, or holding down before it is finally secured.
2. Easy to align and position - It means that insertion is facilitated by well designed chamfers or similar features.
3. Obstructed access - It means that the space available for the assembly operation causes a significant increase in the assembly time.
4. Restricted vision - It means that the operator has to rely mainly on tactile sensing during the assembly process.

The theoretical minimum number of parts is determined by answering to these three questions below (Boothroyd *et al*., 2002).

1. During the normal operating mode of the product, the part moves relative to all other parts already assembled. (Small motions do not qualify if they can be obtained through the use of elastic hinges).
2. The part must be of a different material than, or must be isolated from, all other parts assembled (for insulation, electrical isolation, vibration damping, etc.)
3. The part must be separate from all other assembled parts; otherwise the assembly of parts meeting one of the preceding criteria would be prevented.

If the answer to any of those questions is ‘yes’, then the part cannot be eliminated and it called as the theoretical minimum number of parts. The basic assembly time is the average time for a part that presents no handling, insertion, or fastening difficulties (about 3 seconds).

The basic assembly time will be used in determining the design efficiency. The design efficiency is calculated using the formula below (Boothroyd *et al*., 1994).

$$\text{Design efficiency, } E_{ma} = \frac{N_{min} \text{ x } T_a}{T_{ma}} = \frac{N_{min} \text{ x } 3}{T_{ma}}$$

where; Nmin = theoretical minimum number of parts.

T_a = basic assembly time = average time for a part

T_{ma} = estimated time to complete the assembly of the product.

In general, adding a component to the assembly will involve some or all of the following basic functions (Boothroyd *et al*., 2002):

1. Handling: the process of grasping, transporting, and orienting components.
2. Insertion: the process of adding components to the work fixture or partially built-up assembly.
3. Securing: the process of securing components to the work fixture or partially built-up assembly.
4. Adjustment: the process of using judgement or other decision- making processes to establish the correct relationship between components.
5. Separate Operation: mechanical and non-mechanical fastening processes involving parts already in place but not secured immediately after insertion (eg. bending, upsetting, screw tightening, resistance welding, soldering, adhesive bonding, etc.). Also other assembly operations such as manipulating of parts or subassemblies, adding liquids, etc.
6. Checking: the process of determining that handling, insertion, securing, and adjustment have been carried out properly.

2.3.2 Hitachi Assemblability Evaluation Method (AEM)

Hitachi Assembly Evaluation Method (AEM) is the first evaluation method that was developed at Hitachi corporation in Japan. This method is based on the principle of one motion for one part. For more complicated motions, a point-loss standard is used and the ease of assembly of the whole product is evaluated by subtracting points lost. The method was originally developed in order to rate assemblies for ease of automatic assembly. There are two indicators to effectively improve the design quality for better assemblability which are:

1. An assemblability evaluation score ratio, *E*, used to assess design quality by determining the difficulty of operations.
2. An assembly cost ratio, *K*, used to project elements of assembly cost.

In these methods, the "perfect" part or assembly operation gets the maximum score, usually one hundred, and each element or difficulty is assigned a penalty. There are twenty different operational circumstances, each with its own penalty. Each circumstance is accompanied by a simple icon for identification, permitting the method to be applied easily with little training (Whitney *et al*., 2004).

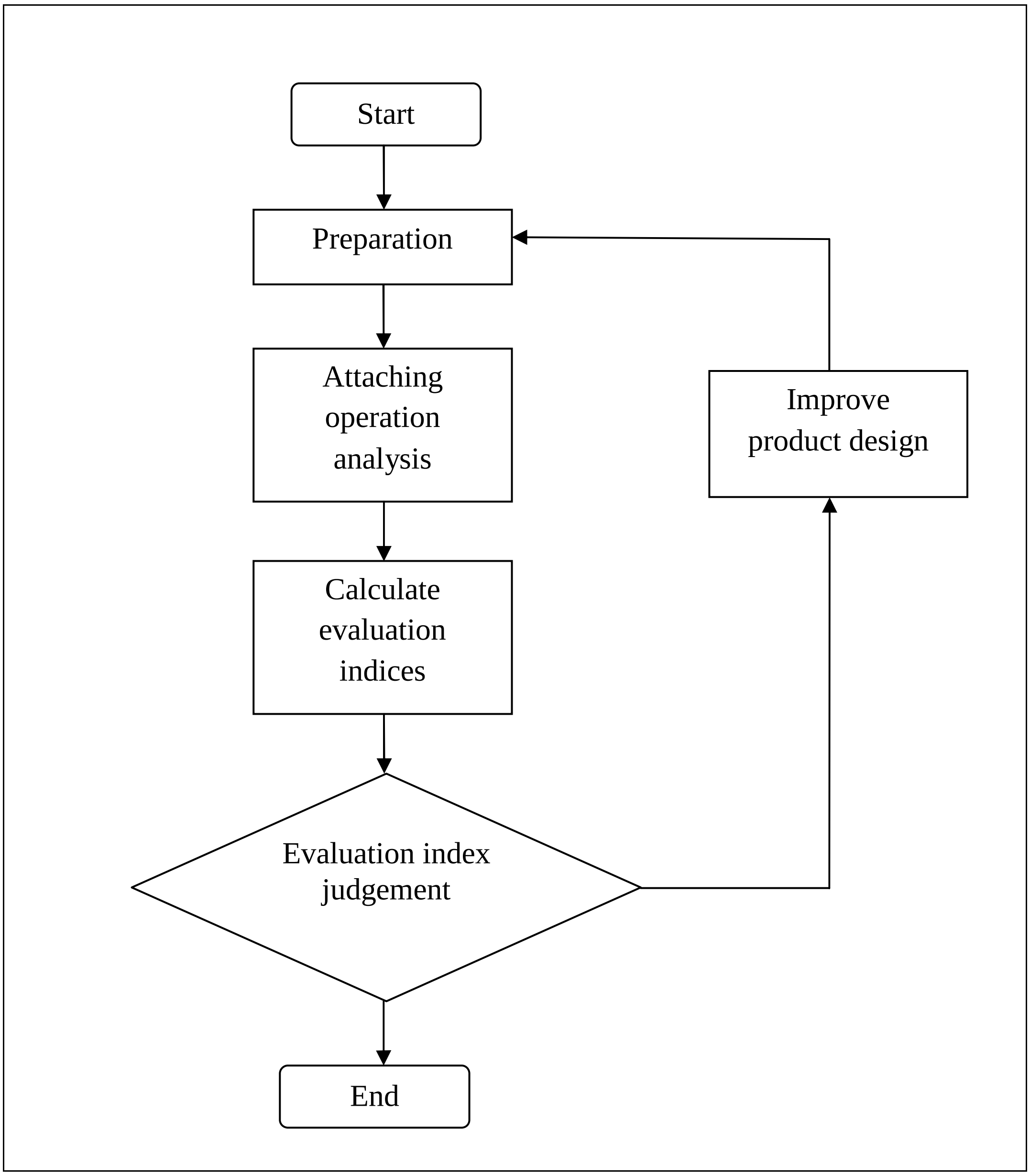


Figure 2.7: Flowchart of Hitachi AEM evaluation method.

Source: (Whitney *et al*., 2004).

When a part or operation is fully evaluated, all the penalties are added up and subtracted from one hundred points. If the score is less than some cut off value, say eighty points, the operation or part is to be subjected to analysis to improve its score. It is one hundred points to a part for its existence and additional points depending on difficulty. The difficulties are concerned on the:

a) Direction of motion.
b) Needs of fixture and forming.
c) Method of joining and processing.
d) Multiple operations.

The score for the entire product is either the sum of all the individual part scores or the average of the part scores. Then, the total points converted to assembly time and the assembly efficiency calculated. In this method, it’s clearly shows that the reduction in part counts is preferable to be better score because fewer penalties are available. However, the method does not include a systematic way of identifying which part might be eliminated (Whitney *et al*., 2004). All the evaluation based on comparing the current design to a base design of the same or a similar product. Because of the depth of the underlying dataset and the ratio technique of evaluation, the method is especially useful for designing the next in a series of similar product.

2.3.3 Lucas-Hull DFA Method

Lucas Hull methodology is one of the many methods developed to rate the efficiency of a design in the context of DFA. Lucas Hull DFA is classified into automated assembly and manual assembly. Lucas Hull method is based on a "point scale" which gives a relative measure of the assembly difficulty. The Lucas Hull DFA method is separated into 3 sequential analysis which are:

1. Functional analysis.
2. Feeding/Handling analysis.
3. Fitting analysis.

The 3 steps in the Lucas-Hull method explained in detail below.

1. Functional analysis - In Functional analysis, components in a product reviewed only for their function. Components are divided into 2 groups:

    a) Group A - In this group, the parts are essential for the product to function
    b) Group B - In this group, the parts are non-essential for the product to function

Below is the formula used in functional analysis which is:

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

where; A = Components from group A
B = Components from group B

The value of 60% or more design efficiency is targeted. The objective is to determine the components necessary for the functioning of the product (Group A) and highlight the non-essential ones (Group B). Improvement can be made by reducing parts from group B through elimination or incorporation. Any designs below 60% should be reconsidered before continuing the following analysis.

2. Feeding/Handling analysis - The relative handling difficulty of a part is analyzed using a table and the difficulty is recorded in a form of index. Generally, a part with an index larger than 1.5 should be considered for redesign. An ideal feeding ratio is generally 2.5 or less. Below is the formula used in feeding/handling analysis which is:

$$\text{Handling Ration (HR)} = \frac{(\sum \text{Feeding Index})}{A}$$

Where,
A = Components from Group A

3. Fitting analysis - The relative fitting difficulty of a part is analyzed using tables. The sequence of the assembly is required for this analysis. It is represented in an assembly flow chart. The several symbol used in the chart are explained below:

   a) The diamond symbol represents index for gripping difficulty
   b) The square symbol represents index for fitting difficulty
   c) The triangle represents index for non-assembly processes

A part with an index larger than 1.5 should be considered for redesign. An ideal fitting ratio is generally 2.5 or less. The Fitting Ratio (FR) is the result of this analysis:

$$\text{Fitting ratio} = \frac{(\text{Total Gripping index} + \text{Total Fitting index} + \text{Total non-assembly index})}{A}$$

where; A = Components from Group A

Lucas Hull DFA methodology utilizes 3 different analysis to completely analyze a design. The results from these 3 analysis are equally important and if a design does not fulfill one of the analysis, redesigning should be considered.

2.4 COMPARISON OF DFA METHODS

2.4.1 Boothroyd Dewhurst's DFA Method

Advantages – It is suitable to redesign the product based on the design efficiency calculation and the part that require high assembly time to assembly and unnecessary parts should be redesign or eliminate**.**

Disadvantages – It does not show the evaluation of the whole assembly sequence and also there is no support on how to redesign the product and shows the poor results.

2.4.2 Lucas-Hull DFA Method

Advantages - The Lucas-Hull method is similar as the Boothroyd Dewhurst method. Suitable in develop new product design based on the design efficiency and also evaluated the parts of the product based on functional, handling and fitting analysis.
Disadvantages - Lucas Hull DFA is classified into automated assembly and manual assembly only. The function analysis does not show why the part should exist.

2.4.3 Hitachi AEM Method

Advantages - Ease or the difficulty of insertion expressed in relative terms allowing applications to a wide range of products.
Disadvantages - This method only focus on the insertion and fastening process only. Part handling considered not as important or considered separately. There was no part reduction step in the original Hitachi AEM method.

2.4.4 DFA Methods Comparison Table

Table 2.1: DFA methods comparison

DFA Method	Advantage	Disadvantage
Boothroyd Dewhurst's	Redesign of product can be evaluated based on the design efficiency calculation.	Less support on how to redesign the product.
Lucas-Hull	Evaluated the parts of the product based on functional, handling and fitting analysis and suitable in developing a new product.	Categorized on automated and manual assembly only.
Hitachi AEM	Ease or the difficulty of insertion expressed in relative terms.	Focus on the insertion and fastening process only.

Source: (Faizal, M., 2007).

2.5 PREVIOUS RESEARCH

Table 2.2: Previous research that using DFA method.

Author	Title	Synopsis
Muhammad Faizal B. Alias (2007)	Redesign of Rice Cooker component by using an integrated Boothroyd Dewhurst DFA and Axiomatic Design.	Current rice cooker is redesign based on the analysis of DFA and Axiomatic Design. Design efficiency is increased from 22.0% to 33.0%.
Mgt Arnaz B. Mgt Ramli (2007)	Design improvement of Wira's driver seat using integrated DFA and VE.	Wira's driver seat is improved using Value Engineering (VE) and DFA. Results shows that DFA index for the proposed design 4.7% compare to current design which is 4.4%.
Hasbro Nazim (2008)	Software Development by integrating the integrated Value Engineering (VE) and Boothroyd Design for Assembly (DFA).	In stapler analysis, the actual value of efficiency is 33.2% and VE-DFA value is 31.02%. For computer mouse analysis, the actual and VE-DFA value is 28.25% and 26.17%. Using Wira's driver seat as a case study, actual value of design efficiency is 4.4% and by using VE-DFA software, the result value is 4.32%.
Ahmad Arif Syazni B. Abd Rahman (2008)	Software Development by integrating the integrated effort flow analysis and Boothroyd Dewhurst DFA.	Can opener is analyzed using DFA software. Can opener selected as case study in the DFA analysis. Current design efficiency is 3.40% and proposed design is 18.11%.

2.6 CONCLUSION

This chapter gives much important knowledge regarding the project. It is clear that the use of DFA method has a tremendous impact when it is properly applied in improving the product. The adaptation of DFA philosophy and cost quantification tools at the early stages of product design will gives greater benefits. The next chapter is about the methodology and it is mainly discussed about the methods used in the project.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter describes method used throughout the project. The methods used including methods in project progress, methods in gathering information, methods in product selection, and methods of using manual calculation. All this methods are useful because when proper methods used, the better results can be obtained in the project. The results for this project will be discussed in the next chapter.

3.2 DESIGN OF PROJECT STUDY

As a starting point for this project, there are lists of the final year project (FYP) title had been given to the students. Each of the projects is assigned a supervisor and/or co-supervisor in purpose of guiding throughout the project. In process of choosing the project title, a short briefing or explanation had been obtained from the supervisor to get more detail information regarding the project titles. A number of ten project title will be chosen according to the preferred title and supervisor. Then, the chosen project titles will be filled in the registration form and submitted to the office of the mechanical faculty.

Project titles that have been sent to the faculty will be evaluated by the project committee and one title will be selected as the finalized title and will be distributed to the student. At the same time when obtained the project title, the logbook also has been obtained from the office of mechanical faculty. The purpose of the logbook is to be used to write the progress of the project.

Then, there had been held one short briefing about the project mainly the important information such as evaluation of the project. Then, first meeting arranged with the supervisor to get more detail in progress of the project. In the first meeting, there are several important things discussed. One of them is the weekly appointment with the supervisor are clarified which is the day of the appointment is every Wednesday and the time is at 3.00pm. Other than that, the title of the project, problem statement of the project, objectives of the project and scope of the project are clarified and understood.

When attended every weekly appointment, the logbook has to be filled before the weekly appointment according to the progress of the project and have to be checked by supervisor and approved by his or her signature. The supervisor or co-supervisor had given important idea or suggestion that had been crucially important for the project in every appointment or meeting with them. After met the supervisor for the first time, the information regarding the project title are asked to be gathered and referred throughout the project. The methods in gathering information related to the project title are discussed in detail in the next subtopic.

A meeting has been made with the project supervisor for at least once in a week. It is better to meet supervisor or co-supervisor constantly so that they know the progress of the project and they can give any important and useful advice regarding the project. The main supervisor and co-supervisor should be made clear so that both of them can be referred for problems or for the purpose of discussion later on. Besides that, should be remembered that the project title, project objectives and scopes are the three main things that have to be verified with the project supervisor.

Then, the product to be analyzed in this project is surveyed at the current market and a radio selected as a suitable product. The methods used in product selection are discussed in detail in the subtopic later on. After selected a suitable product for this project which is the radio, it is dissembled and the components inside consist of parts and fasteners are analyzed. During diassembled time, photos of the each component are taken before and after diassembled so that it is easier to relocate the component back at the radio by referring to the radio’s photos. Later in this project, an analysis to get the result had been done using Boothroyd-Dewhurst manual calculation.

Then, after completion of the work needed for the project, preparation for the project presentation is made by discussion with the supervisor about the content of the presentation, schedule of project presentation, panels for project presentation and other necessary information regarding the project presentation. It is understood that the project draft consist all information that in the thesis.

At the same time, the log book and the slide presentation also had been given to the supervisor for evaluation purpose. Other than that, the approval form for presentation also had been filled and given to the project supervisor for the approval purpose. After the form was approved by the project supervisor, the form has to be given to the project presentation panels during project presentation. Then, the presentation of FYP 1 and 2 had been done according to the schedule given by the faculty and each project presentation had been judged by 3 panels.

3.3 METHODS IN GATHERING INFORMATION

The progress of the project is started with gathering information regarding the project title. Before that, an appointment with the supervisor has been made and the suggestion by the supervisor is to find at least 10 journals and 5 reference books regarding the project title so that there will be a general idea on how to conduct the project. One main reference identified which is the hard cover reference book about the project title is Product Design for Manufacture and Assembly.

Other than that, the information regarding the project title also obtained from websites and journals in the internet. Some journals are referred from the university’s database. Several journals has been studied and kept as a future reference to be used later. Thesis of the previous final year student that has been done about the same project title also referred as a source of information while doing the project. Some of the similar methods from the thesis are adapted such as the methods of questionnaire on asking public about the product.

Questionnaire about the Takada radio is done to get the public response about the product. That response will be important information that can be used for the progress of the project. At the same time, the public requirement for the product also can be obtained from the results of the questionnaire. The questionnaire is mainly consisting of general questions and specific questions about the product. There are total of seven questions asked in the questionnaire. For more detail about the questionnaire, an example of the questionnaire used in this project is attached in the appendix.

When first time using the Boothroyd-Dewhurst DFA handling and manual tables, it is really difficult to understand the steps to do the analysis and there is no proper guidance to use it. In solving this problem and for gaining more information about the tables, co-supervisor of the project is referred for advice. In solving the problem, co-supervisor of the project gives briefing about the tables and gives a manual guidance about several pages on how to use the tables. That manual is really useful in learning the about the two tables and to do the analysis on the project's product

3.4 METHODS IN PRODUCT SELECTION

In this project, a suitable product will be selected for improvement in terms of assembly efficiency and manufacturing operation that used to produce the product. The product selection is made by analyzing various products in shopping complex and product stores. While analyzing the product, the number of parts inside the product has to be estimated so that there will be more parts can be studied and analyzed in this project.

Besides that, products that are more to the electrical and electronic products such as VCD player and hand phone are not allowed by the supervisor. It is because, in this project, the scope has been stated that the electrical and electronic components not very suitable and have to be ignored. In this case, if product that is more to electrical and electronic is selected, there will be no point of improvement because most of the parts inside the product are electrical or electronic parts. Other than that, it is also not in the field of mechanical to study the electrical and electronic component where this project focused in mechanical field.

The project supervisor also suggested several products for selection such as blender, stationary product, and bread toaster. The project supervisor also advice not to select product of water heater or kettle because there is so many similar studies have been conducted on those products. On the other hand, project supervisor also advice not to select product which is too expensive because maybe the product have to be bought and disassembled for analyzing the product parts later on.

All aspect such as project supervisor advice, market situation on products and the price of the product are taking into consideration before selection of the suitable product for the project. Finally, a radio product selected as the product for the project. Although it is estimated there are several electrical and electronic parts inside the radio, but it can be seen that there are many assembly parts required to make that product. The several electrical parts such as wire are ignored and electronic parts such as circuit board are assumed to be one part of the product without taking consideration of the detail part on the circuit board.

3.5 METHODS OF BOOTHROYD DEWHURST DFA

The analysis of the project was done using Boothroyd Dewhurst DFA manual calculation method rather than the Boothroyd Dewhurst DFA software method. Manual calculation comprises the total time of parts assembly, the total operation cost, and the design efficiency. These two tables are very useful in Boothroyd Dewhurst DFA manual calculation method.

Firstly, the two-digit code and the time of the parts assembly can be obtained from the manual handling table and insertion table based on how the parts manually handled and inserted. Then, the labor cost per month was set up and the operation cost for each working second is calculated. After that, the assembly time and the operation cost were totaled up and finally the design efficiency was calculated in the form of percentage as the main aim of this project. The design efficiency will be used to compare between the original design and the redesign of the radio.

3.6 STEPS IN THESIS COMPLETION

As a starting point, the chapter 1 which is the introduction for the project are done after the radio product are selected and the radio are disassembled. For the information needed for this chapter, project supervisor is referred and had been asked opinion about the format of the thesis. Then, the project supervisor gives briefing about how is the format for thesis writing and had been given softcopy and guide on the thesis format.

Then, the subtopics used in the chapter had to be shown first to the project supervisor and opinion had been given whether it is suitable or not for that chapter. Other than the format used during the thesis writing, the grammar also had been considered and it is very important in thesis writing because it shows crucial information regarding when, how or what is presented in the thesis.

For the next chapter which is chapter 2 and 3, the same steps as in chapter 1 are taken after meeting with the project supervisor. For chapter 2 which is literature review, the all information gained from various sources. The methods used to obtain that information are discussed in detail in the previous subtopics such as using hard cover reference books, journals mainly from the university's database and the information from the internet.

In chapter 3 which is the methodology part of the project, all the methods used in producing this project are stated. In each subtopic, it had been discussed in detail about the steps, methods and how the work is done such as how to product selected, how to conduct the Boothroyd-Dewhurst analysis and how the overall project was done.

