DESIGN A LOW COST HAIR DRYER USING DFMA ANALYSIS

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This report is submitted in fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering (Design and Innovation)

Faculty of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "Design a Low Cost Hair Dryer Using DFMA Analysis" is the result of my own work except as cited in the references.

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design and Innovation).

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DEDICATION

To my beloved mother and father

ABSTRACT

The aim of this project is to design a low cost hairdryer using Design for Manufacturing and Assembly (DFMA). DFMA is an analysis method that consists of two parts, i.e. Design for Manufacturing (DFM) and Design for Assembly (DFA). DFMA analysis is a systematic philosophy that can be applied at the early stage of design. It can helps designers to reduce the number of part count of a product. By applying DFMA in design stage, the design efficiency of a product can increase. In another words, the design of a product can be more efficient. Applying DFMA analysis in the product designing process can also reduce the total number of part count of a product. Hence, the total assembly time and the total manufacturing cost of a product can be reduced. In this project, two different brands of hairdryer Khind and Elba are selected to be analysed using DFMA. The DFA index of Khind and Elba are found to be 0.1059 and 0.1757 respectively. The product with higher DFA index is chosen for modification and improvement in order to achieve an even higher DFA index. Some improvements have been made to Elba hairdryer. For example, the fastening method of the hairdryer had changed from screw fastening to snap-fit fastening method. The design efficiency of the hairdryer increase from 0.1757 to 0.3003. The objective of the project has achieved.

ABSTRAK

Tujuan projek ini adalah untuk mereka bentuk pengering rambut yang berkos rendah menggunakan ***Design for Manufacturing and Assembly (DFMA).*** *DFMA adalah satu kaedah analisis yang terdiri daripada dua bahagian, iaitu Design for Manufacturing (DFM) dan Design for Assembly (DFA). Analisis DFMA adalah falsafah yang sistematik yang boleh digunakan pada peringkat awal reka bentuk. Ia boleh membantu pereka untuk mengurangkan jumlah bahagian dalam sesuatu produk. Dengan menggunakan DFMA dalam peringkat reka bentuk, kecekapan reka bentuk produk boleh ditingkatkan. Dalam erti kata yang lain, reka bentuk produk boleh menjadi lebih cekap. Menggunakan analisis DFMA dalam proses mereka bentuk produk juga boleh mengurangkan jumlah bahagian dalam produk. Oleh itu, jumlah masa pemasangan dan jumlah kos pengeluaran produk boleh dikurangkan. Dalam projek ini, dua pengering rambut yang berbeza jenama, Khind dan Elba telah dipilih untuk dianalisis menggunakan DFMA. DFA indeks Khind dan Elba didapati adalah 0.1059 dan 0.1757. Produk yang mempunyai indeks DFA yang lebih tinggi dipilih untuk pengubahsuaian dan penambahbaikan bagi mencapai indeks DFA yang lebih tinggi. Beberapa penambahbaikan telah dibuat untuk pengering rambut Elba. Sebagai contoh, kaedah penyambungan pengering rambut telah diubah daripada penyambungan skru kepada snap-fit. Kecekapan reka bentuk pengering rambut meningkat dari 0.1757 ke 0.3003. Objektif projek ini telah dicapai.*

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This project consumed huge amount of work, research and dedication. Still, implementation would not be possible if I did not have support from many individuals and lecturers. Therefore, I would like to extend our sincere gratitude to all of them.

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Furthermore, I would also like to express my gratitude to my second examiner, Dr. Mohd Nizam bin Sudin as he had made valuable comments and suggestions on this project which gave me inspirations to improve my report.