3.7 METHODOLOGY FLOWCHART

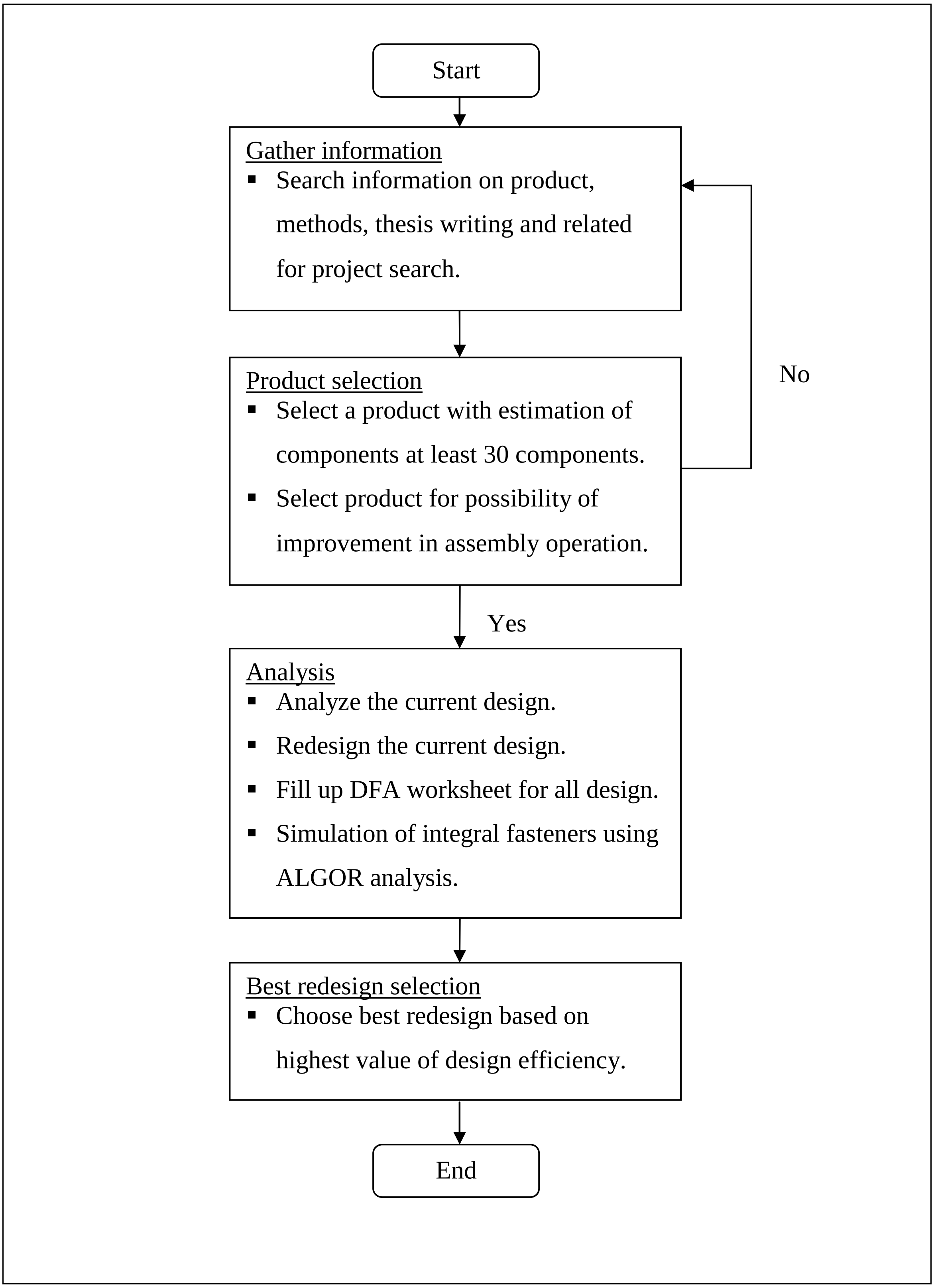


Figure 3.1: Project methodology flowchart

3.8 CONCLUSION

This chapter gives much important knowledge regarding all the methods used in the project. Various methods have been used to get the information for the project such as methods used in product selection for the project, methods used when using the Boothroyd-Dewhurst DFA manual calculation and steps taken in writing thesis. By referring to the methodology flowchart in Figure 3.1, the flow of the project can be seen and understood easily.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter presents results of this project and further the results are discussed in detail. The results for the current design and redesign of the radio are stated. Further, there are some simulation of the snap fit reliability in both current and redesign of the radio. In this project, the results are obtained by using Boothroyd Dewhurst DFA method for DFA analysis and using ALGOR software for the integral fasteners simulation. The recommendations for this project will be discussed in the next chapter.

4.2 PRODUCT INFORMATION

Takada radio is used mainly for listening to the music either by using cassette or by FM radio. This radio also used for music recording purpose. There are some special features in this radio which are built-in microphone, auto-stop after playing music, soft cassette ejecting system, rotary volume control and ergonomic radio shape and radio handle. The radio is powered by AC power 220-240V and consists of 3 circuit boards to run the radio’s working mechanism.

Takada radio consists of 63 different components including 53 different parts, 7 different fasteners and 3 different operations. The total number of radio components is 114 components including 61 parts, 35 fasteners and 18 operations. Operations such as adhesive bonding, bending and grease operation are done using assembly process. In Takada radio, there are two types of fastener used which are screw and bolt. These fasteners are all in different sizes and material.

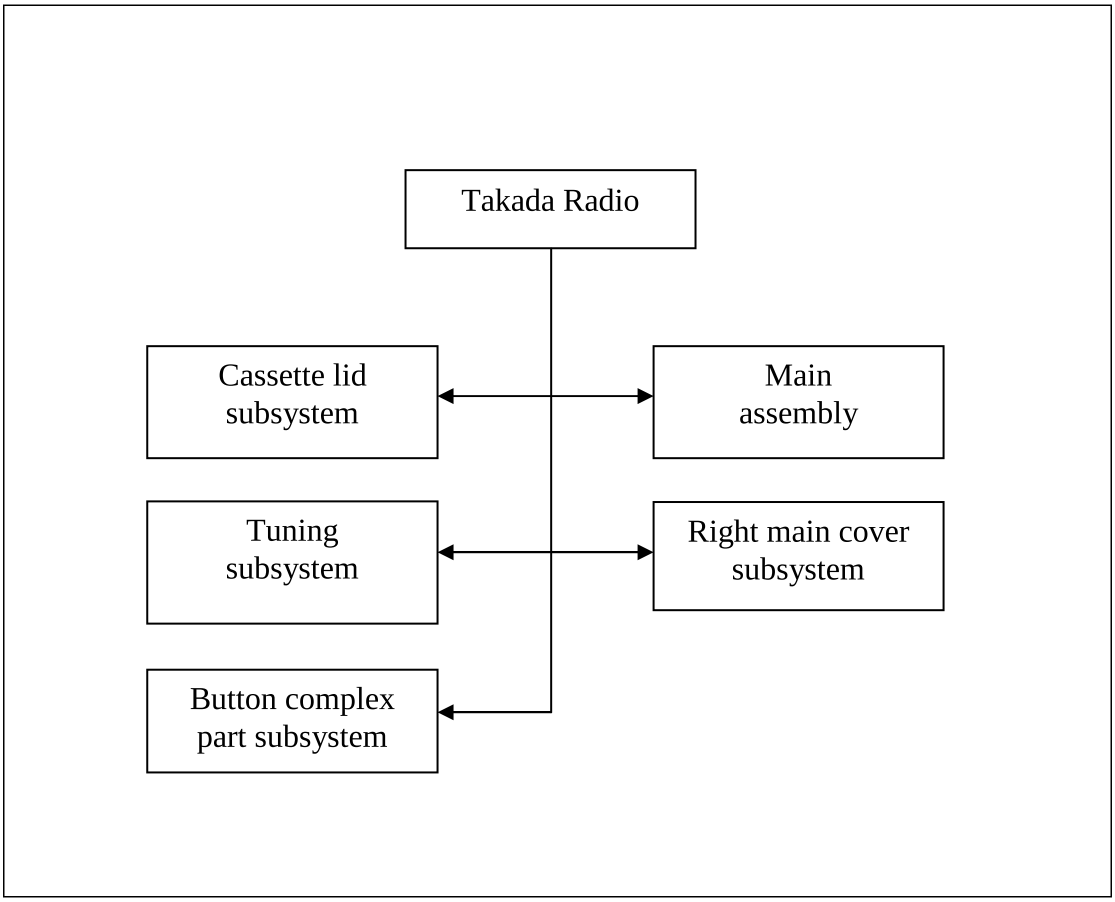


Figure 4.1: Product tree of current radio design.

Source: Takada radio

Figure 4.1 above shows product tree of Takada radio that consist of main assembly and 4 subsystems. The components in Takada radio is categorized according to main assembly and 4 subsystems of Takada radio. The main assembly and four other subsystems are assembled together during assembly process to make the Takada radio product. Below is the list of components assembled in the main assembly.

1. Left main cover.
2. Mock speakers.
3. Tuning plastic front cover.
4. Tuning silver front cover
5. Double sided tuning gear

6. Volume and Tuning outer cover
7. Tuning outer gear
8. Outer oval cover
9. Upper small cover
10. Flexible tuning part cover
11. Left and Right big speaker supporters
12. Left and Right mock speaker cover
13. Opening lid gear
14. Left and Right big speaker cover
15. Big speakers
16. Battery cover
17. Tuning supporting part

There are four subsystems in Takada radio and one of the main subsystems is right main cover subsystem. Right main cover subsystem consist high number of components compare to other Takada radio subsystems. Below are the components in the right main cover subsystem.

1. Right main cover
2. Antenna
3. Transformer
4. AC socket
5. Headphone socket
6. Headphone socket cover
7. Spiral battery spring
8. Conical battery spring
9. Attached conical battery spring
10. Battery cover

Next subsystem is the second subsystem which is cassette lid subsystem. In this subsystem, there are a lot of cover part assembled because cassette lid subsystem is the lid for the music cassette in Takada radio. The name of components in cassette lid subsystem is listed below.

1. Grey plastic front cover
2. Transparent plastic front cover
3. Silver plastic front cover
4. Grey plastic front cover
5. White plastic front part

Then, the third subsystem in Takada radio is button complex part subsystem. This subsystem consists of buttons of radio and one button complex part. This subsystem is to hold the radio buttons and cassette. The components that are assembled to make this subsystem are listed below.

1. Button complex part
2. Pause button
3. Stop button
4. Rewind button
5. Forward button
6. Play button
7. Record button

Tuning subsystem is the last subsystem of Takada radio which has only two parts to be assembled together. Tuning subsystem's components are easier to be assembled and also need less time to be assembled because of its least components. Below is the name of the two parts in tuning subsystem.

1. Tuning circuit board
2. Tuning circuit gear

4.3 SURVEY ANALYSIS

A survey on radio product was done by distributing questionnaire (refer Appendix A) to the mechanical engineering university student and manufacturing company's operators. The questionnaire consist list of questions asked about the radio product based on the assembly aspect. Feedback from the respondents later used in the radio current design analysis to reduce the Takada radio assembly time and cost.

Most of the questions answered by the respondents will not be 100% accurate and be accepted due to some human error or technical error. In the radio current design analysis, most of the answers can be assumed valid and can be referred in reducing the component assembly time and cost. Other than that, the questionnaire can be referred in improving the radio components for ease of assembly.

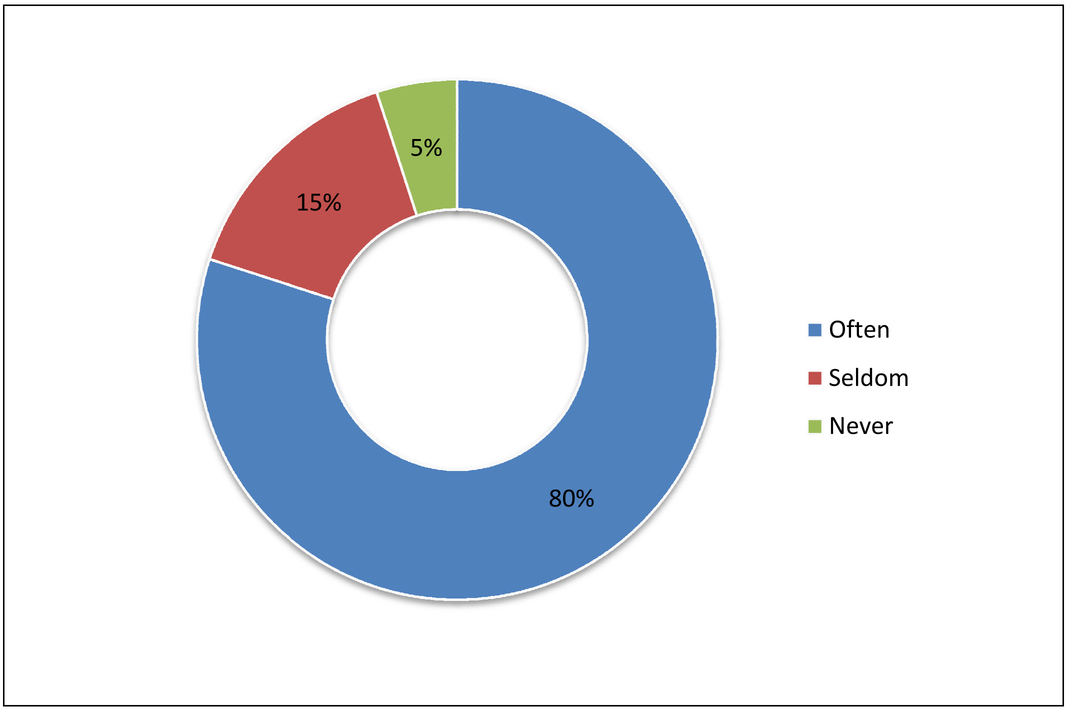


Figure 4.2: Question 1 from the survey.

Source: Product questionnaire (Refer Appendix A)

Question 1 in the survey in this project asks respondents on how frequently they use the radio product. The respondents are asked of about the radio product and not the radio application in the hand phone or laptop. From Figure 4.2, the feedback for using radio often is 80%, seldom in using radio is 15% and never using the radio is 5%. This answer is important to determine the validity of their other questions' answer based on respondent experience of using the radio product.

According to the survey, most of the respondents have been experiencing in using the radio and small amount of respondents are not frequently using the radio. By this result, the purpose of redesigning the radio is applicable because people frequently using the radio product and the radio product manufacturer have to produce it because of the radio product demand. So, redesigning the radio for minimized assembly time and cost in this project can be a demand from the radio product manufacturer.

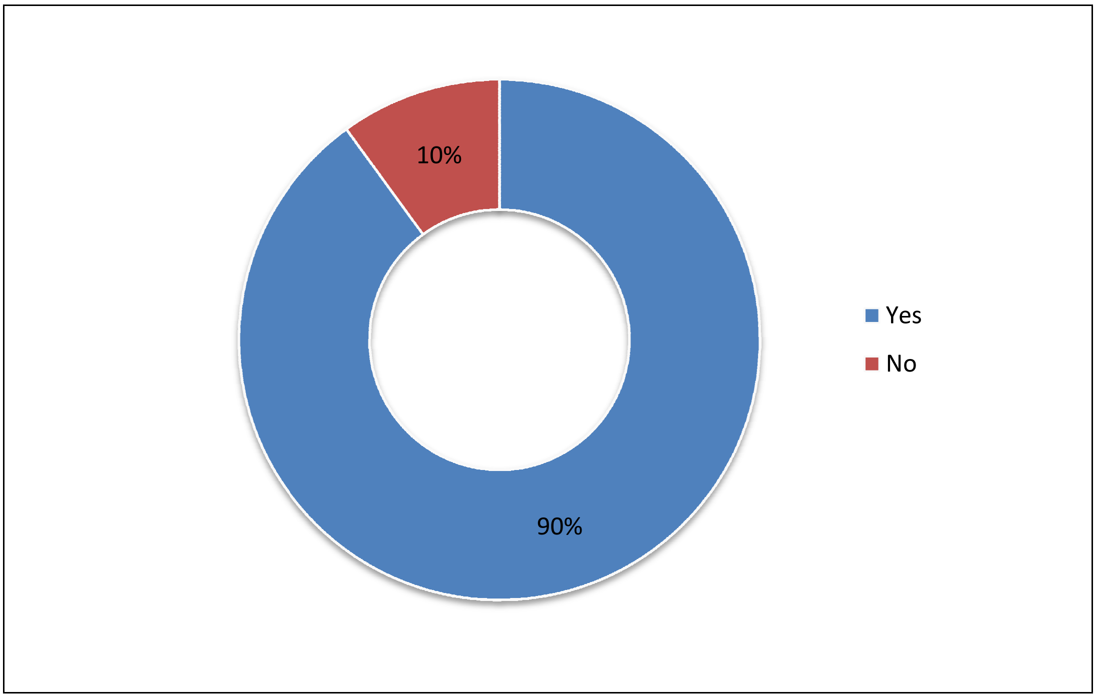


Figure 4.3: Question 2 from the survey.

Source: Product questionnaire (Refer Appendix A)

Question 2 asks respondents on the price of radio. Respondents were asked whether the price should be lower than the current market price. The feedback from Figure 4.3 shows that to reduce the price of the radio is 90% and feedback not to reduce the radio price is 10%. This answer is to be used as a guide point to reduce the cost of the radio product assembly.

Although, the respondent feedback is more to reducing the price of the radio, it is always necessary to reduce the price of the radio. This is because; the radio manufacturer always needs constant profit by reducing the price of the radio. By reducing the assembly time of the radio's component, the cost of the radio's component assembly can be reduced. Further, the overall price of the radio will be reduced too.

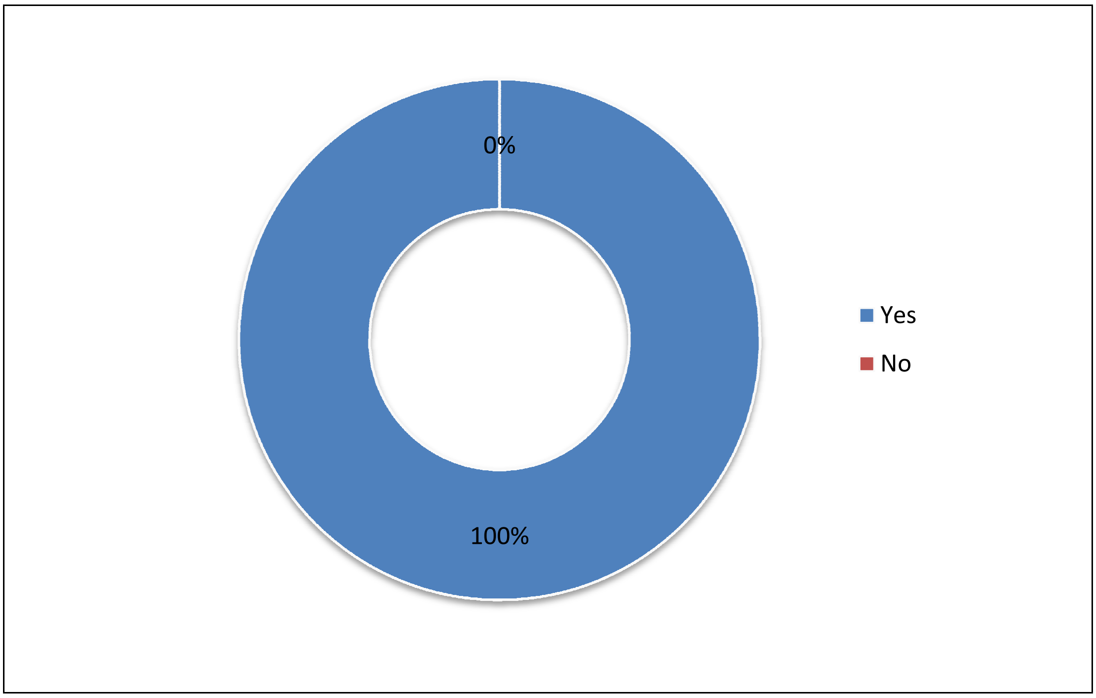


Figure 4.4: Question 3 from the survey.

Source: Product questionnaire (Refer Appendix A)

Next, Question 3 asks respondents whether the radio must be redesigned so that it can be safely when used. From Figure 4.4, the feedback to make the design of the radio safe when used is 100%. From this result, it can be determined that all respondent wants the radio to be designed safe when it is used. When redesigning the radio product, safety of the radio design is considered as one of important thing.

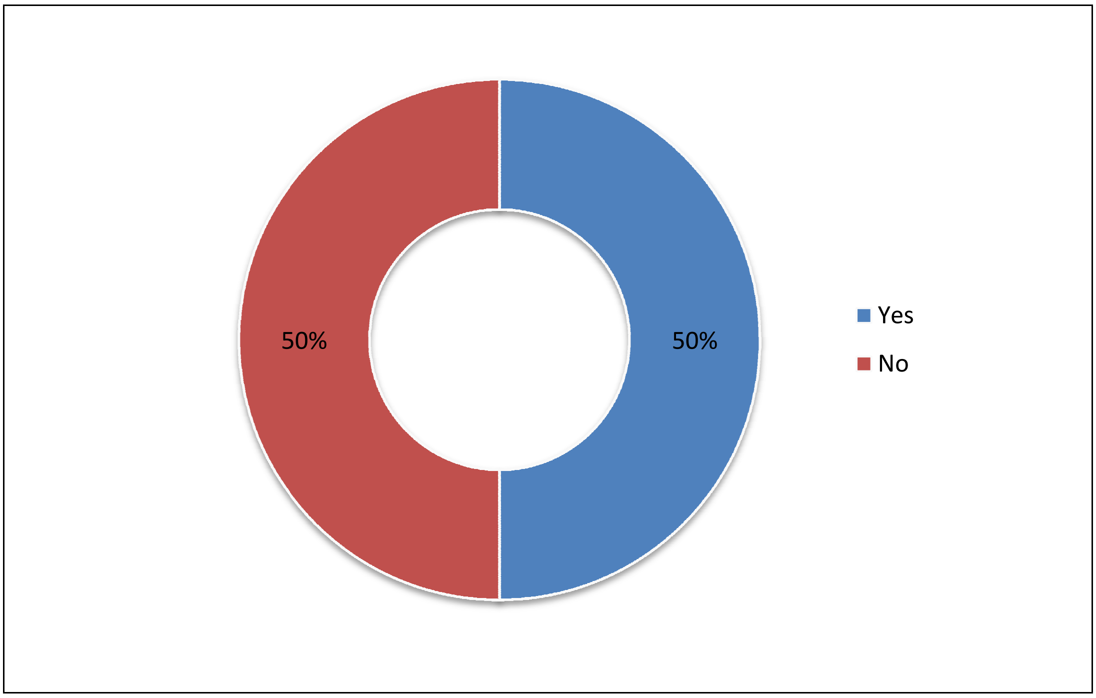


Figure 4.5: Question 4 from the survey.

Source: Product questionnaire (Refer Appendix A)

Then, Question 4 asks respondents about the intricacy of the current radio components. Respondents were asked on the intricacy of the components viewed mainly in assembly aspect. The respondent feedback for the radio components to be intricate is 50% and respondent feedback for the radio components to be not intricate is 50% according to the Figure 4.5. The results for the respondent to agree and disagree with the questions are equal.

This results shows that the radio's component can be redesigned to be consist of less intricate components. Redesigning will improve the components in term of ease of assembly. The intricate components are sometimes not only difficult in during assembly but high in cost to manufacture it. But sometimes, the intricate component is a need for certain functioning purpose and this kind of component cannot be redesigned.

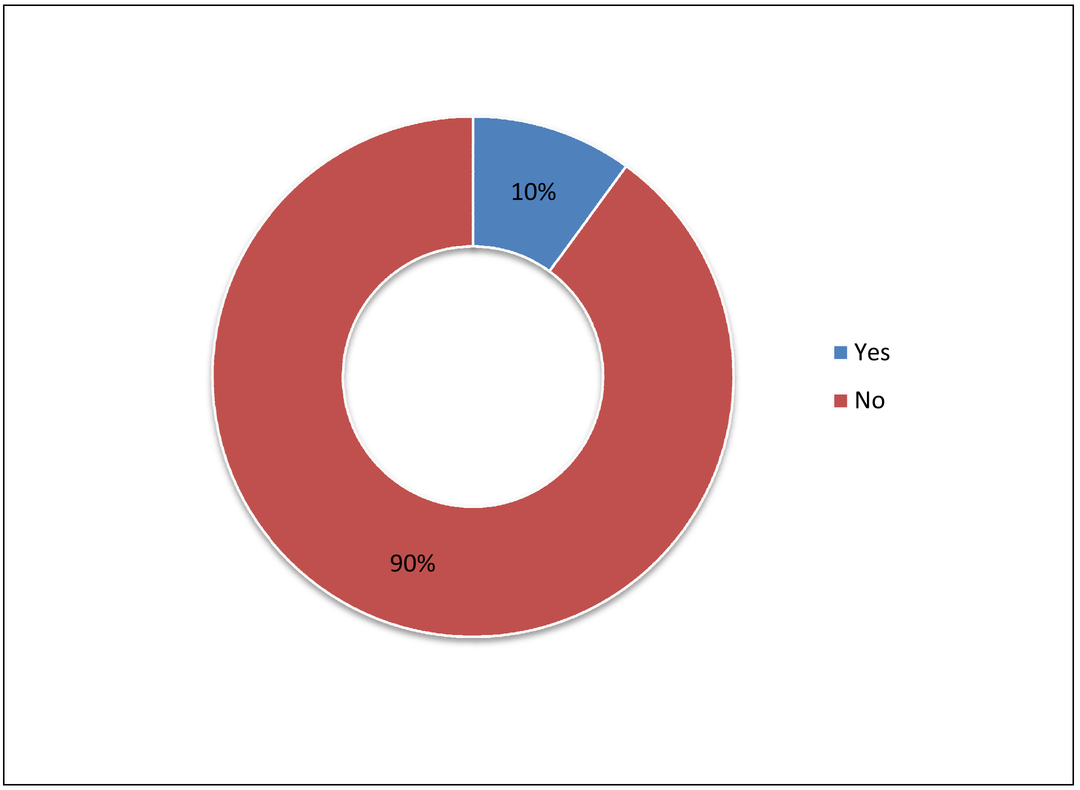


Figure 4.6: Question 5 from the survey.

Source: Product questionnaire (Refer Appendix A)

While, Question 5 asks respondents about the ease when assemble the radio product. Respondent may have less experience in assemble the radio product but they can predict the level of easiness to assemble the radio product. From Figure 4.6, the respondent feedback saying it is easy to assemble the radio product is only 10% and the respondent feedback saying it is not easier to assemble the radio product is 90%.

Most of the answer from the respondent disagrees by saying it is difficult to assemble the radio product. The radio product should be easier to be assembled. In this project, main purpose in redesigning the radio product is to make the radio product easier to assemble. So, this result supports this project's objective to make the radio's product easier to be assembled.

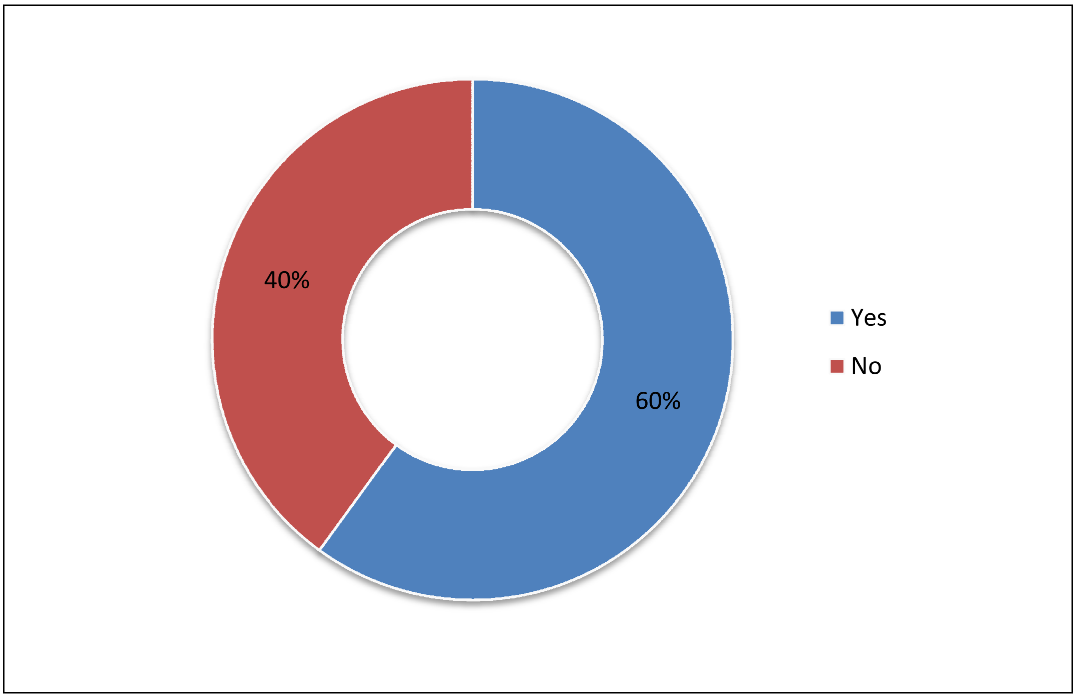


Figure 4.7: Question 6 from the survey.

Source: Product questionnaire (Refer Appendix A)

Next, Question 6 asks respondents about the ease when disassemble the radio product. Most of the respondents can answer quickly because they have experience in disassemble the radio product. The respondent feedback from Figure 4.7 saying it is easier to disassemble the radio product is only 60% and the respondent feedback saying it is not easier to disassemble the radio product is 40%.

Difficulties in disassemble the radio product maybe results of using many fasteners in the radio product such as screws and bolt. It is because the fastener need more time to be disassembled from the radio product. Permanent joining process such as bending operation and adhesive bonding will also resulting in the radio components to be hardly disassembled. So, in redesigning the radio product, the ease in disassembles should be considered so that certain components that need to be disassembled through the cycle life of the radio product can be disassembled easily.

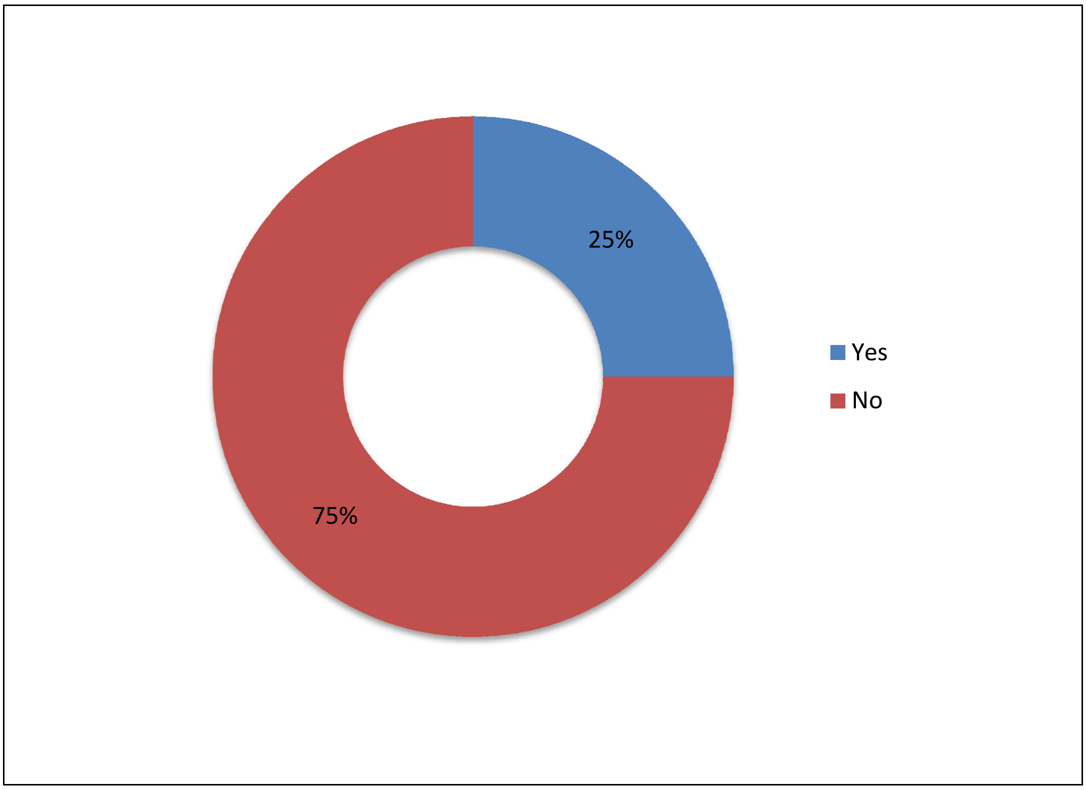


Figure 4.8: Question 7 from the survey.

Source: Product questionnaire (Refer Appendix A)

Last question which is Question 7 asks respondents about the ease when handling and inserting the radio components during assembly process. The respondent feedback from Figure 4.8 that agrees it is easier when handling and inserting the components is 25% and for the vice versa answer, the result is 75%. This answer is to be used as a guide point in reducing the time and cost of the radio product assembly.

The majority of the respondent answer is disagreed with the radio components can be ease in handling and inserting the radio components. Majority of the radio components are designed to be intricate in shape. So, it is difficult in handling when it is kept in bulk. On the other hand, when inserting the intricate radio components, there might be resistance during insertion. It can be say that most of the radio components are difficult in handling and insert it into the proper place. The radio product should be redesign so that there will be ease in handling and inserting the components to the appropriate place.

4.4 PRODUCT DESIGN ANALYSIS

The current radio design analysis is started after disassemble the entire radio product component. Below are the steps in completing the whole analysis for the current radio product design:

a) Decision has to be made on whether the radio product components can be considered as a candidate for elimination or combination with other components in the assembly.
b) Determine the theoretical minimum number of parts for the radio product components which is the minimum number of components necessary to perform the function.
c) Estimation of the time taken to grasp, manipulate, and insert each radio product component to its main assembly.
d) Calculate the total radio product assembly time and assembly cost.
e) Calculate the design efficiency for the radio product in percentage value.

According to the step (b) above, the theoretical minimum number of parts is obtained by answering 3 questions. If the answer to any of the questions is 'yes' then either a "1" is placed in the column. Otherwise, if all the answer for the 3 theoretical minimum number of parts questions is ‘n’ then put ‘0’ in the column (refer Table 4.1). Below is the 3 theoretical minimum number of parts questions:

a) Does the part move relative to all other parts already assembled? (small motions where elastic hinges are possible can be ignored)
b) Does the part have to be in different material or be isolated from all other parts already assembled?
c) Does the part have to be separated from all other parts already assembled because of possible assembly or disassembly?

4.5 ORIGINAL DESIGN ANALYSIS

Original Takada radio design consists of 63 different components including 53 different parts, 7 different fasteners and 3 different operations. The fasteners used in this original Takada radio design will be always a candidate for elimination. For original Takada radio design, the total assembly time to assemble all the components is 850.84 seconds. On the other hand, total cost of assemble all the components of original Takada radio design is RM1.1818.

By observing the original Takada radio design, many improvements in term of ease of assembly can be done. There are possible components for elimination from the original Takada radio design. Other than that, certain components seem possible for combination with the already assembled components. In the redesign of Takada radio, those elimination and combination will be considered.

Table 4.1 shows DFA worksheet for the original Takada radio design. The DFA worksheet is a sheet used to evaluate each components of the Takada radio in term of many aspects. The aspects that will be evaluated are shown below:

1. Proper names are given for each component of Takada radio.
2. Number of times the operation is carried out consecutively for each component is determined.
3. Handling code and handling time for each component is determined from Manual Handling Chart.
4. Insertion code and insertion time for each component is determined from Manual Insertion Chart.
5. Operation time for each component obtained by adding each component's handling and insertion time.
6. Operation cost for each component is calculated by costing assumption done for each component.
7. Finally the theoretical minimum number of part is obtained by answering three questions.

Table 4.1: Boothroyd Dewhurst DFA worksheet for original radio product design.

Part ID. No.	Number of times the operation is carried out consecutively	Manual Handling Code	Manual Handling Time	Insertion Code	Insertion Time	Operation Time	Operation cost	Theoretical Minimum Number of Part	Part Name
1.	1	30	1.95	00	1.50	3.45	0.0048	1	Right main cover
2.	1	30	1.95	00	1.50	3.45	0.0048	1	Right main cover subsystem
3.	1	30	1.95	00	1.50	3.45	0.0048	1	Left main cover
4.	1	20	1.80	00	1.50	3.30	0.0046	1	Upper small cover
5.	1	30	1.95	30	2.00	3.95	0.0055	1	Cassette lid gear
6.	2	-	-	99	12.00	24.00	0.0333	-	Grease operation
7.	2	30	1.95	30	2.00	7.90	0.0110	0	Outer oval cover
8.	9	-	-	97	12.00	108.00	0.1500	-	Adhesive bonding
9.	2	10	1.50	00	1.50	6.00	0.0083	1	Mock speaker
10.	1	20	1.80	11	5.00	6.80	0.0094	1	Left mock speaker cover
11.	1	20	1.80	11	5.00	6.80	0.0094	1	Right mock speaker cover
12.	4	-	-	90	4.00	16.00	0.0222	-	Bending operation
13.	1	30	1.95	30	2.00	3.95	0.0055	1	Tuning silver front cover
14.	1	30	1.95	30	2.00	3.95	0.0055	1	Tuning plastic front cover
15.	2	10	1.50	06	5.50	14.00	0.0194	1	Big speaker
16.	2	30	1.95	06	5.50	14.90	0.0207	0	Left big speaker supporter
17.	2	30	1.95	06	5.50	14.90	0.0207	0	Right big speaker supporter
18.	1	30	1.95	11	5.00	6.95	0.0097	1	Left big speaker cover
19.	1	30	1.95	11	5.00	6.95	0.0097	1	Right big speaker cover
20.	1	30	1.95	30	2.00	3.95	0.0055	1	Cassette lid subsystem

21.	1	30	1.95	00	1.50	3.45	0.0048	1	Grey plastic front cover
22.	1	30	1.95	41	7.50	9.45	0.0131	1	White plastic front part
23.	1	20	1.80	40	4.50	6.30	0.0088	1	Silver plastic front cover
24.	1	33	2.51	02	1.50	4.01	0.0056	1	Transparent plastic front cover
25.	1	30	1.95	00	6.00	7.95	0.0110	0	Cassette lid supporter
26.	1	30	1.95	32	4.00	5.95	0.0083	1	Flexible tuning part
27.	1	33	2.51	30	2.00	4.51	0.0063	1	Flexible tuning part cover
28.	1	35	2.73	51	9.00	11.73	0.0163	1	Lid opening spring
29.	1	30	1.95	00	1.50	3.45	0.0048	1	Button complex part
30.	1	35	2.73	00	1.50	4.23	0.0059	1	Button complex part subsystem
31.	1	30	1.95	06	5.50	7.45	0.0103	1	Middle circuit board
32.	1	30	1.95	01	2.50	4.45	0.0062	1	Volume circuit board
33.	1	30	1.95	00	1.50	3.45	0.0048	0	Volume outer cover
34.	1	10	1.50	00	1.50	3.00	0.0042	1	Double-sided tuning gear
35.	1	30	1.95	02	2.50	4.45	0.0062	1	Tuning supporting part
36.	1	20	1.80	00	1.50	3.30	0.0046	1	Tuning circuit gear
37.	1	10	1.50	00	1.50	3.00	0.0042	1	Tuning outer gear
38.	1	30	1.95	01	2.50	4.45	0.0062	1	Tuning circuit board
39.	1	31	2.25	16	8.00	10.25	0.0142	1	Tuning subsystem
40.	1	30	1.95	00	1.50	3.45	0.0048	0	Tuning outer cover
41.	1	30	1.95	06	5.50	7.45	0.0103	1	Headphone socket
42.	1	20	1.80	06	5.50	7.30	0.0101	1	Headphone socket cover
43.	1	20	1.80	06	5.50	7.30	0.0101	1	AC socket
44.	1	30	1.95	08	6.50	8.45	0.0117	1	Transformer
45.	1	38	3.34	01	2.50	5.84	0.0081	1	Spiral battery spring
46.	1	35	2.73	01	2.50	5.23	0.0073	1	Conical battery spring
47.	1	35	2.73	00	1.50	4.23	0.0059	1	Attached conical battery

									spring
48.	1	30	1.95	30	2.00	3.95	0.0055	1	Pause button
49.	1	30	1.95	30	2.00	3.95	0.0055	1	Stop button
50.	1	30	1.95	30	2.00	3.95	0.0055	1	Rewind button
51.	1	30	1.95	30	2.00	3.95	0.0055	1	Forward button
52.	1	30	1.95	30	2.00	3.95	0.0055	1	Play button
53.	1	30	1.95	30	2.00	3.95	0.0055	1	Record button
54.	1	30	1.95	30	2.00	3.95	0.0055	1	Battery cover
55.	1	20	1.80	18	9.00	10.80	0.0150	1	Antenna
56.	4	03	1.69	30	2.00	14.76	0.0205	1	Sponge base supporter
57.	7	10	1.50	59	12.00	94.50	0.1313	1	Outer screws
58.	17	11	1.80	39	8.00	166.60	0.2314	1	Circuit screws
59.	6	11	1.80	39	8.00	58.80	0.0817	1	Speaker screws
60.	2	11	1.80	39	8.00	19.60	0.0272	1	Transformer screws
61.	1	11	1.80	49	10.50	12.30	0.0171	1	Tuning outer gear screws
62.	1	11	1.80	49	10.50	12.30	0.0171	1	Big bolt
63.	1	60	4.80	59	12.00	16.80	0.0233	1	Small bolt
TOTAL						**850.84**	**1.1818**	**58**	

Source: Bootyroyd Dewhurst DFA worksheet of original radio design.

4.5.1 Original Design Calculations

For the calculation part, design efficiency needs to be calculated in a percentage value. It is important to find the design efficiency for the Takada radio original design and for the each Takada radio redesign so that the assembly efficiency between Takada radio design can be compared and evaluated. Below are the costing assumptions that have been made to find the design efficiency for the original design.

1. Labor cost per month for one labor to produce the product is assumed RM 800.
2. Working day per week for one labor is assumed 5 days.
3. Working hour per day for one labor is assumed 8 hours.
4. Working hour per month for one labor is:
   (4 weeks x 5 days x 8 hours) = 160 hours
5. Labor cost per hour per month for one labor is:
   RM 800 ÷ 160 hours = RM 5.00
6. Labor cost per second for one labor is RM 0.001389

Below are steps of calculation to find the design efficiency for the original Takada radio design:

$$\text{Design Efficiency} = \frac{3 \times Nm}{Tm}$$

$$= \frac{3 \times 58}{850.84}$$

$$= 0.2045$$

$$= 20.5\%$$

From the calculation, the result of design efficiency for the original Takada radio design has been obtained. The value of design efficiency for the original design is 20.5%.

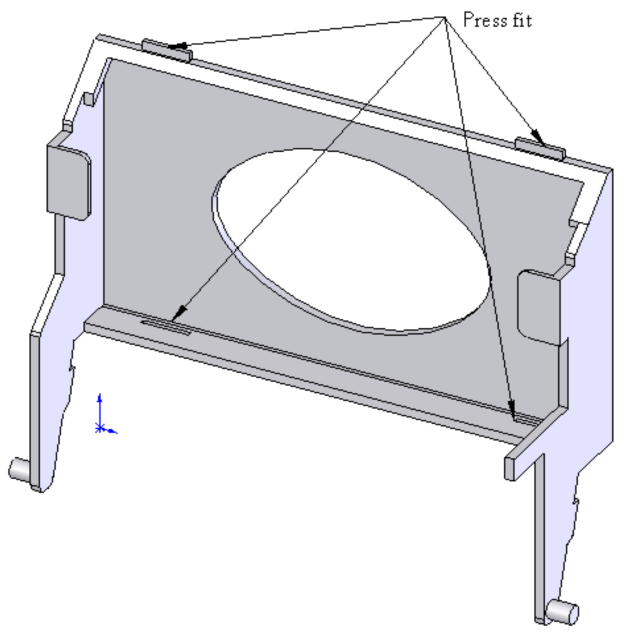
4.6 REDESIGN 1 ANALYSIS

Figure 4.9 shows white plastic front part before and after modification. Before modification, there are 4 press fits and some of them are difficult for insertion. In original radio design, it needs 9.45 to assemble white plastic front part but it only needs 2.00 seconds in redesign 1. It needs only RM0.0055 of assembly cost to assemble white plastic front part in redesign of Takada radio. By comparing to the original design, it needs RM0.00131 to assemble it where it is higher in assembly cost.

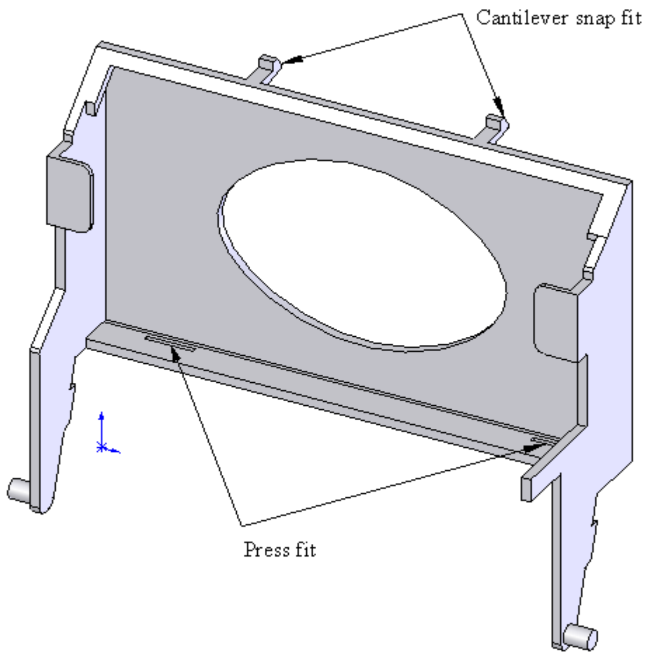
It is much easier to insert the white plastic front part using the snap fit rather than the press fit in the original design. Snap fit is an integral fastener where this kind of fastener is already manufactured with the parts. It can replace screws, nut and washers in the product. Snap with also can minimize the risk of improper assembly in a product. Other than that, other fasteners, adhesives, solvents, welding, or special equipment is not required in during usage of snap fit.