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LIST OF ABBREVIATION

3D	3-dimensional
AEM	Assembly Evaluation Method
BDI	Boothroyd Dewhurst, Inc.
CAD	Computer Aided Design
DFA	Design for Assembly
DFE	Design for Environment
DFM	Design for Manufacture
DFMA	Design for Manufacture and Assembly
DFR	Design for Reliability
DFS	Design for Serviceability
FDM	Fused Deposition Modelling
HSM	High Speed Machining
IDA	Institute of Defense Analyse
QFD	Quality Function Development
R&D	Research and Development
SPF	Superplastic Forming
UK	United Kingdom

LIST OF SYMBOLS

E	Assemblability evaluation score ratio
E_{ma}	Design efficiency of the design
K	Assembly cost ratio
N_{min}	Theoretical minimum number of parts
t_a	Basic assembly time for one part
t_{ma}	Estimated time to complete the assembly of the whole product

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Design for Manufacture and Assembly (DFMA) is a fusion of Design for Manufacture (DFM) and Design for Assembly (DFA). The word "manufacture" in this extend represents the fabrication of the individual component or part of a product; whereas the word "assembly" represents the addition or joining process of a few components to form a complete product. DFM has a long history. It dates back to the early 18th century when a Frenchman named LeBlanc concocted the concept of substitutable parts in the manufacturing of muskets which formerly were individually handmade. DFM is a development practice that emphasise on manufacturing issues throughout product development process (Karl et al., 2000). In another word, it is a practice that ease the manufacturing process of the assemblage of components that will become a final product after assembly. Without sacrificing the quality of the product, a successful DFM can results in lower production cost. It involves application of part-forming models such as basic rules, analytic formulas, complex process finite element process simulations (Kevin et al., 2003).

Similarly, the concept of DFA is not new. In the late 20th century, an American professor, Geoff Boothroyd developed the DFA method. DFA aims to make assembly directions and methods simpler. It is used to estimate the manual assembly time and assembly cost of the product on an automatic assembly machine (Boothroyd et al., 1980). The decrement of the number of separate components in a product is the most important factor in reducing the assembly cost. Therefore, some simple criteria were introduced by

Boothroyd in order to ease the combination and elimination of unnecessary parts in a product. These criteria are significantly important for performing a successful DFA analysis.

In this era of globalisation, DFMA is used in concurrent engineering studies to provide solutions to the designers in reducing manufacturing time and assembly cost as well as to quantify improvements. It can also be used as a bench marking tool to study competitors' products and as a "should-cost tool" to assist in supplier negotiations (Boothroyd et al., 2002). Products designed using DFMA analysis will have better quality, reliability and durability compared to traditionally designed products. It reduces the transition time from design phase to the production phase by making the transition process is as smooth and fast as possible. There are many principles of DFMA that can be applied in mechanism design in order to reduce the manufacturing time and assembly cost, for example, by minimising the number of surfaces, eliminating interfaces, optimising the manufacturing process and etcetera. Figure 1.1 shows the definition of Design for Manufacture and Assembly (DFMA).

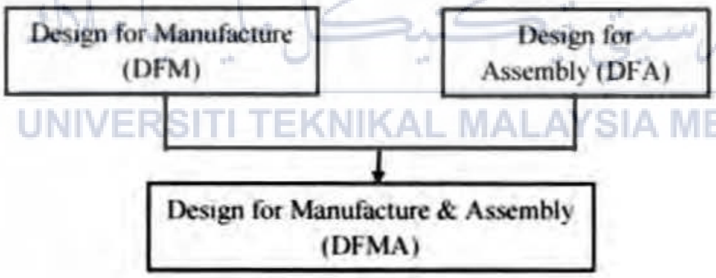


Figure 1.1: Definition of Design for Manufacture and Assembly (DFMA)

The objective of this project is to optimise the designs of two different brands of hairdryers. The new hairdryer proposed after optimisation should have higher quality, lesser number of parts and lower manufacturing costs. Therefore, DFMA analysis is the most suitable method that can be used to improve the design of the products chosen. This project focuses on the optimisation of the hairdryer design, comparisons of design efficiencies for existing and new design and etcetera. DFMA, DFM and DFA analysis will be discussed in the following chapters. All 3D drawings for existing and new designs will be included in this project.