When the big speaker of Takada radio is assembled to the portion of left main cover, it needs support by the right and left big speaker supporters along with the screws. By the usage of right and left big speaker supporter and screws, the big speakers can be secured firmly at it place. In the assembly time and cost view, it needs more time to assemble and needs higher cost to assemble it. Figure 4.10 shows the assembly of big speaker and of big speaker before and after modification.

By modification, annular snap fit is used to assemble the big speakers with the portion of left main cover. The right and left big speaker supporter and the screws are eliminated in this redesign 1. Annular snap fit also is an integral fastener where this kind of fasteners is widely used in bottle cap. Speaker sometimes is disassembled for service purpose, so the annular snap is suitable because it can be assemble and disassemble easily. During assembly, the big speaker edge will be slipping into the groove of the portion of left main cover easily. By using annular snap fit, it reduces time amount of 69.90 seconds of assembly time and RM 0.0959 of assembly cost.



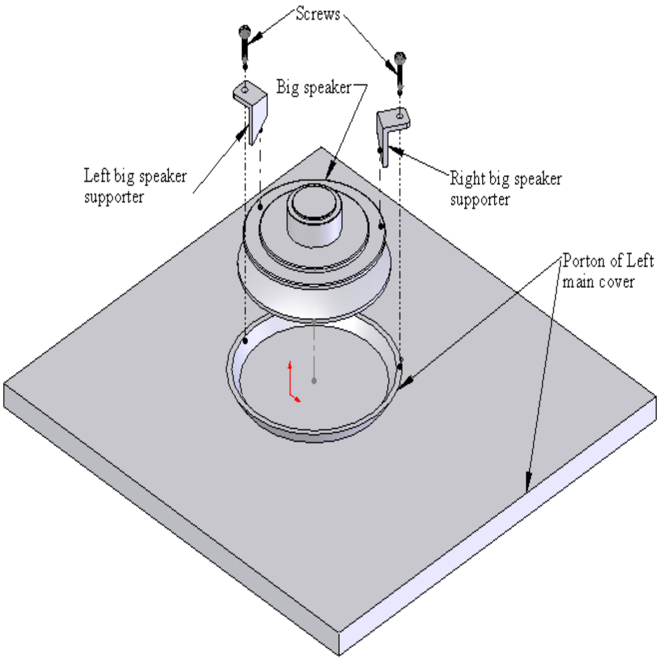
(before)



(after)

Figure 4.9: White plastic front part before and after modification.

Source: Solidwork software 2006.



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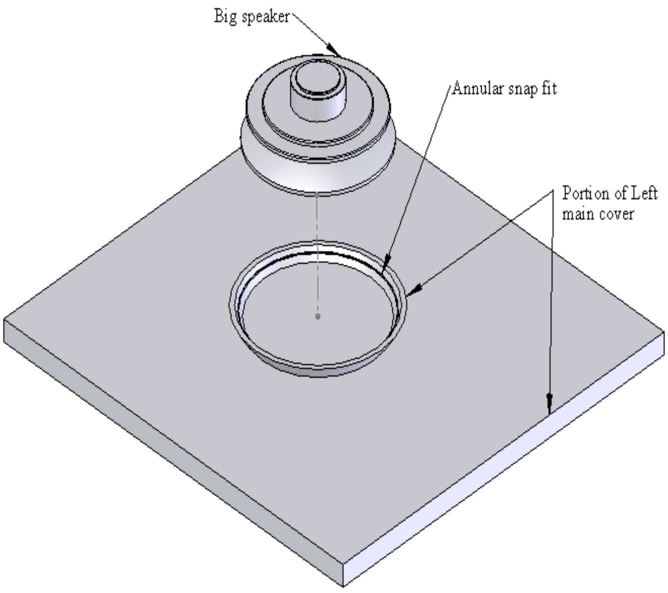
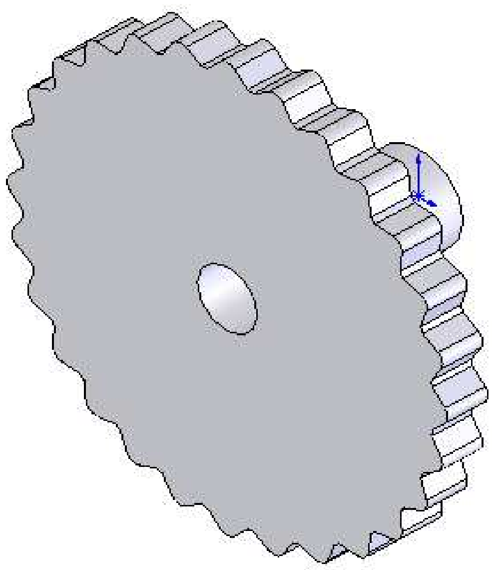


(after)

Figure 4.10: Big speaker assembly before and after modification.

Source: Solidwork software 2006.



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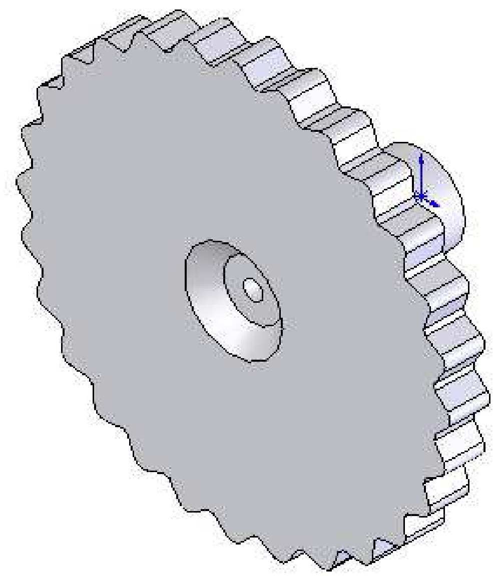
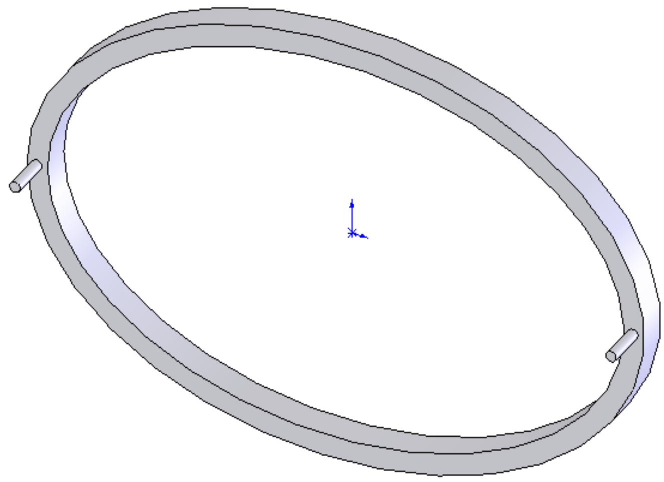


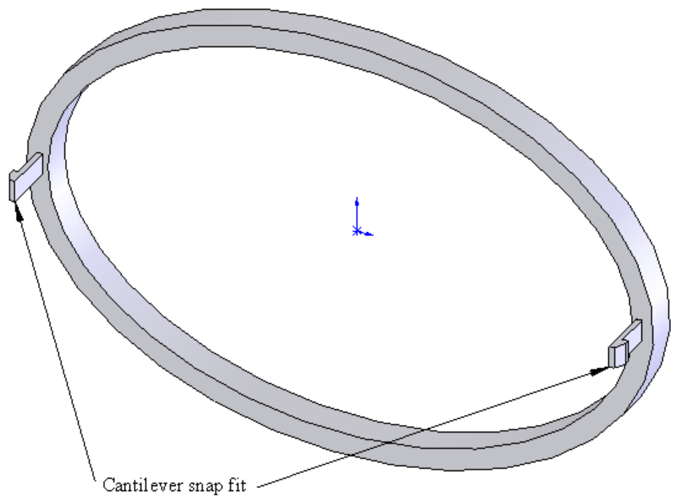
(after)

Figure 4.11: Tuning circuit gear before and after modification.

Source: Solidwork software 2006.



(before)



(after)

Figure 4.12: Silver plastic front cover before and after modification.

Source: Solidwork software 2006.

Figure 4.11 shows tuning circuit gear before and after modification. During tuning circuit gear assembly, the screwing operation is needed as subsequent process to secure and fastens the tuning circuit gear at the circuit board. In the original design, it is hard to insert screws and performed screwing operation because there is high depth on the tuning circuit gear.

By modification of the tuning circuit gear in redesign 1, low depth is used in the middle of the tuning circuit gear so that the screw can be position and inserted easily. Other than that, the edge at the screw insertion place also chamfered so that it is easier to position the screw without obstructed access or restricted vision. This modification in redesign 1 will result in reduction of the assembly time and cost.

Figure 4.12 shows tuning silver front cover before and after modification. In the original design, the silver plastic front cover has two press fit used to secure the part.By using those press fit, it is quite hard to insert the silver plastic front cover because of the obstructed access. Sometimes, the part will jam before it is fully secured at it position. The tuning silver front cover also has to be aligned before it is inserted.

In the modification design in redesign 1, the two press fit in the original design replaced with the two snap fits at the same place. These snap fit much easier to be inserted and secured and it saves assembly time and cost. From the original design, it takes 6.30 seconds to assemble it compare to redesign 1 where it takes only 3.80 seconds. In assembly cost, to assemble the silver plastic front cover in original design, it needs RM 0.0088 compare to RM 0.0053 in redesign 1.

Table 4.2 shows Boothroyd Dewhurst DFA worksheet for the redesign 1 of the Takada radio. Improvement has been done to the components in the original design of Takada radio and resulting in redesign 1 of Takada radio. By redesigning the original Takada radio, the total assembly time that has been reduced is 101.00 seconds and the total assembly cost reduced is RM 0.1403.

Table 4.2: Boothroyd Dewhurst DFA worksheet for redesign 1 of radio product.

Part ID. No.	Number of times the operation is carried out consecutively	Manual Handling Code	Manual Handling Time	Insertion Code	Insertion Time	Operation Time	Operation cost	Theoretical Minimum Number of Part	Part Name
1.	1	30	1.95	00	1.50	3.45	0.0048	1	Right main cover
2.	1	30	1.95	00	1.50	3.45	0.0048	1	Right main cover subsystem
3.	1	30	1.95	00	1.50	3.45	0.0048	1	Left main cover
4.	1	20	1.80	00	1.50	3.30	0.0046	1	Upper small cover
5.	1	30	1.95	30	2.00	3.95	0.0055	1	Cassette lid gear
6.	2	-	-	99	12.00	24.00	0.0333	-	Grease operation
7.	2	30	1.95	30	2.00	7.90	0.0110	0	Outer oval cover
8.	7	-	-	97	12.00	84.00	0.1167	-	Adhesive bonding
9.	2	10	1.50	00	1.50	6.00	0.0083	1	Mock speaker
10.	1	20	1.80	11	5.00	6.80	0.0094	1	Left mock speaker cover
11.	1	20	1.80	11	5.00	6.80	0.0094	1	Right mock speaker cover
12.	4	-	-	90	4.00	16.00	0.0222	-	Bending operation
13.	1	30	1.95	30	2.00	3.95	0.0055	1	Tuning silver front cover
14.	1	30	1.95	30	2.00	3.95	0.0055	1	Tuning plastic front cover
15.	2	10	1.50	06	5.50	14.00	0.0194	1	Big speaker
16.	1	30	1.95	11	5.00	6.95	0.0097	1	Left big speaker cover
17.	1	30	1.95	11	5.00	6.95	0.0097	1	Right big speaker cover
18.	1	30	1.95	30	2.00	3.95	0.0055	1	Cassette lid subsystem

19.	1	30	1.95	00	1.50	3.45	0.0048	1	Grey plastic front cover
20.	1	30	1.95	30	2.00	3.95	0.0055	1	White plastic front part
21.	1	20	1.80	30	2.00	3.80	0.0053	1	Silver plastic front cover
22.	1	33	2.51	02	1.50	4.01	0.0056	1	Transparent plastic front cover
23.	1	30	1.95	00	6.00	7.95	0.0110	0	Cassette lid supporter
24.	1	30	1.95	32	4.00	5.95	0.0083	1	Flexible tuning part
25.	1	33	2.51	30	2.00	4.51	0.0063	1	Flexible tuning part cover
26.	1	35	2.73	51	9.00	11.73	0.0163	1	Lid opening spring
27.	1	30	1.95	00	1.50	3.45	0.0048	1	Button complex part
28.	1	35	2.73	00	1.50	4.23	0.0059	1	Button complex part subsystem
29.	1	30	1.95	06	5.50	7.45	0.0103	1	Middle circuit board
30.	1	30	1.95	01	2.50	4.45	0.0062	1	Volume circuit board
31.	1	30	1.95	00	1.50	3.45	0.0048	0	Volume outer cover
32.	1	10	1.50	00	1.50	3.00	0.0042	1	Double-sided tuning gear
33.	1	30	1.95	02	2.50	4.45	0.0062	1	Tuning supporting part
34.	1	20	1.80	00	1.50	3.30	0.0046	1	Tuning circuit gear
35.	1	10	1.50	00	1.50	3.00	0.0042	1	Tuning outer gear
36.	1	30	1.95	01	2.50	4.45	0.0062	1	Tuning circuit board
37.	1	31	2.25	16	8.00	10.25	0.0142	1	Tuning subsystem
38.	1	30	1.95	00	1.50	3.45	0.0048	0	Tuning outer cover
39.	1	30	1.95	06	5.50	7.45	0.0103	1	Headphone socket
40.	1	20	1.80	06	5.50	7.30	0.0101	1	Headphone socket cover
41.	1	20	1.80	06	5.50	7.30	0.0101	1	AC socket
42.	1	30	1.95	08	6.50	8.45	0.0117	1	Transformer
43.	1	38	3.34	01	2.50	5.84	0.0081	1	Spiral battery spring
44.	1	35	2.73	01	2.50	5.23	0.0073	1	Conical battery spring
45.	1	35	2.73	00	1.50	4.23	0.0059	1	Attached conical battery

									spring
46.	1	30	1.95	30	2.00	3.95	0.0055	1	Pause button
47.	1	30	1.95	30	2.00	3.95	0.0055	1	Stop button
48.	1	30	1.95	30	2.00	3.95	0.0055	1	Rewind button
49.	1	30	1.95	30	2.00	3.95	0.0055	1	Forward button
50.	1	30	1.95	30	2.00	3.95	0.0055	1	Play button
51.	1	30	1.95	30	2.00	3.95	0.0055	1	Record button
52.	1	30	1.95	30	2.00	3.95	0.0055	1	Battery cover
53.	1	20	1.80	18	9.00	10.80	0.0150	1	Antenna
54.	4	03	1.69	30	2.00	14.76	0.0205	1	Sponge base supporter
55.	7	10	1.50	59	12.00	94.50	0.1313	1	Outer screws
56.	17	11	1.80	39	8.00	166.60	0.2314	1	Circuit screws
57.	2	11	1.80	39	8.00	19.60	0.0272	1	Speaker screws
58.	2	11	1.80	39	8.00	19.60	0.0272	1	Transformer screws
59.	1	11	1.80	49	10.50	12.30	0.0171	1	Tuning outer gear screws
60.	1	11	1.80	49	10.50	12.30	0.0171	1	Big bolt
61.	1	60	4.80	59	12.00	16.80	0.0233	1	Small bolt
TOTAL						**749.84**	**1.0415**	**56**	

Source: Bootyroyd Dewhurst DFA worksheet of radio redesign 1.

4.6.1 Redesign 1 Calculations

Below are the costing assumptions that have been made to find the design efficiency for the redesign 1 of Takada radio. These costing assumptions same as used for the original Takada radio design.

1. Labor cost per month for one labor to produce the product is assumed RM 800.
2. Working day per week for one labor is assumed 5 days.
3. Working hour per day for one labor is assumed 8 hours.
4. Working hour per month for one labor is:
   (4 weeks x 5 days x 8 hours) = 160 hours
5. Labor cost per hour per month for one labor is:
   RM 800 ÷ 160 hours = RM 5.00
6. Labor cost per second for one labor is RM 0.001389

Below are steps of calculation to find the design efficiency for the Redesign 1 Takada radio design:

$$\text{Design Efficiency} = \frac{3 \times Nm}{Tm}$$

$$= \frac{3 \times 56}{749.84}$$

$$= 0.224$$

$$= 22.4\%$$

From the calculation, the result of design efficiency for the Redesign 1 of Takada radio design has been obtained. The value of design efficiency for the Redesign 1 is 22.4%.

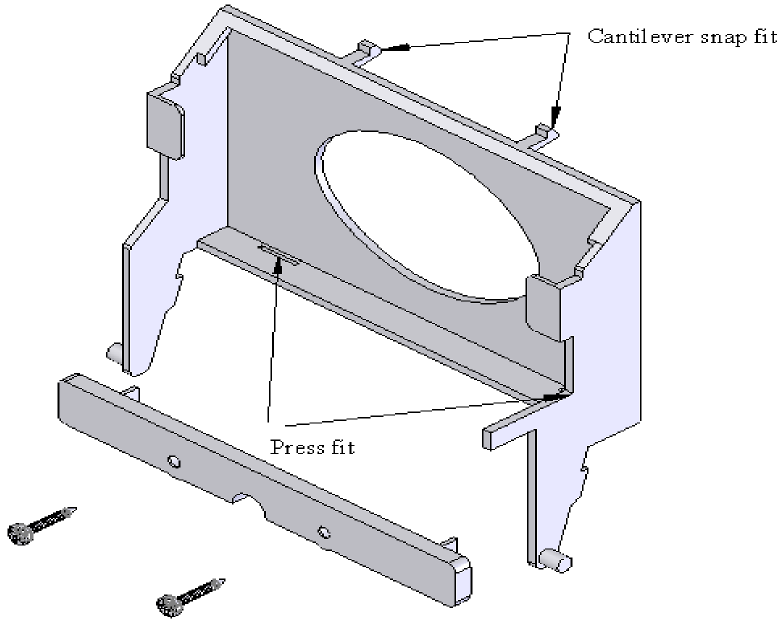
4.7 REDESIGN 2 ANALYSIS

White plastic front part is improved again after it is improved previously in the redesign 1 of Takada radio. In previous redesign 1 of Takada radio, white plastic front part is improved by replacing press fit with snap fit features. In this redesign 2, white plastic front part is added white another two press fit features at the side part. Figure 4.13 shows the white plastic front part before and after modification in redesign 2 of Takada radio.

By the modification, the cassette lid supporter and the two screws is eliminated. These new features of the press fit also gives ease and speed in assembly process. By elimination of cassette lid supporter and the two screws, the assembly time reduced by this new design is 27.55 seconds and the reduction of cost from this new design is RM 0.0382.

Figure 4.14 shows transformer assembly before and after modification for redesign 2. For transformer assembly, it needs two screws to fasten the transformer to the portion of left main cover. Before fasten the transformer, it needs to align the transformer at the portion of left main cover. It takes time to align the transformer because the design of portion of left main cover is not very good for placing the transformer.

By modification, the portion of left main cover is redesign so that the transformer is easy to be aligned when positioning it. When the transformer is easier to be position and aligned, it is easier to place the two screws beside the transformer and it is easier to performed screwing operation. Other than that, this new design also provides no resistance for transformer insertion and will give easiness during the transformer assembly process.



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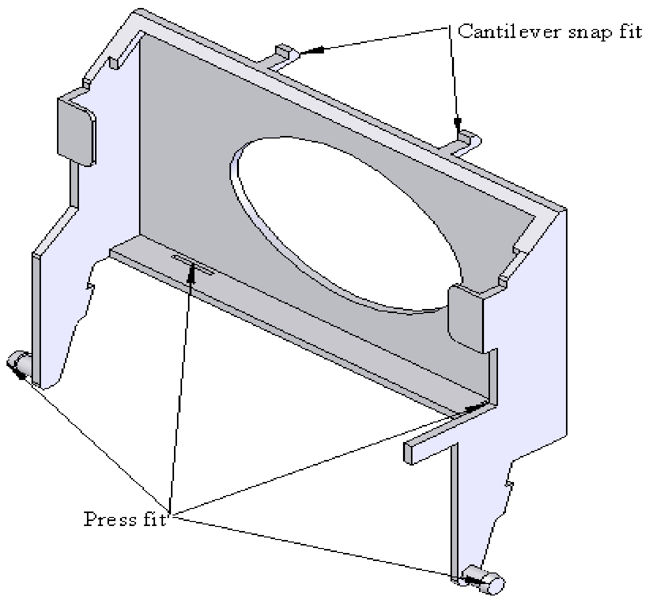
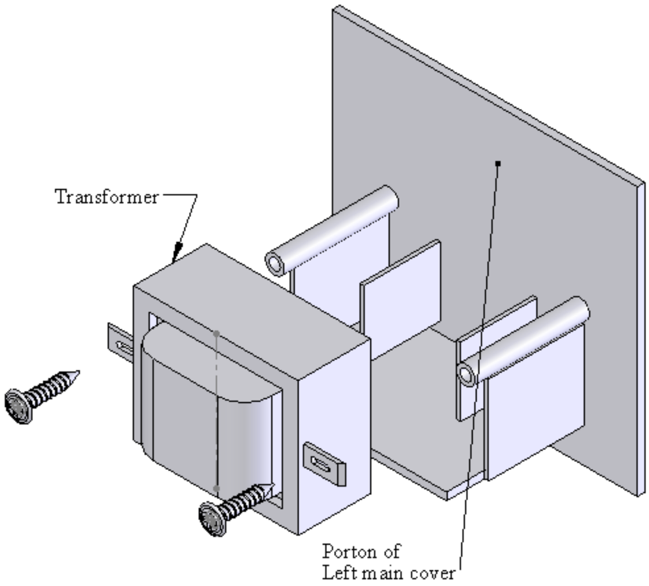


(after)

Figure 4.13: White plastic front part before and after modification.

Source: Solidwork software 2006.



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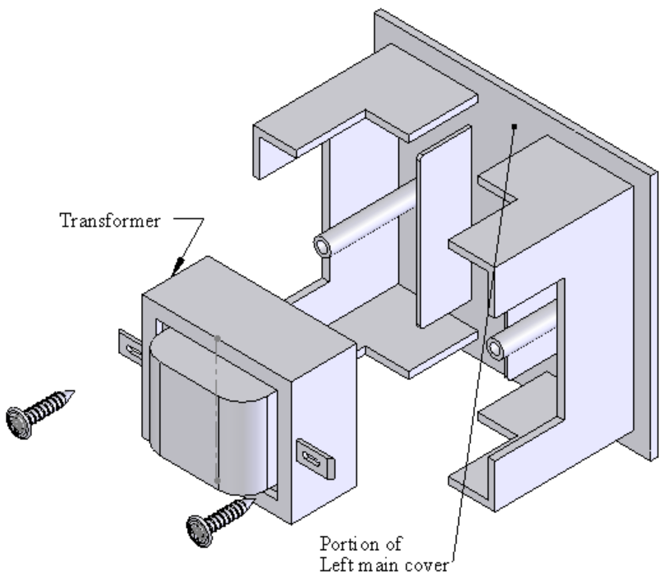

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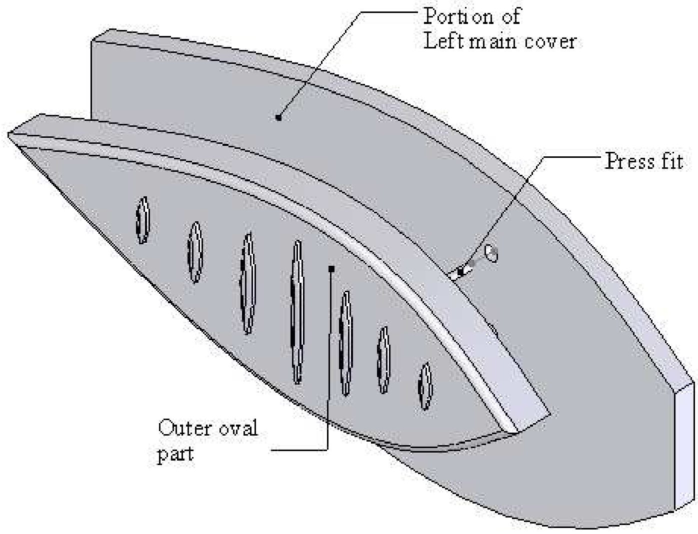
Figure 4.14: Transformer assembly before and after modification.

Source: Solidwork software 2006.



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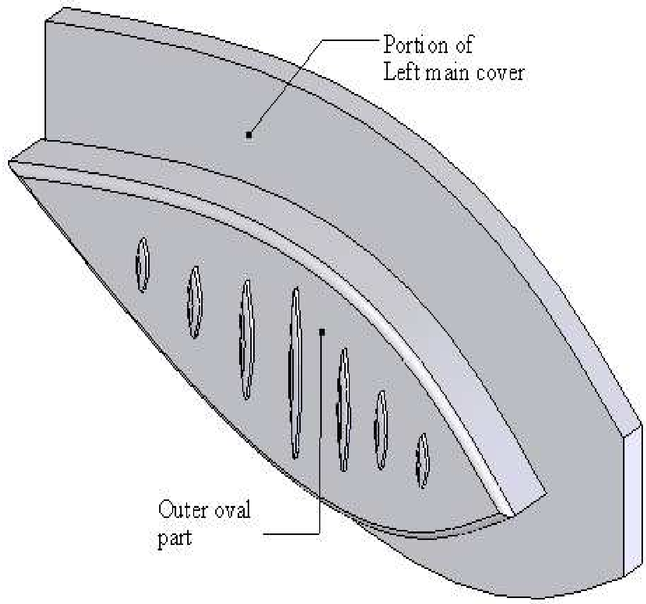

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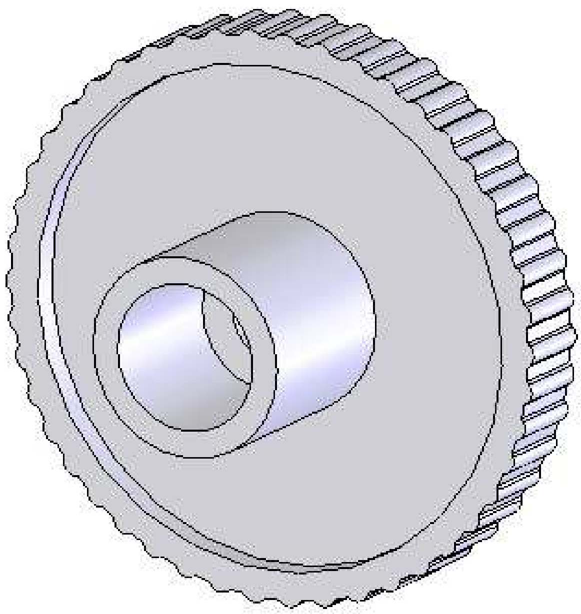
Figure 4.15: Outer oval cover before and after modification.

Source: Solidwork software 2006.



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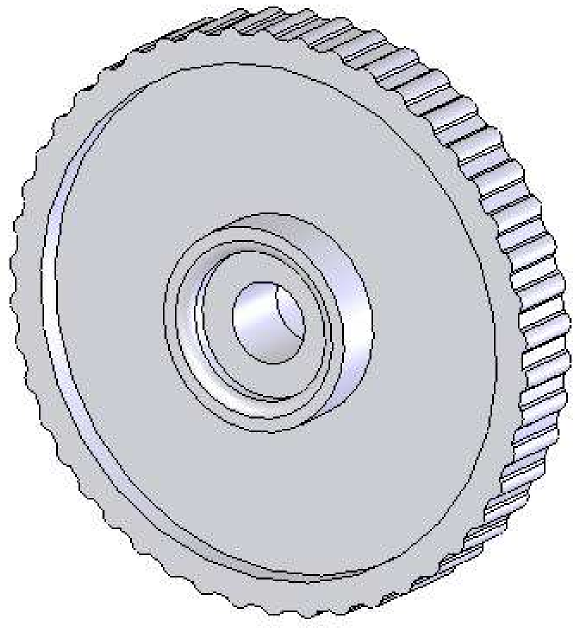


(after)

Figure 4.16: Tuning outer gear before and after modification.

Source: Solidwork software 2006.

Figure 4.15 shows the outer oval cover before and after modification in the redesign 2 of Takada radio. In the previous original design, the outer oval part is attached to the portion of left main cover using rod attachments and adhesive is applied at the backside of the outer oval cover. The rod attachment has very small thickness and can be broken during assembly process. During assembly, outer oval cover is not easy to be aligned and there is resistance for insertion.

By the new design in this redesign 2, outer oval cover is combined to the portion of left main cover. By this combination, the outer oval cover is actually eliminated and this part will be manufactured combined with the left main cover of Takada radio. Therefore, the adhesive operation also eliminated too. By the elimination of two outer oval cover, the assembly time reduced is 7.90 seconds and the assembly cost reduced is RM 0.0110. By adhesive operation elimination, it saves assembly time of 12.00 seconds and saves assembly cost of RM 0.0833.

Figure 4.16 shows tuning outer gear before and after modification in redesign 2 of Takada radio. During tuning outer gear assembly, the screwing operation is needed as subsequent process to secure and fastens the tuning outer gear at the left main cover. In the original design, it is hard to insert screws and performed screwing operation because there is high depth on the tuning circuit gear.

By modification of the tuning outer gear in redesign 2 of Takada radio, low depth is used in the middle of the tuning outer gear so that the screw can be position and inserted easily. Other than that, the edge at the screw insertion place also chamfered so that it is easier to position the screw without obstructed access or restricted vision. This modification in redesign 2 of Takada radio will result in reduction of the assembly time and cost.

Table 4.3 shows Boothroyd Dewhurst DFA worksheet for redesign 2 of the Takada radio. Improvement has been done to the components in the redesign 1 of Takada radio and resulting in redesign 2 of Takada radio. By redesigning the redesign 1 of Takada radio, the total assembly time that has been reduced is 64.45 seconds and the total assembly cost reduced is RM 0.0894.

Table 4.3: Boothroyd Dewhurst DFA worksheet for redesign 2 of radio product.

Part ID. No.	Number of times the operation is carried out consecutively	Manual Handling Code	Manual Handling Time	Insertion Code	Insertion Time	Operation Time	Operation cost	Theoretical Minimum Number of Part	Part Name
1.	1	30	1.95	00	1.50	3.45	0.0048	1	Right main cover
2.	1	30	1.95	00	1.50	3.45	0.0048	1	Right main cover subsystem
3.	1	30	1.95	00	1.50	3.45	0.0048	1	Left main cover
4.	1	20	1.80	00	1.50	3.30	0.0046	1	Upper small cover
5.	1	30	1.95	30	2.00	3.95	0.0055	1	Cassette lid gear
6.	2	-	-	99	12.00	24.00	0.0333	-	Grease operation
7.	5	-	-	97	12.00	60.00	0.0833	-	Adhesive bonding
8.	2	10	1.50	00	1.50	6.00	0.0083	1	Mock speaker
9.	1	20	1.80	11	5.00	6.80	0.0094	1	Left mock speaker cover
10.	1	20	1.80	11	5.00	6.80	0.0094	1	Right mock speaker cover
11.	4	-	-	90	4.00	16.00	0.0222	-	Bending operation
12.	1	30	1.95	30	2.00	3.95	0.0055	1	Tuning silver front cover
13.	1	30	1.95	30	2.00	3.95	0.0055	1	Tuning plastic front cover
14.	2	10	1.50	06	5.50	14.00	0.0194	1	Big speaker
15.	1	30	1.95	11	5.00	6.95	0.0097	1	Left big speaker cover
16.	1	30	1.95	11	5.00	6.95	0.0097	1	Right big speaker cover
17.	1	30	1.95	30	2.00	3.95	0.0055	1	Cassette lid subsystem

18.	1	30	1.95	00	1.50	3.45	0.0048	1	Grey plastic front cover
19.	1	30	1.95	30	2.00	3.95	0.0055	1	White plastic front part
20.	1	20	1.80	30	2.00	3.80	0.0053	1	Silver plastic front cover
21.	1	33	2.51	02	1.50	4.01	0.0056	1	Transparent plastic front cover
22.	1	30	1.95	32	4.00	5.95	0.0083	1	Flexible tuning part
23.	1	33	2.51	30	2.00	4.51	0.0063	1	Flexible tuning part cover
24.	1	35	2.73	51	9.00	11.73	0.0163	1	Lid opening spring
25.	1	30	1.95	00	1.50	3.45	0.0048	1	Button complex part
26.	1	35	2.73	00	1.50	4.23	0.0059	1	Button complex part subsystem
27.	1	30	1.95	06	5.50	7.45	0.0103	1	Middle circuit board
28.	1	30	1.95	01	2.50	4.45	0.0062	1	Volume circuit board
29.	1	30	1.95	00	1.50	3.45	0.0048	0	Volume outer cover
30.	1	10	1.50	00	1.50	3.00	0.0042	1	Double-sided tuning gear
31.	1	30	1.95	02	2.50	4.45	0.0062	1	Tuning supporting part
32.	1	20	1.80	00	1.50	3.30	0.0046	1	Tuning circuit gear
33.	1	10	1.50	00	1.50	3.00	0.0042	1	Tuning outer gear
34.	1	30	1.95	01	2.50	4.45	0.0062	1	Tuning circuit board
35.	1	31	2.25	16	8.00	10.25	0.0142	1	Tuning subsystem
36.	1	30	1.95	00	1.50	3.45	0.0048	0	Tuning outer cover
37.	1	30	1.95	06	5.50	7.45	0.0103	1	Headphone socket
38.	1	20	1.80	06	5.50	7.30	0.0101	1	Headphone socket cover
39.	1	20	1.80	06	5.50	7.30	0.0101	1	AC socket
40.	1	30	1.95	00	1.50	3.45	0.0048	1	Transformer
41.	1	38	3.34	01	2.50	5.84	0.0081	1	Spiral battery spring
42.	1	35	2.73	01	2.50	5.23	0.0073	1	Conical battery spring
43.	1	35	2.73	00	1.50	4.23	0.0059	1	Attached conical battery spring

44.	1	30	1.95	30	2.00	3.95	0.0055	1	Pause button
45.	1	30	1.95	30	2.00	3.95	0.0055	1	Stop button
46.	1	30	1.95	30	2.00	3.95	0.0055	1	Rewind button
47.	1	30	1.95	30	2.00	3.95	0.0055	1	Forward button
48.	1	30	1.95	30	2.00	3.95	0.0055	1	Play button
49.	1	30	1.95	30	2.00	3.95	0.0055	1	Record button
50.	1	30	1.95	30	2.00	3.95	0.0055	1	Battery cover
51.	1	20	1.80	18	9.00	10.80	0.0150	1	Antenna
52.	4	03	1.69	30	2.00	14.76	0.0205	1	Sponge base supporter
53.	7	10	1.50	59	12.00	94.50	0.1313	1	Outer screws
54.	15	11	1.80	39	8.00	147.00	0.2042	1	Circuit screws
55.	2	11	1.80	39	8.00	19.60	0.0272	1	Speaker screws
56.	2	11	1.80	39	8.00	19.60	0.0272	1	Transformer screws
57.	1	11	1.80	49	10.50	12.30	0.0171	1	Tuning outer gear screws
58.	1	11	1.80	49	10.50	12.30	0.0171	1	Big bolt
59.	1	60	4.80	59	12.00	16.80	0.0233	1	Small bolt
TOTAL						**685.39**	**0.9520**	**54**	

Source: Bootyroyd Dewhurst DFA worksheet of radio redesign 2.

4.7.1 Redesign 2 Calculations

Below are the costing assumptions that have been made to find the design efficiency for the redesign 2 of Takada radio. These costing assumptions same as used for the original Takada radio design.

1. Labor cost per month for one labor to produce the product is assumed RM 800.
2. Working day per week for one labor is assumed 5 days.
3. Working hour per day for one labor is assumed 8 hours.
4. Working hour per month for one labor is:
   (4 weeks x 5 days x 8 hours) = 160 hours
5. Labor cost per hour per month for one labor is:
   RM 800 ÷ 160 hours = RM 5.00
6. Labor cost per second for one labor is RM 0.001389

Below are steps of calculation to find the design efficiency for the Redesign 2 Takada radio design:

$$\text{Design Efficiency} = \frac{3 \times Nm}{Tm}$$

$$= \frac{3 \times 54}{685.39}$$

$$= 0.2364$$

$$= 23.6\%$$

From the calculation, the result of design efficiency for the Redesign 2 of Takada radio design has been obtained. The value of design efficiency for the Redesign 2 is 23.6%.

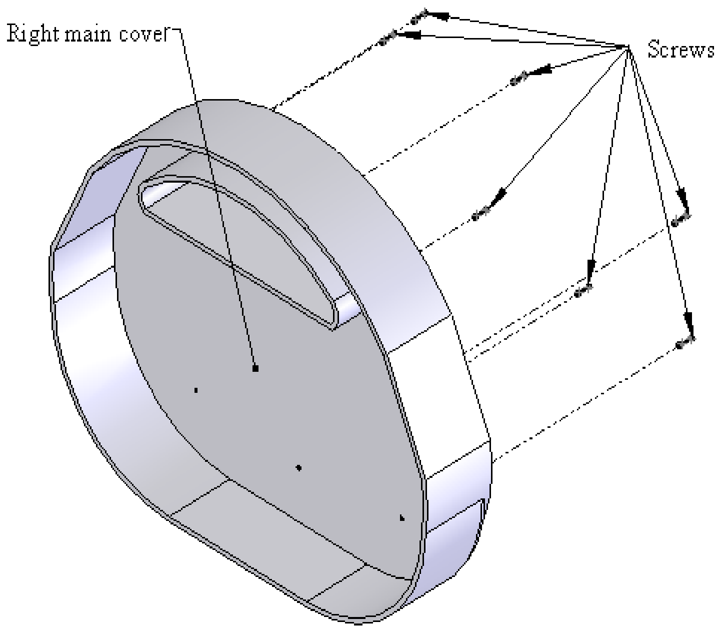
4.8 REDESIGN 3 ANALYSIS

Figure 4.17 shows right main cover before and after modification. In the original design, it needs 7 screws to fasten the right main cover to the left main cover**.** It is not easy to align all the screws before the screwing operation can be done. It is because the place for screw insertion is high in depth. Moreover, it is quite hard to align the right main cover's edge to the left main cover's edge and it takes more time to assemble the two main covers.

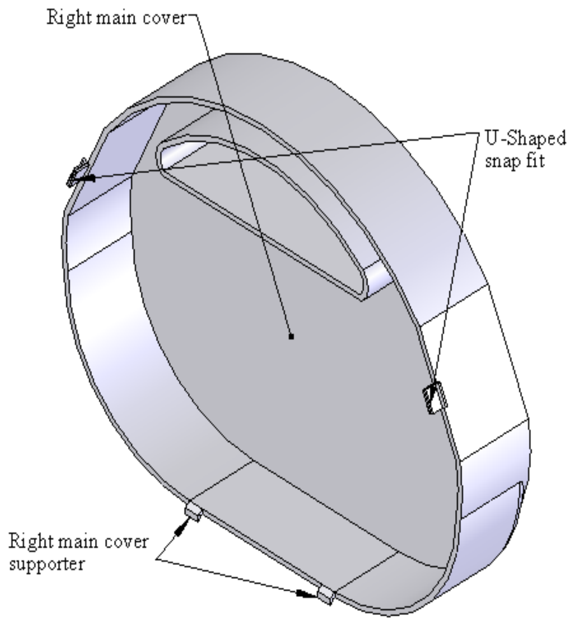
By modification of right main cover in redesign 3, all 7 screws are eliminated. In this new design, two integral fasteners which are U-shaped snap fit used in right main cover. Other than that, two right main cover supporters are designed at the bottom of the right main cover of Takada radio. By this design, it is much easier to assemble the right main cover. It can save assembly time of 108.90 seconds and save assembly cost of RM 0.1513.

Silver plastic front cover in the original design has two rod attachment so that the silver plastic front cover can inserted to its place of insertion. Figure 4.18 shows the silver plastic front cover before and after modification. In the original design, after the silver plastic front cover is inserted to its place, secondary operation is required to secure the silver plastic front cover. The secondary operation is by applying adhesive at the back of silver plastic front cover after orienting the left main cover of Takada radio.

The rod attachment is modified into the snap fit feature. It is easier to assemble the silver plastic front cover using the snap fit features because it is easier to be aligned and inserted to its place. Moreover, snap fit no need the adhesive applying operation to attach it so the adhesive operation is eliminated from the previous design. In this new design, it saves assembly time of 3.80 seconds and saves assembly cost of RM0.00. By elimination of adhesive operation, it saves assembly time of 12.00 seconds and assembly cost of RM 0.0167.



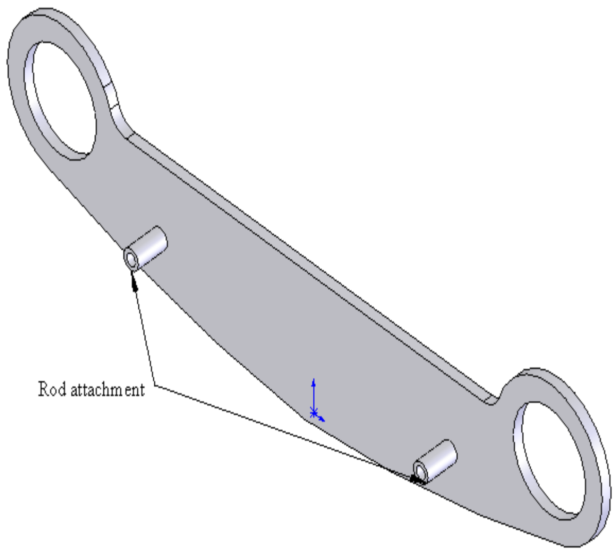
(before)



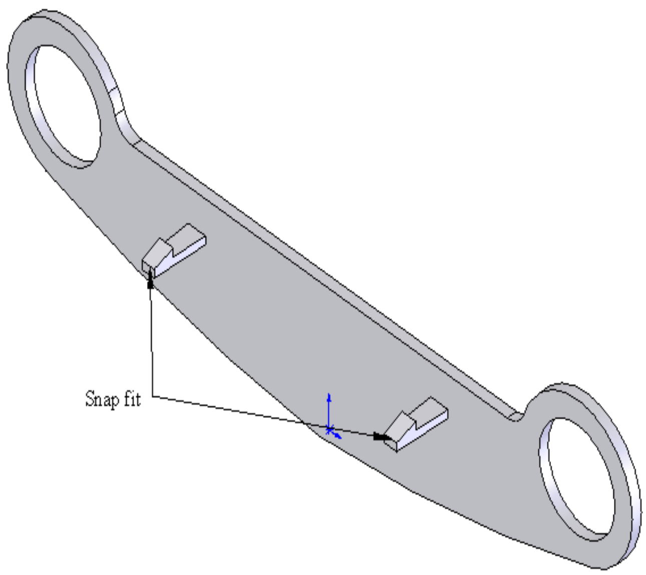
(after)

Figure 4.17: Right main cover before and after modification.

Source: Solidwork software 2006.



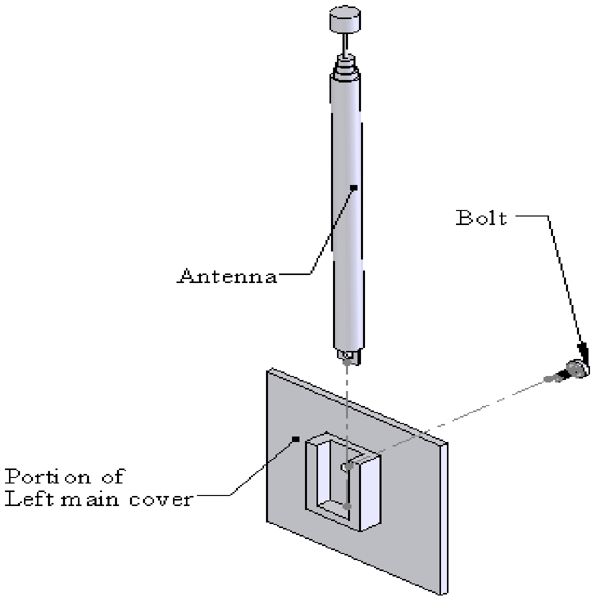
(before)



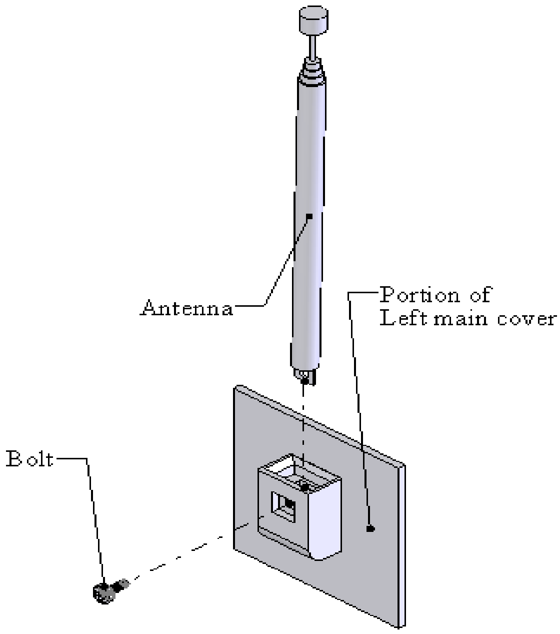
(after)

Figure 4.18: Silver plastic front cover before and after modification.

Source: Solidwork software 2006.



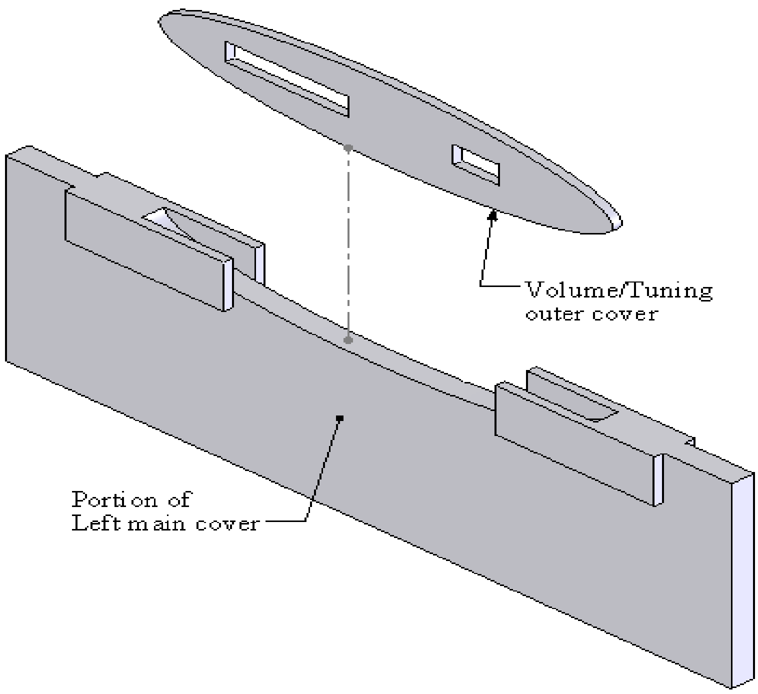
(before)



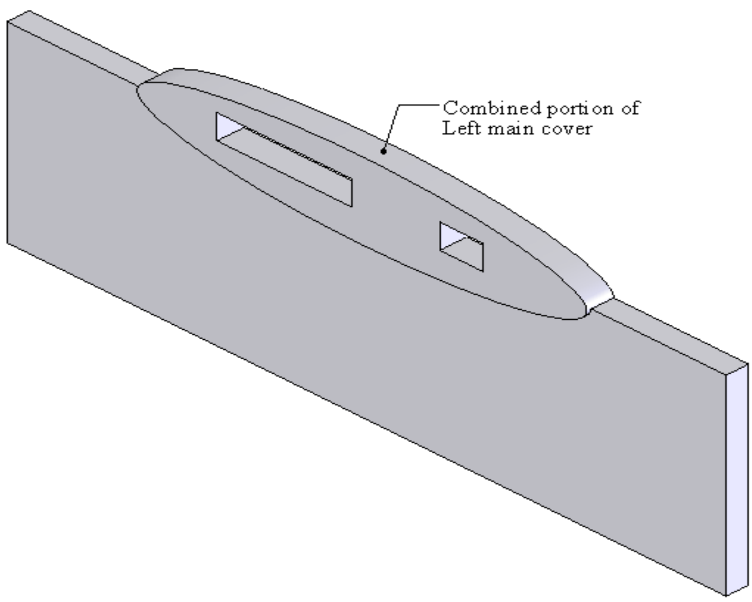
(after)

Figure 4.19: Antenna assembly before and after modification.

Source: Solidwork software 2006.



(before)



(after)

Figure 4.20: Volume/tuning outer cover before and after modification.

Source: Solidwork software 2006.

In the original design of Takada radio, it needs a bolt to fasten an antenna to the portion of right main cover. Figure 4.19 shows the antenna assembly in Takada radio. It is not easy to align the antenna at the portion of right main cover during assembly. The antenna needs for holding down so that it is always in the position. The bolt only can be fasten to antenna when the antenna really at the correct alignment and position. When screwing operation, it quite hard to align the antenna because the design of the portion of right main cover is not proper to support the antenna during screwing operation. There is also restricted vision during screwing operation because the right main cover has to be continuously oriented to check whether the bolt is inserted in the right way or not.

Then, in the redesign 3, the portion of right main cover is redesigned and improved so that the antenna can be aligned easily and no need to hold it down during screwing operation. The direction of the bolt to be inserted also has been changed to avoid the restricted vision during assembly. A suitable depth is designed at the portion of right main cover so that the antenna is not moving during screwing operation. The assembly time is reduced 7.50 seconds and the assembly cost reduced is RM 0.0104.

Figure 4.20 shows the volume or tuning outer cover of Takada radio before and after modification. The volume and tuning outer cover is same in shape and dimensions. In the previous original design, the volume or tuning outer cover is inserted to the portion of left main cover. During assembly, volume or tuning outer cover is not easy to be aligned and need to hold it down sometimes.

By the new design in this redesign 3, volume or tuning outer cover is combined to the portion of left main cover. By this combination, the volume or tuning outer cover is actually eliminated and those parts will be manufactured combined with the left main cover of Takada radio. By this new design, the assembly time reduced is 6.90 seconds and the assembly cost reduced is RM 0.0096.

Table 4.4: Boothroyd Dewhurst DFA worksheet for redesign 3 of radio product.

Part ID. No.	Number of times the operation is carried out consecutively	Manual Handling Code	Manual Handling Time	Insertion Code	Insertion Time	Operation Time	Operation cost	Theoretical Minimum Number of Part	Part Name
1.	1	30	1.95	00	1.50	3.45	0.0048	1	Right main cover
2.	1	30	1.95	00	1.50	3.45	0.0048	1	Right main cover subsystem
3.	1	30	1.95	00	1.50	3.45	0.0048	1	Left main cover
4.	1	20	1.80	00	1.50	3.30	0.0046	1	Upper small cover
5.	1	30	1.95	30	2.00	3.95	0.0055	1	Cassette lid gear
6.	2	-	-	99	12.00	24.00	0.0333	-	Grease operation
7.	4	-	-	97	12.00	48.00	0.0667	-	Adhesive bonding
8.	2	10	1.50	00	1.50	6.00	0.0083	1	Mock speaker
9.	1	20	1.80	11	5.00	6.80	0.0094	1	Left mock speaker cover
10.	1	20	1.80	11	5.00	6.80	0.0094	1	Right mock speaker cover
11.	4	-	-	90	4.00	16.00	0.0222	-	Bending operation
12.	1	30	1.95	30	2.00	3.95	0.0055	1	Tuning silver front cover
13.	1	30	1.95	30	2.00	3.95	0.0055	1	Tuning plastic front cover
14.	2	10	1.50	06	5.50	14.00	0.0194	1	Big speaker
15.	1	30	1.95	11	5.00	6.95	0.0097	1	Left big speaker cover
16.	1	30	1.95	11	5.00	6.95	0.0097	1	Right big speaker cover
17.	1	30	1.95	30	2.00	3.95	0.0055	1	Cassette lid subsystem

18.	1	30	1.95	00	1.50	3.45	0.0048	1	Grey plastic front cover
19.	1	30	1.95	30	2.00	3.95	0.0055	1	White plastic front part
20.	1	20	1.80	30	2.00	3.80	0.0053	1	Silver plastic front cover
21.	1	33	2.51	02	1.50	4.01	0.0056	1	Transparent plastic front cover
22.	1	30	1.95	32	4.00	5.95	0.0083	1	Flexible tuning part
23.	1	33	2.51	30	2.00	4.51	0.0063	1	Flexible tuning part cover
24.	1	35	2.73	51	9.00	11.73	0.0163	1	Lid opening spring
25.	1	30	1.95	00	1.50	3.45	0.0048	1	Button complex part
26.	1	35	2.73	00	1.50	4.23	0.0059	1	Button complex part subsystem
27.	1	30	1.95	06	5.50	7.45	0.0103	1	Middle circuit board
28.	1	30	1.95	01	2.50	4.45	0.0062	1	Volume circuit board
29.	1	10	1.50	00	1.50	3.00	0.0042	1	Double-sided tuning gear
30.	1	30	1.95	02	2.50	4.45	0.0062	1	Tuning supporting part
31.	1	20	1.80	00	1.50	3.30	0.0046	1	Tuning circuit gear
32.	1	10	1.50	00	1.50	3.00	0.0042	1	Tuning outer gear
33.	1	30	1.95	01	2.50	4.45	0.0062	1	Tuning circuit board
34.	1	31	2.25	16	8.00	10.25	0.0142	1	Tuning subsystem
35.	1	30	1.95	06	5.50	7.45	0.0103	1	Headphone socket
36.	1	20	1.80	06	5.50	7.30	0.0101	1	Headphone socket cover
37.	1	20	1.80	06	5.50	7.30	0.0101	1	AC socket
38.	1	30	1.95	00	1.50	3.45	0.0048	1	Transformer
39.	1	38	3.34	01	2.50	5.84	0.0081	1	Spiral battery spring
40.	1	35	2.73	01	2.50	5.23	0.0073	1	Conical battery spring
41.	1	35	2.73	00	1.50	4.23	0.0059	1	Attached conical battery spring
42.	1	30	1.95	30	2.00	3.95	0.0055	1	Pause button
43.	1	30	1.95	30	2.00	3.95	0.0055	1	Stop button

44.	1	30	1.95	30	2.00	3.95	0.0055	1	Rewind button
45.	1	30	1.95	30	2.00	3.95	0.0055	1	Forward button
46.	1	30	1.95	30	2.00	3.95	0.0055	1	Play button
47.	1	30	1.95	30	2.00	3.95	0.0055	1	Record button
48.	1	30	1.95	30	2.00	3.95	0.0055	1	Battery cover
49.	1	20	1.80	00	1.50	3.30	0.0046	1	Antenna
50.	4	03	1.69	30	2.00	14.76	0.0205	1	Sponge base supporter
51.	5	10	1.50	59	12.00	67.50	0.0938	1	Outer screws
52.	16	11	1.80	39	8.00	156.80	0.2178	1	Circuit screws
53.	2	11	1.80	39	8.00	19.60	0.0272	1	Speaker screws
54.	2	11	1.80	39	8.00	19.60	0.0272	1	Transformer screws
55.	1	11	1.80	49	10.50	12.30	0.0171	1	Tuning outer gear screws
56.	1	11	1.80	49	10.50	12.30	0.0171	1	Big bolt
57.	1	60	4.80	59	12.00	16.80	0.0233	1	Small bolt
TOTAL						**641.79**	**0.8914**	**52**	

Source: Bootyroyd Dewhurst DFA worksheet of radio redesign 3.

4.8.1 Redesign 3 Calculations

Below are the costing assumptions that have been made to find the design efficiency for the redesign 3 of Takada radio. These costing assumptions same as used for the original Takada radio design.

1. Labor cost per month for one labor to produce the product is assumed RM 800.
2. Working day per week for one labor is assumed 5 days.
3. Working hour per day for one labor is assumed 8 hours.
4. Working hour per month for one labor is:
   (4 weeks x 5 days x 8 hours) = 160 hours
5. Labor cost per hour per month for one labor is:
   RM 800 ÷ 160 hours = RM 5.00
6. Labor cost per second for one labor is RM 0.001389

Below are steps of calculation to find the design efficiency for the Redesign 3 Takada radio design:

$$\text{Design Efficiency} = \frac{3 \times Nm}{Tm}$$

$$= \frac{3 \times 52}{641.79}$$

$$= 0.2431$$

$$= 24.3\%$$

From the calculation, the result of design efficiency for the Redesign 3 of Takada radio has been obtained. The value of design efficiency for the Redesign 3 is 24.3%.

4.9 ALGOR SOFTWARE ANALYSIS

The reliability of the integral fasteners such as cantilever snap fit, U-shaped snap fit and press fit are tested using simulation. The simulation of those three fasteners is done using ALGOR software. Below is the assumption during this simulation.

1. Force on the integral fasteners is assumed in a range between 0N to 10N and maximum force of 50N.
2. Material used for the integral is assumed to be Acrylonitrile Butadiene Styrene (*ABS) material.*

4.9.1 Cantilever Snap Fit

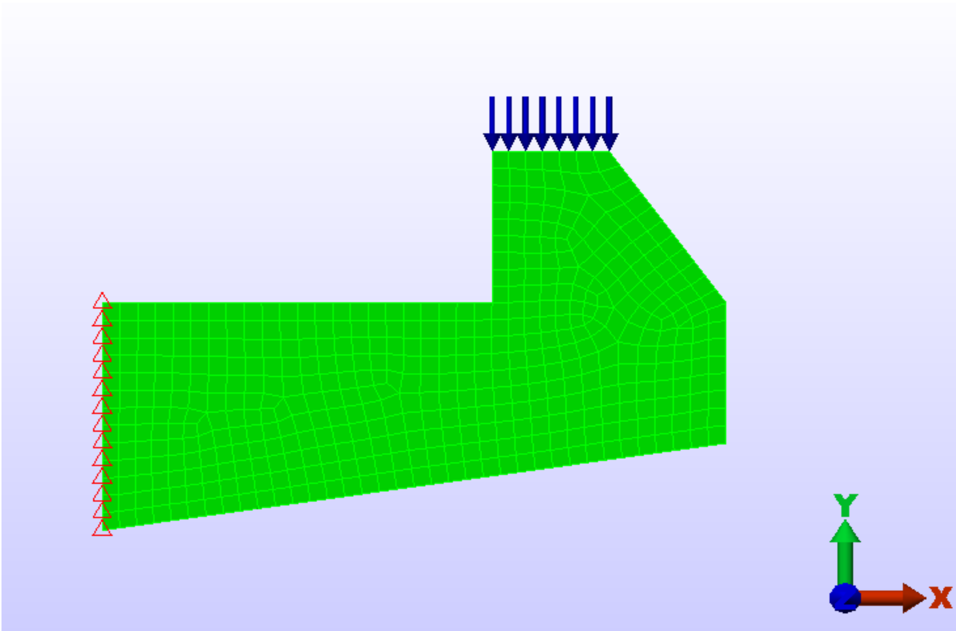


Figure 4.21: Cantilever snap fit with force loading direction.

Source: ALGOR software 2008

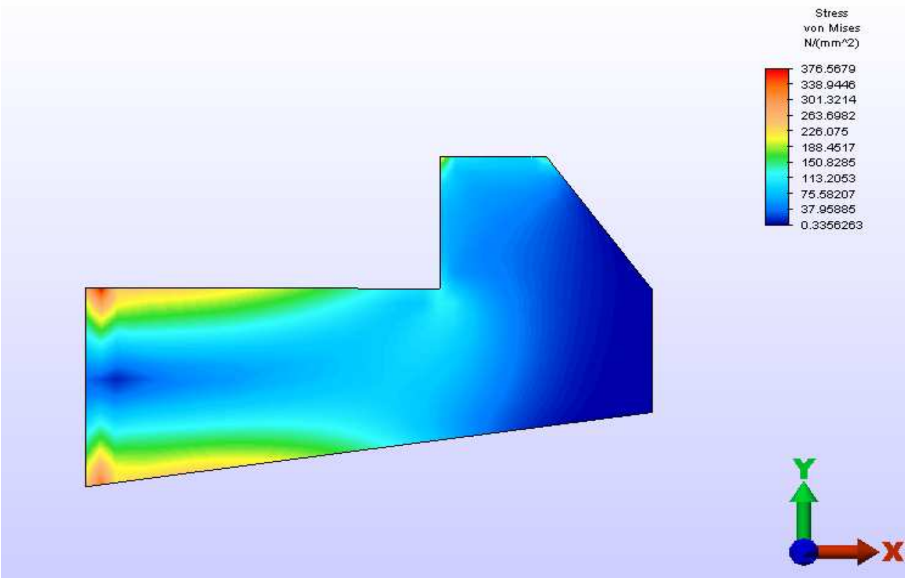


Figure 4.22: Cantilever snap fit with force 2N.

Source: ALGOR software 2008

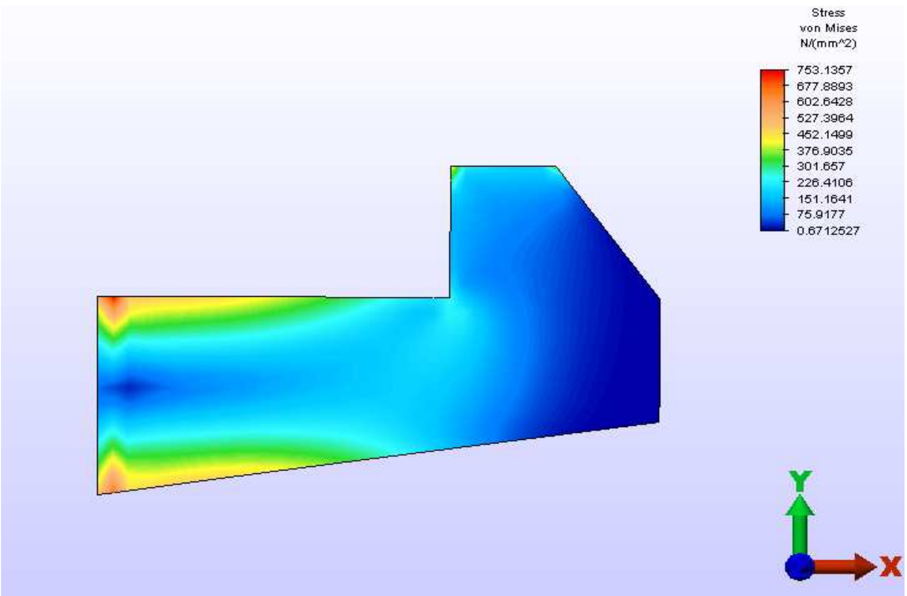


Figure 4.23: Cantilever snap fit with force 4N.

Source: ALGOR software 2008

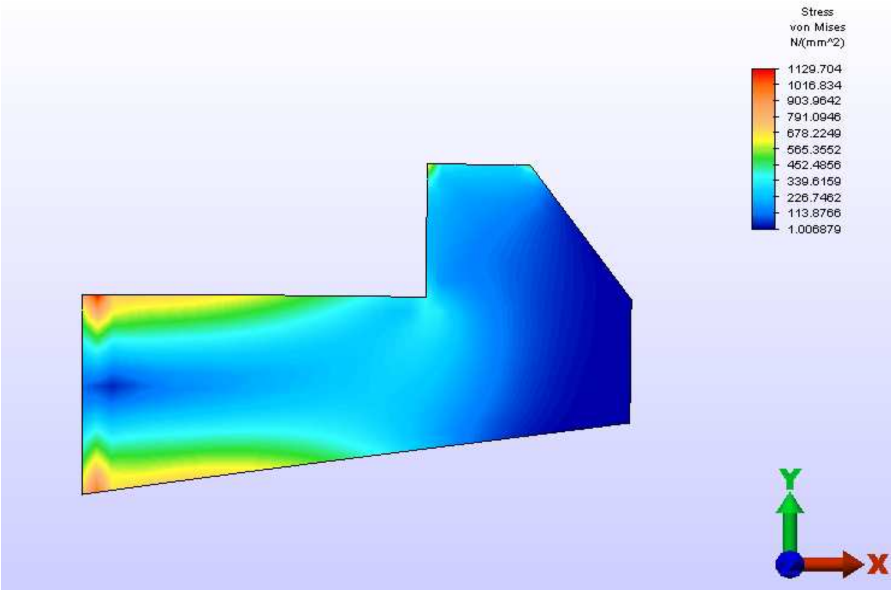


Figure 4.24: Cantilever snap fit with force 6N.

Source: ALGOR software 2008

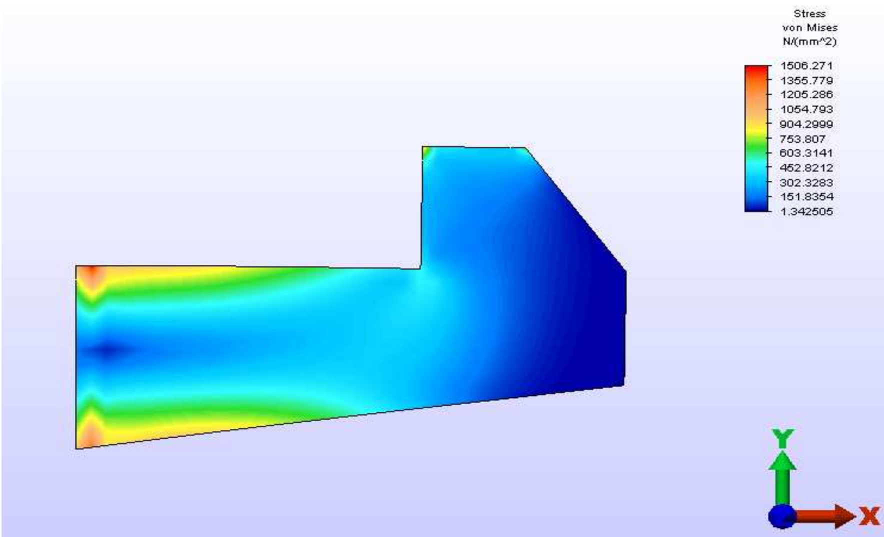


Figure 4.25: Cantilever snap fit with force 8N.

Source: ALGOR software 2008

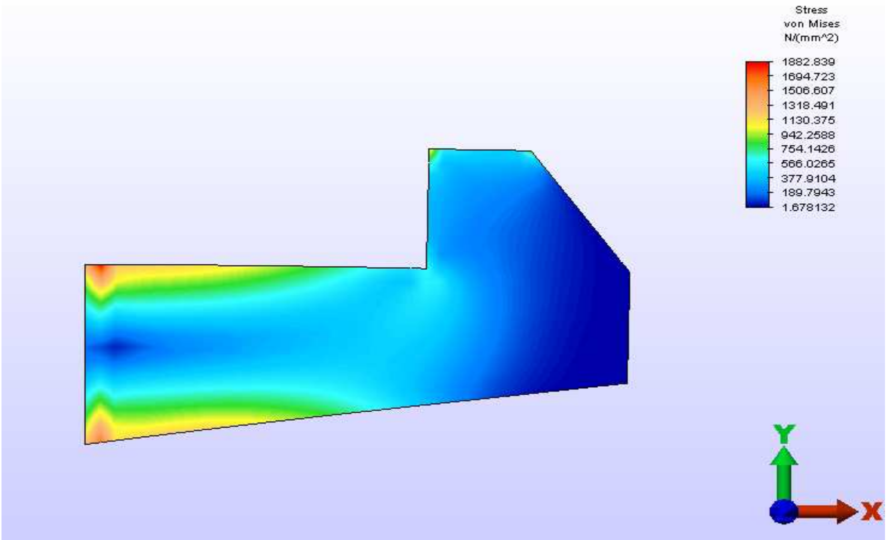


Figure 4.26: Cantilever snap fit with force 10N.

Source: ALGOR software 2008

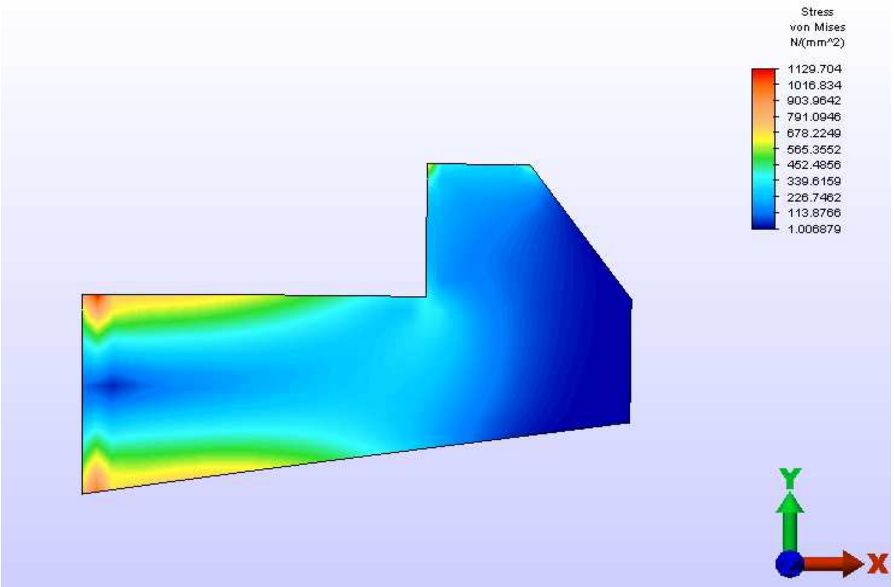


Figure 4.27: Cantilever snap fit with maximum force 50N.

Source: ALGOR software 2008

4.9.2 U-Shaped Snap Fit

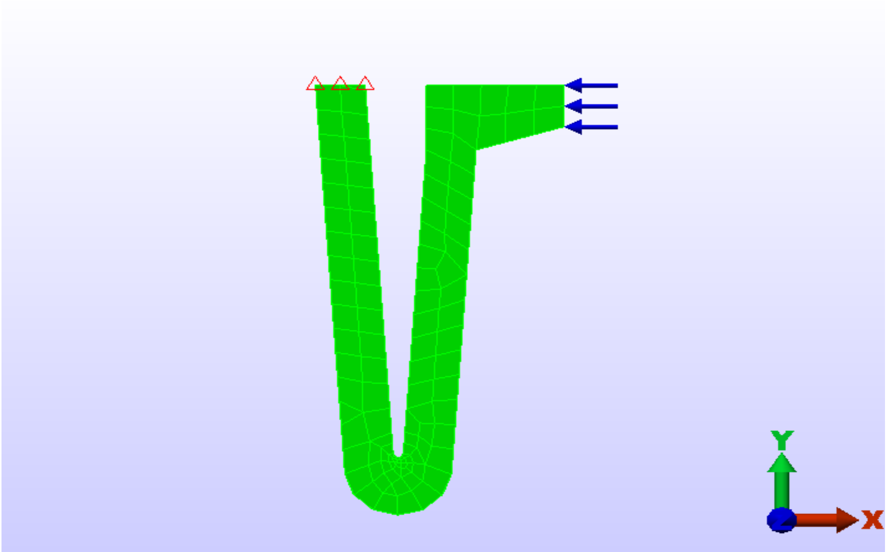


Figure 4.28: U-shaped snap fit with force loading direction.

Source: ALGOR software 2008

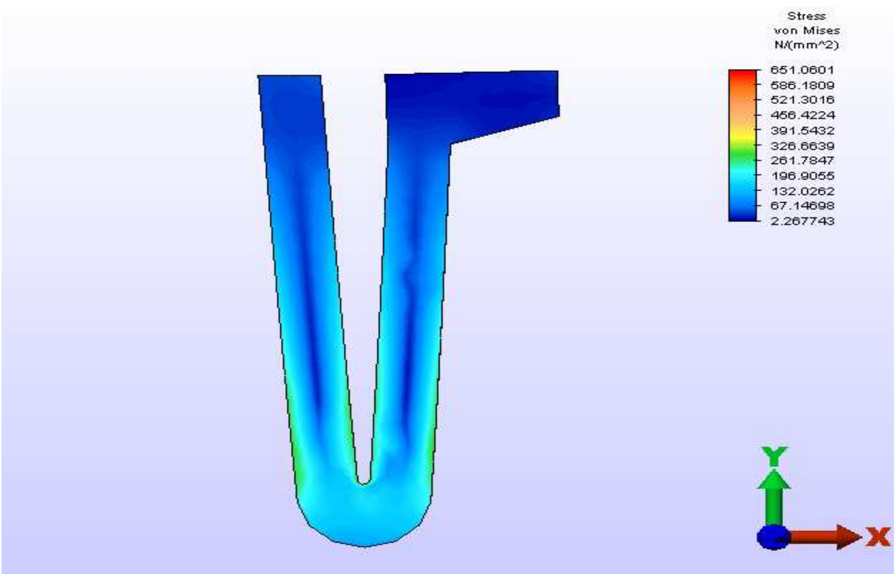


Figure 4.29: U-shaped snap fit with force 2N.

Source: ALGOR software 2008

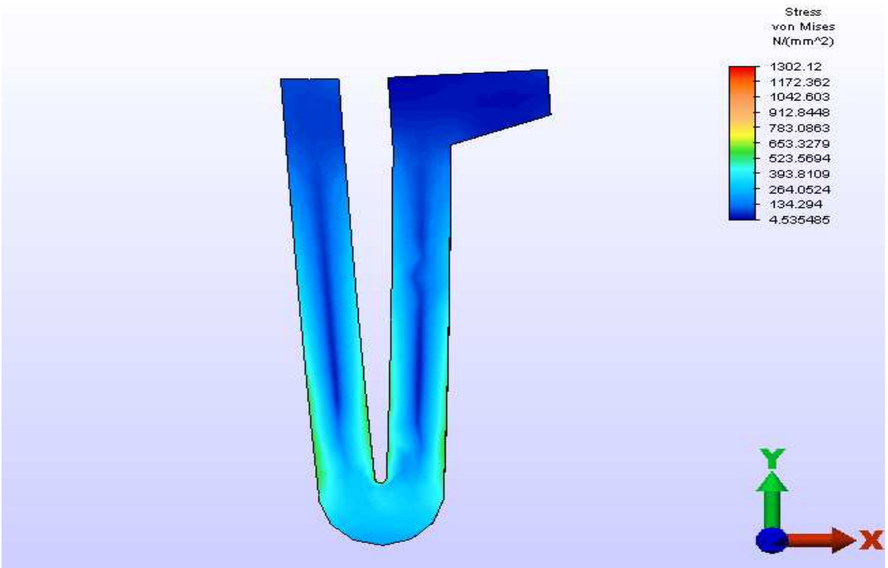


Figure 4.30: U-shaped snap fit with force 4N.

Source: ALGOR software 2008

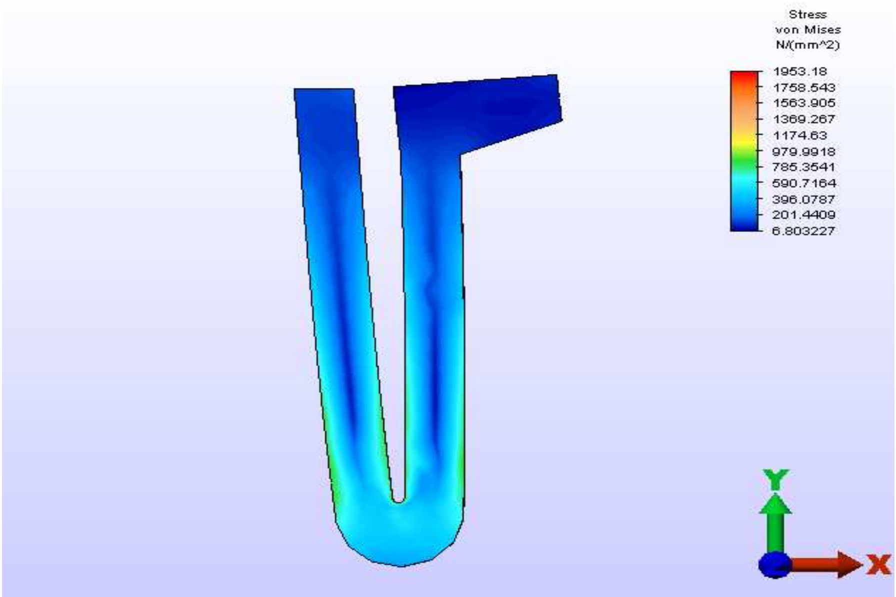


Figure 4.31: U-shaped snap fit with force 6N.

Source: ALGOR software 2008

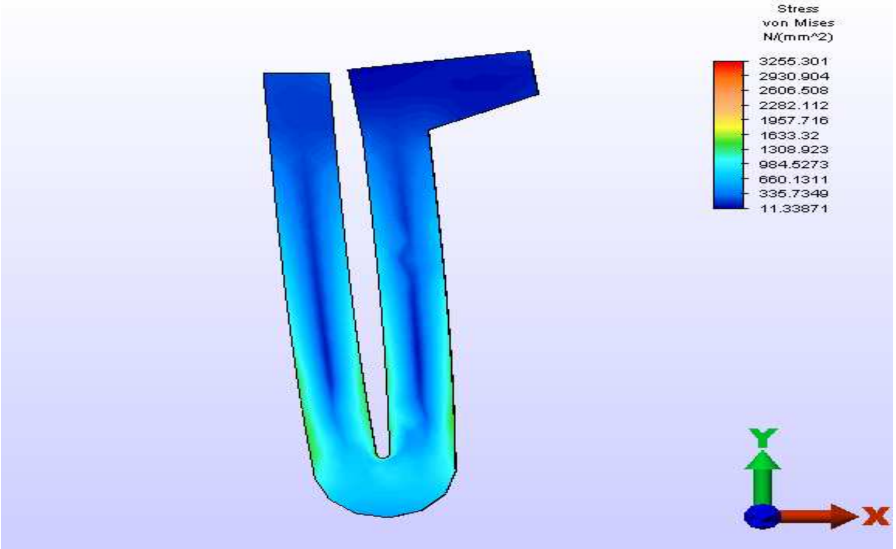


Figure 4.32: U-shaped snap fit with force 8N.

Source: ALGOR software 2008

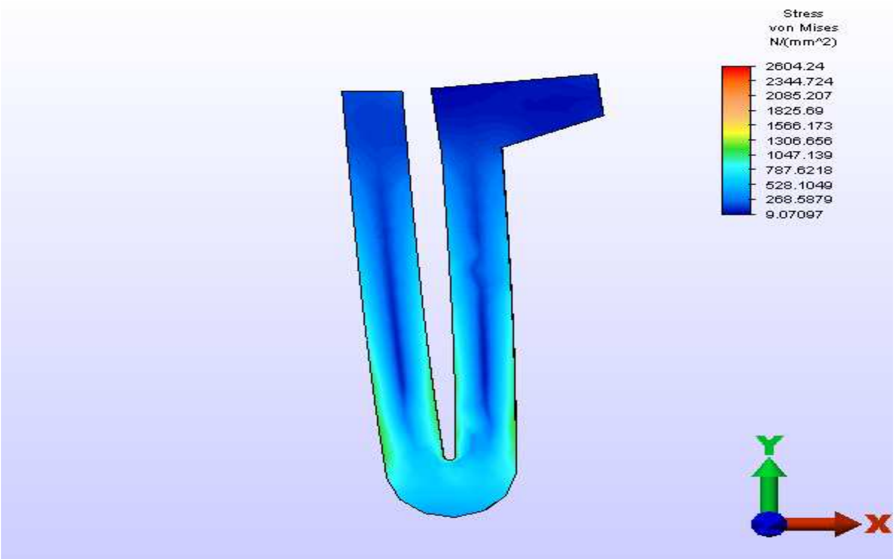


Figure 4.33: U-shaped snap fit with force 10N.

Source: ALGOR software 2008

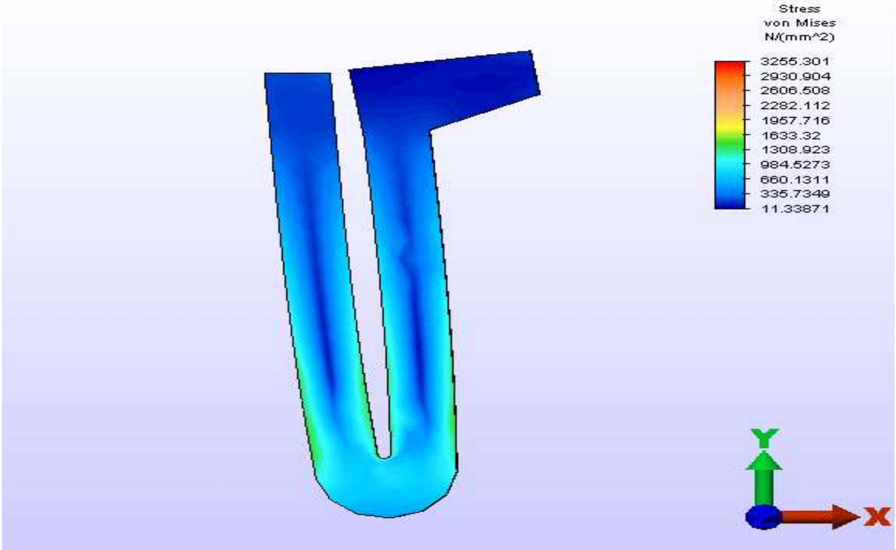


Figure 4.34: U-shaped snap fit with maximum force 50N.

Source: ALGOR software 2008

4.9.3 Press Fit

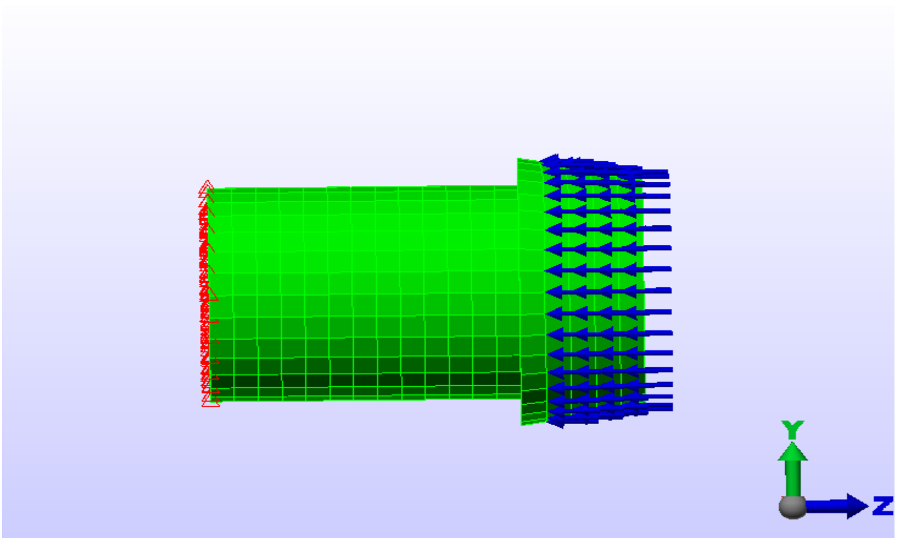


Figure 4.35: Press fit with force loading direction.

Source: ALGOR software 2008

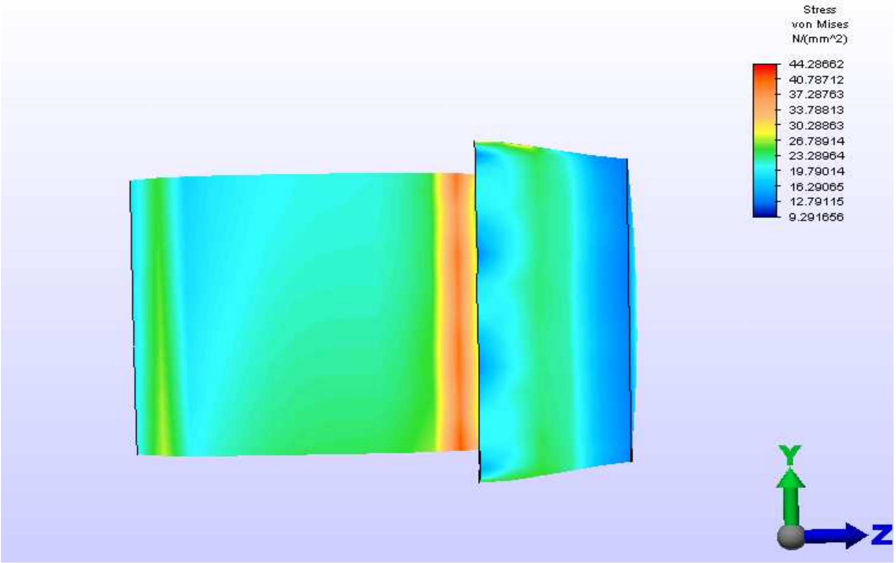


Figure 4.36: Press fit with force 2N.

Source: ALGOR software 2008

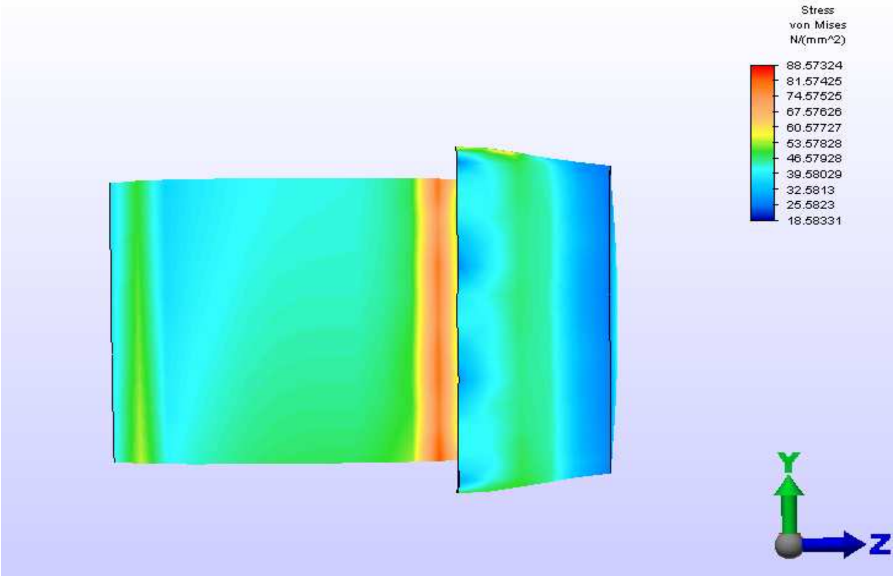


Figure 4.37: Press fit with force 4N.

Source: ALGOR software 2008

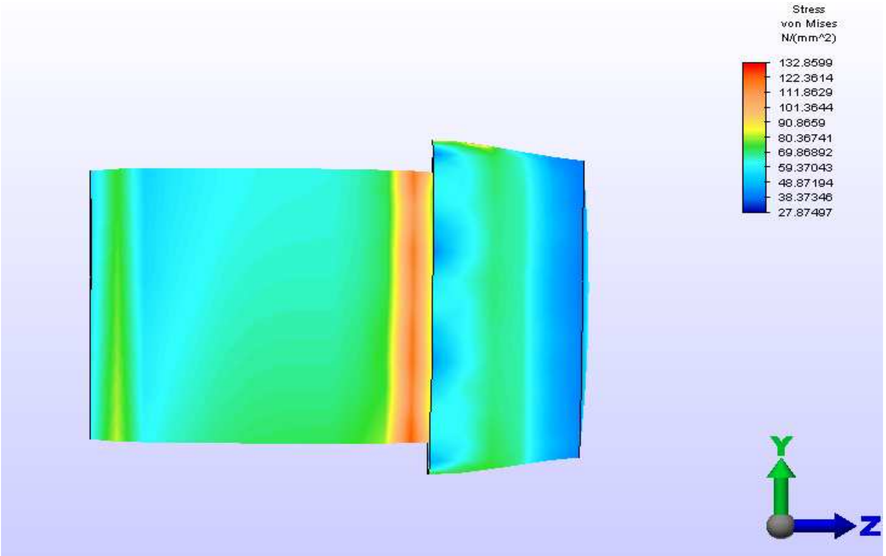


Figure 4.38: Press fit with force 6N.

Source: ALGOR software 2008

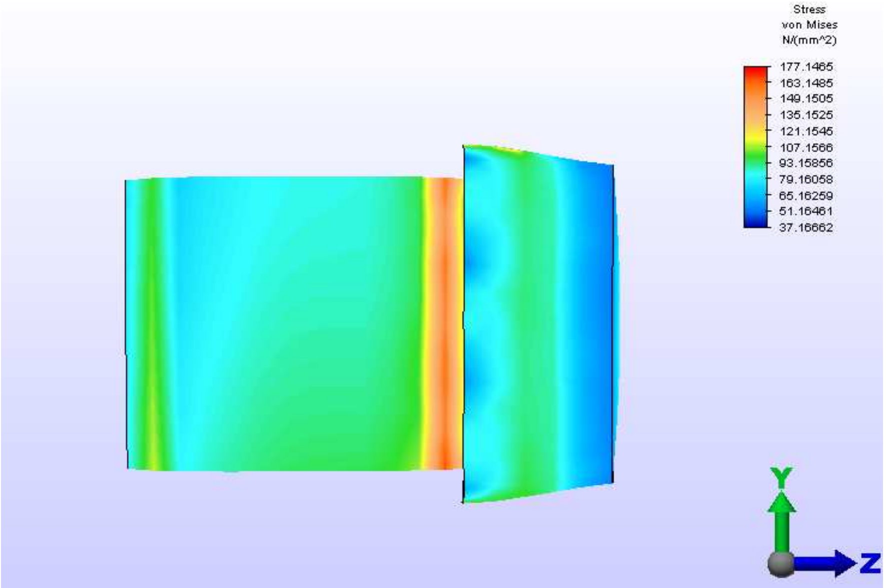


Figure 4.39: Press fit with force 8N.

Source: ALGOR software 2008

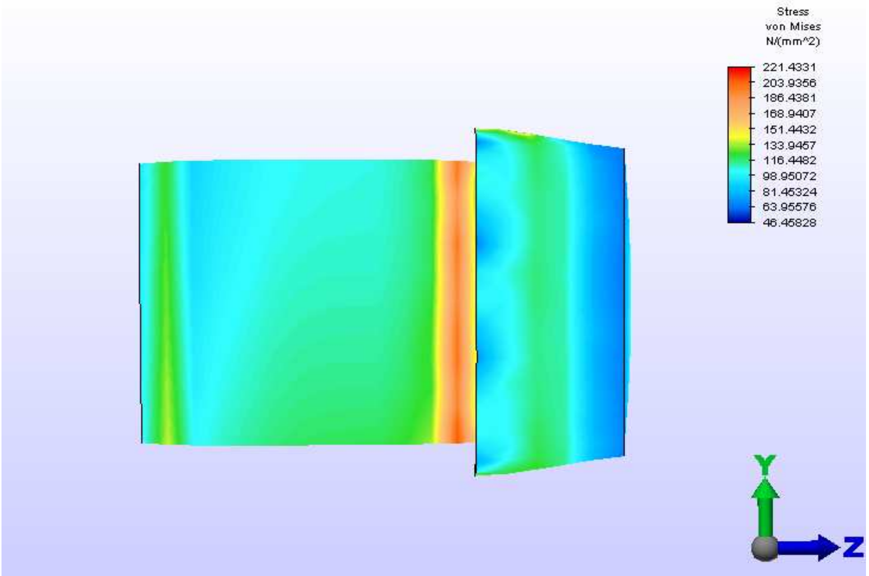


Figure 4.40: Press fit with force 10N.

Source: ALGOR software 2008

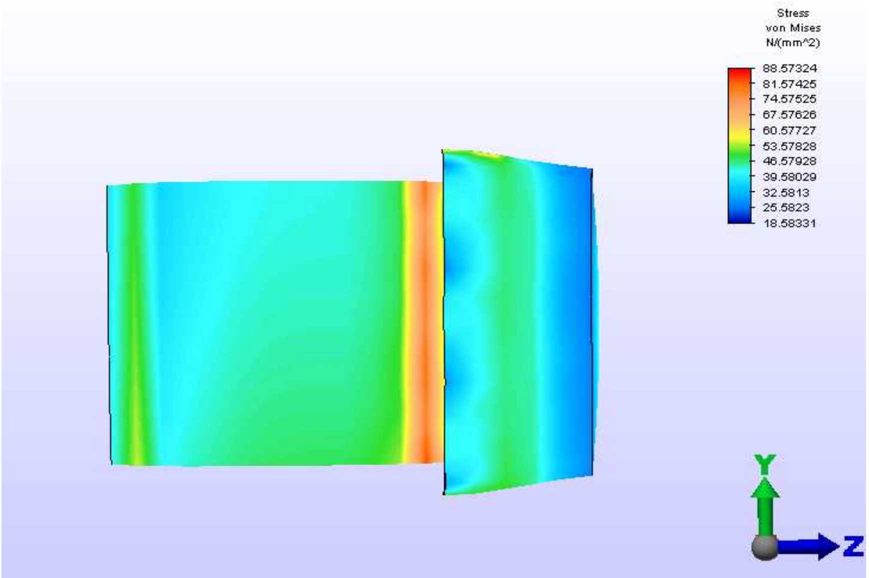


Figure 4.41: Press fit with maximum force 50N.

Source: ALGOR software 2008

4.10 TOTAL RESULT

Table 4.5: Total result of all radio design.

Design	Number of different components	Total Assembly time (second)	Total Assembly cost (RM)	Design efficiency (%)
Original Design	58	850.84	1.1818	20.5%
Redesign 1	56	749.84	1.0415	22.4%
Redesign 2	54	685.39	0.9520	23.6%
Redesign 3	52	641.79	0.8914	24.3%

4.11 SUMMARY

After performing the ALGOR analysis, the result from the ALGOR software shows that the cantilever snap fit, U-shaped snap fit and press fit will not break or failure when the range of force between 0N to 10N and the maximum force of 50N is acted. This range of force is applicable for those three types of integral fasteners. This force will act on the fasteners where the fasteners are attached to the components.

From Boothroyd Dewhurst DFA analysis, original design and each redesign of Takada radio is evaluated in term of assembly efficiency. All related data to the Boothroyd Dewhurst DFA analysis of the Takada radio original design and redesign are stated in the Boothroyd Dewhurst DFA worksheet. All total result for all design is shown in Table 4.5. After the full analysis of Boothroyd Dewhurst is completed, it is chose that the redesign 3 of Takada radio is the best design compare to redesign 1 and 2 of Takada radio.

After many improvements in term of assembly efficiency on the design of Takada radio starting from original design, redesign 1 and 2. For redesign 3 of Takada radio, the total assembly time is 641.79 seconds and the total assembly cost is RM 0.8914. The design efficiency for redesign 3 of Takada radio is 0.2431 or 24.3%. This percentage of design efficiency is the highest among the all design of Takada radio.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter summarized the conclusion and recommendations for the overall objective of the project based on Boothroyd Dewhurst DFA analysis and ALGOR software analysis.

5.2 CONCLUSIONS

From the analysis conducted, several conclusions can be drawn as follows:

1. Takada radio is selected as a product to be analyzed in this project.
2. Survey about Takada radio is conducted by distributing questionnaire to the university students and manufacturing company workers.
3. Original design of Takada radio is analyzed and result for assembly efficiency is obtained by Boothroyd Dewhurst DFA method.
4. Redesign of Takada radio is produced using Solidwork software.
5. Redesign of Takada radio is analyzed and result for assembly efficiency is obtained by Boothroyd Dewhurst DFA method.
6. ALGOR software analysis is performed on the integral fasteners that have been used in the three redesign of Takada radio.
7. The best redesign which is redesign 3 of Takada radio is chosen.

5.3 RECOMMENDATIONS

For further research, the Boothroyd Dewhurts DFM analysis can be conducted on Takada radio. By combination of the DFM and DFA analysis in the further research, it will result to the DFMA analysis. The DFMA analysis can give result based on assembly efficiency and manufacturing efficiency. By DFMA analysis, a fully analysis of the Takada radio from design stage into to the manufacturing stage can be performed effectively.

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APPENDIX A

SAMPLE OF QUESTIONNAIRE

FACULTY OF MECHANICAL ENGINEERING, UMP

A survey of a mechanical student from the Faculty of Mechanical Engineering for the final year project regarding on redesigning of a Takada radio using Boothroyd Dewhurst DFMA methods. Please tick the appropriate answer.

Figure: Takada radio.

1. How frequently you use radio?

   Often ☐ Seldom ☐ Never ☐

2. Is the price of radio should be lower than the current market price?

   Yes ☐ No ☐ If 'yes', state the price:

3. Radio must be redesigned so that it can be safely when used?

   Yes ☐ No ☐

4. Is the current radio parts are too complicated?

   Yes ☐ No ☐

5. Do you think that the radio easier when assembled?

   Yes ☐ No ☐

6. Is the radio easier when disassembled?

   Yes ☐ No ☐

7. Do you think that the radio parts are easier to be handled and inserted to the appropriate place?

   Yes ☐ No ☐

Thank You for your co-operation.

APPENDIX B1

GANTTCHART OF FYP 1

No.	Activities	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Project Progress																
1.	Obtain FYP title	Planning															
		Actual															
2.	Setting appointment with the supervisor	Planning															
		Actual															
3.	Searching journals and reference books	Planning															
		Actual															
4.	Select one product for improvement	Planning															
		Actual															
5.	Learn Boothroyd Dewhurst Software	Planning															
		Actual															
6.	Presentation preparation	Planning															
		Actual															
7.	Submission of Draft 1 with logbook	Planning															
		Actual															
8.	FYP 1 presentation	Planning															
		Actual															

ing to complete work　　Actual completed work

APPENDIX B2

GANTTCHART OF FYP 1

No.	Activities	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Thesis writing progress																
1.	Chapter 1: Introduction	Planning															
		Actual															
2.	Chapter 2: Literature review	Planning															
		Actual															
3.	Chapter 3: Methodology	Planning															
		Actual															
4.	Chapter 4: Conclusion	Planning															
		Actual															
5.	Finalyzing thesis writing as Draft 1	Planning															
		Actual															

ning to complete work   Actual completed work

APPENDIX C1

GANTTCHART OF FYP 2

No.	Activities	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Project Progress																
1.	Redesign radio using Solidwork software	Planning															
		Actual															
2.	Fill up Boothroyd-Dewhurst DFA worksheet for all design.	Planning															
		Actual															
3.	Analyze using ALGOR software	Planning															
		Actual															
4.	Obtained full results.	Planning															
		Actual															
5.	Presentation preparation.	Planning															
		Actual															
6.	Submission of final draft with logbook.	Planning															
		Actual															
7.	FYP 2 presentation.	Planning															
		Actual															
8.	Submission of thesis for binding	Planning															
		Actual															

Planning to complete work   Actual completed work

APPENDIX C2

GANTTCHART OF FYP 2

No.	Activities	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Thesis writing progress																
1.	Chapter 4: Results and Discussions	Planning															
		Actual															
2.	Chapter 5: Conclusions and Recommendations	Planning															
		Actual															
3.	Final draft completion	Planning															
		Actual															
4.	Correction of final draft	Planning															
		Actual															
5.	Finalyzing thesis for binding	Planning															
		Actual															

Planning to complete work   Actual completed work

APPENDIX D1

FLOWCHART OF CASSETTE LID SUBSYSTEM

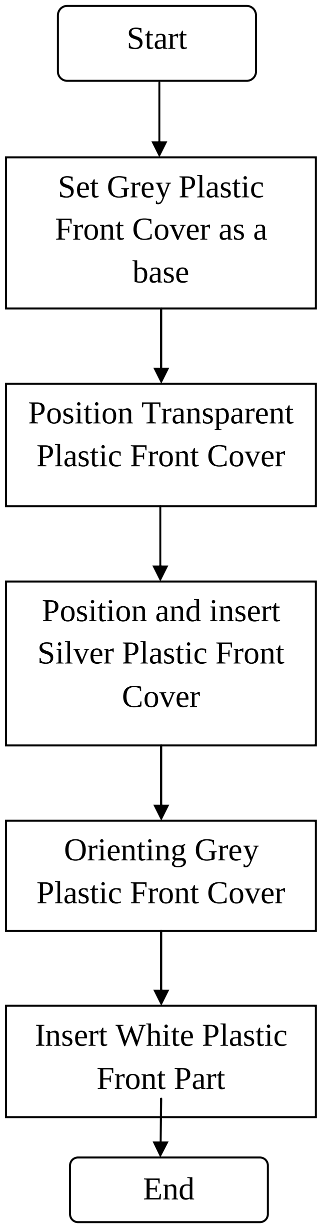


Figure D1: Flowchart of Cassette lid subsystem

APPENDIX D2

FLOWCHART OF TUNING SUBSYSTEM

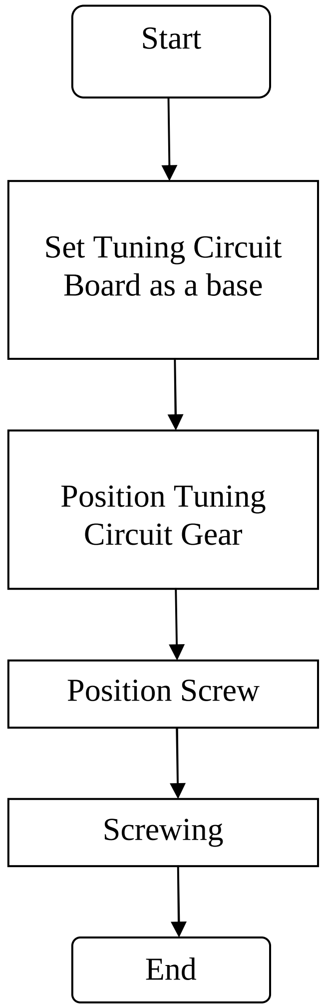


Figure D2: Flowchart of Tuning subsystem

APPENDIX D3

FLOWCHART OF BUTTON COMPLEX PART SUBSYSTEM

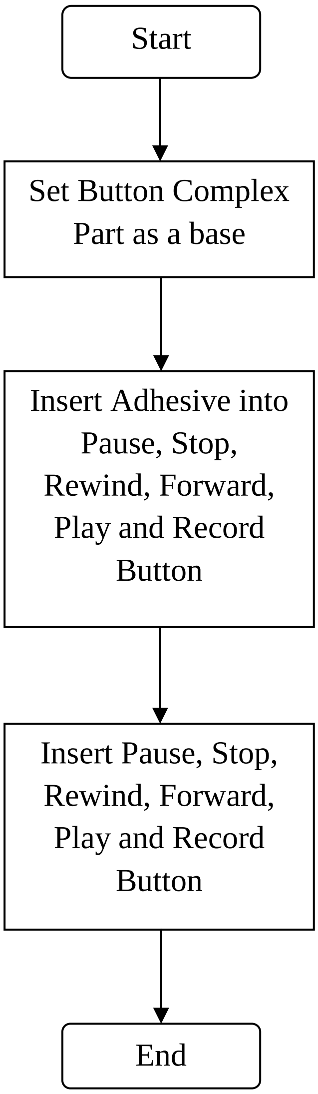
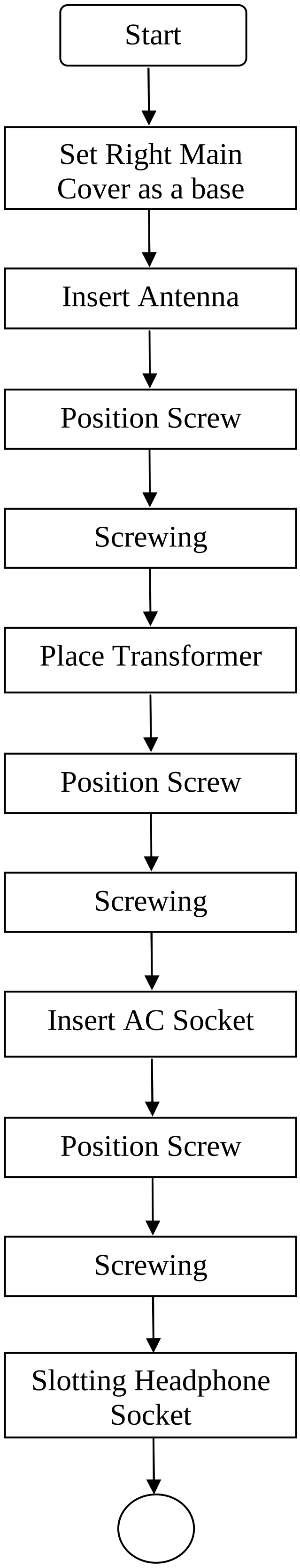


Figure D3: Flowchart of Button Complex Part Subsystem

APPENDIX D4

FLOWCHART OF RIGHT MAIN COVER SUBSYSTEM



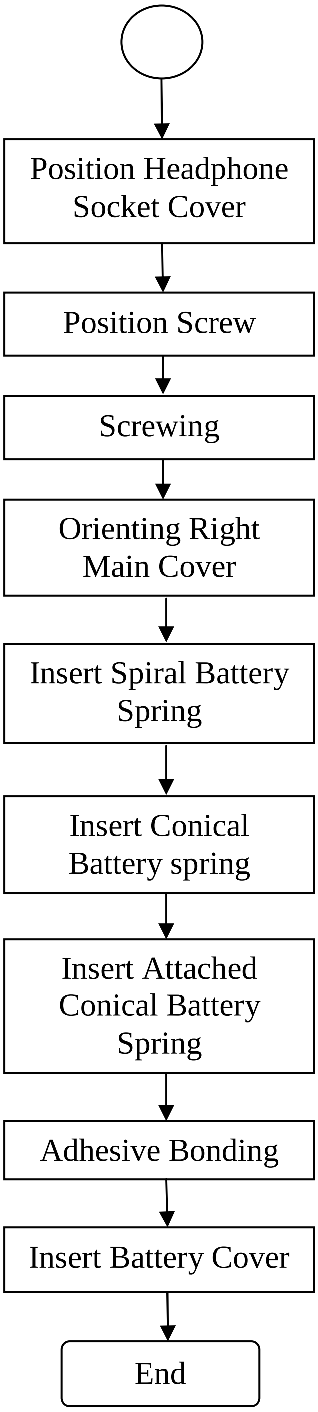
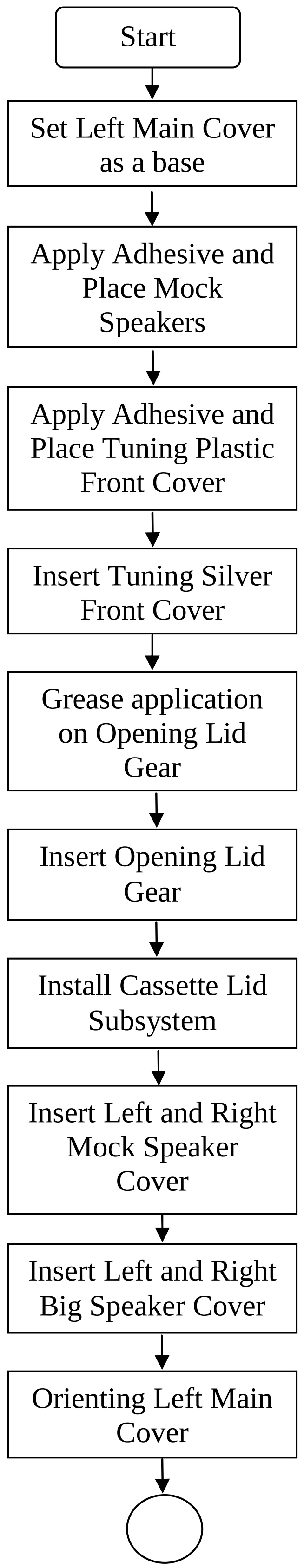
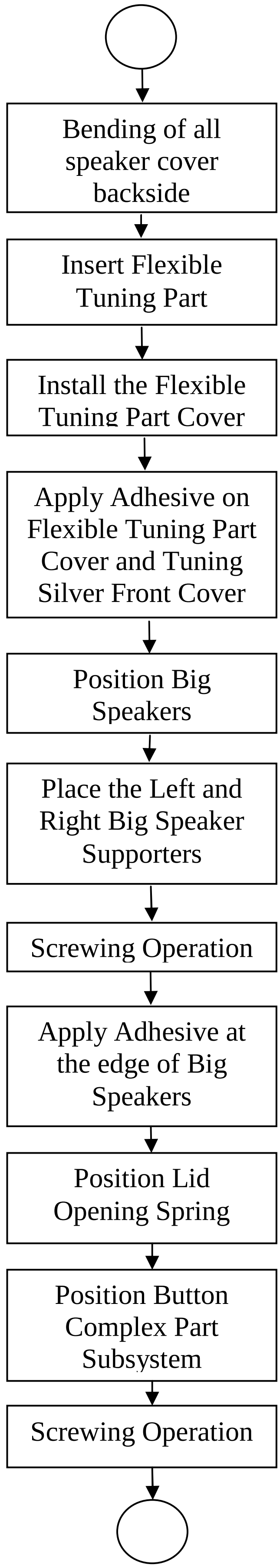


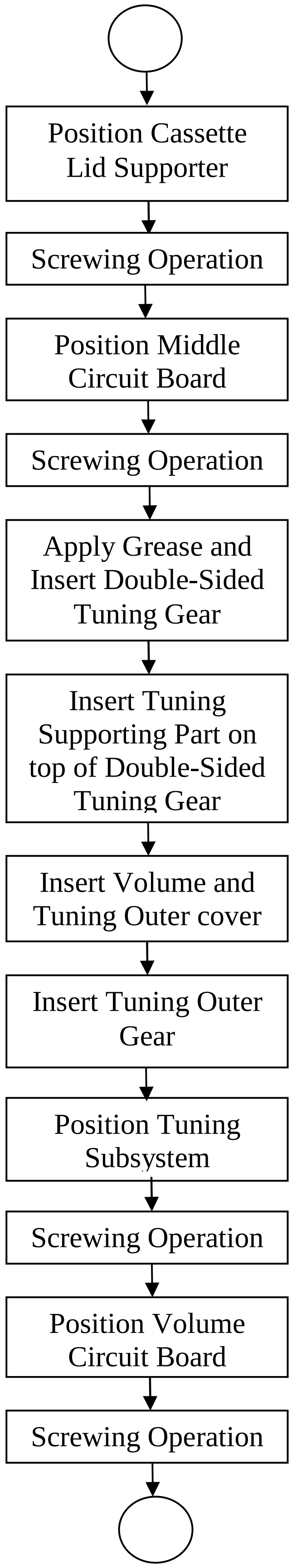
Figure D4: Flowchart of Right main cover subsystem

APPENDIX D5

FLOWCHART OF MAIN ASSEMBLY OF TAKADA RADIO




Bending of all speaker cover backside
Insert Flexible Tuning Part
Install the Flexible Tuning Part Cover
Apply Adhesive on Flexible Tuning Part Cover and Tuning Silver Front Cover
Position Big Speakers
Place the Left and Right Big Speaker Supporters
Screwing Operation
Apply Adhesive at the edge of Big Speakers
Position Lid Opening Spring
Position Button Complex Part Subsystem
Screwing Operation


Position Cassette Lid Supporter
Screwing Operation
Position Middle Circuit Board
Screwing Operation
Apply Grease and Insert Double-Sided Tuning Gear
Insert Tuning Supporting Part on top of Double-Sided Tuning Gear
Insert Volume and Tuning Outer cover
Insert Tuning Outer Gear
Position Tuning Subsystem
Screwing Operation
Position Volume Circuit Board
Screwing Operation

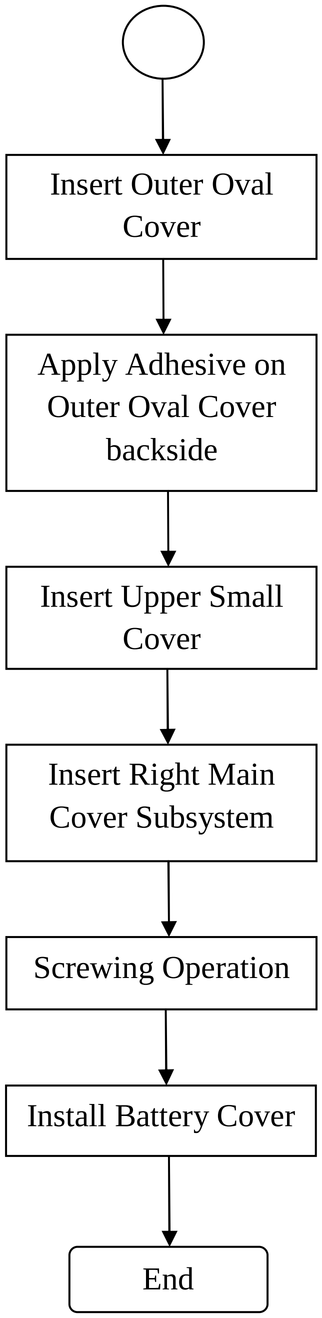


Figure D5: Flowchart of main assembly of Takada radio