1.2 PROBLEM STATEMENT

Contrary to the past, the designs of hairdryers nowadays tend to be more and more complex. The complexity of the hairdryers had led to a higher manufacturing cost and assembly time. Most of the hairdryers available in the market serve the same function, though, most of them are over-designed. Manufacturing industries in this era of globalisation mainly focus on mass production concept. All products are required to be manufactured in large quantity and short time. The manufacturing cost and assembly time for over-designed products will be unnecessarily high and long. In this case, over-design products disobey the mass production concept. Therefore, analysis using DFMA principle need to be done during the product design stage in order to produce a competitively priced, high performance product at a minimal cost and time.

1.3 OBJECTIVES

The objectives of this project are as follows:

i. To analyse the design efficiency and to make comparisons between two different brands of low cost hairdryer.

ii. To suggest improvement for a new hairdryer design.

1.4 SCOPE OF PROJECT

The scopes of this project are:

i. Two selected hairdryers will be dismantled, each and every parts of the hairdryers will be drawn using 3D drawing software.

ii. Comparisons on the design efficiency of both the hairdryers will be done using DFMA analysis.

iii. Improvements for a new hairdryer design will be proposed, 3D drawing of the new designed hairdryer will be produced.

iv. Only two hairdryers are selected for comparison in this project due to limited time and cost.

CHAPTER 2

LITERATURE REVIEW

This chapter describes Design for Manufacture and Assembly (DFMA), Design for Assembly (DFA) and Design for Manufacture (DFM) in detail. The history of DFA, DFM and DFMA as well as types of evaluation method are discussed. Several case studies are also reviewed in this chapter.

2.1 Design for Manufacture and Assembly (DFMA)

Before 1940's, Ford and Chrysler had applied DFM analysis in the innovation and manufacturing process of weapons as well as tanks (Xie, 2003). At the beginning of 1970's, Dr. Geoffrey Boothroyd and Dr. Peter Dewhurst did a research on the new DFMA philosophy for product design optimisation and then in 1982, Boothroyd Dewhurst, Inc. (BDI) was founded (Boothroyd et al., 2002). "DFMA" is a trademark of Boothroyd Dewhurst, Inc. (BDI).

DFM is a method that can be used to reduce manufacturing cost of a product by optimising the materials and manufacturing processes. DFA is a method that is used to reduce the assembly cost of a product by reducing the labour assembly time of the product and at the same time, reduce the complexity of the product. Often, DFM and DFA methods are used together to achieve effective results in optimising the design of a product. This combination of DFM and DFA is known as Design for Manufacture and Assembly (DFMA) method. DFMA method aims to minimise the production cost of a product by reducing the number of part count and by utilising the use of manufacturing processes. It is a systematic method that can be used to analyse a design from the aspect of assembly time and manufacturing processes. The product engineers should apply the DFMA analysis at the early stage of product design process. By doing so, all the factors that will affect the final output while fabricating the product can be considered as early as possible. Extra time spent in the early stage of design will be lesser than the time spent in the redesign process of the product. By this means, costs such as material cost, redesign cost, replacement of tooling cost and etcetera can be reduced.

To perform DFMA analysis, the first step is to analyse the existing product with DFA method. This step aims to simplify the product by reducing the total number of separate parts of the product. Boothroyd-Dewhurst DFMA criteria can be used as a guidance by the designers in minimising the number of parts. This criteria will be discussed in detailed in the section below. After applying The DFA analysis to the existing product, the total assembly time and cost need to be calculated before the second step is carried out. This is to make sure that possible savings can be taken into account when reconsidering for redesign. After DFA analysis, DFM analysis needs to be done. DFM estimates the cost of the manufactured parts to quantify the design improvements effects suggested by the inceptive DFA analysis (Boothroyd et al., 2002). During DFM analysis, the best-suit machining process and material that can be used for that particular components are considered. Then, a reliable and realistic estimation of piece part cost can be obtained. Figure 2.1 illustrated the classic steps taken in DFMA analysis using DFMA software.

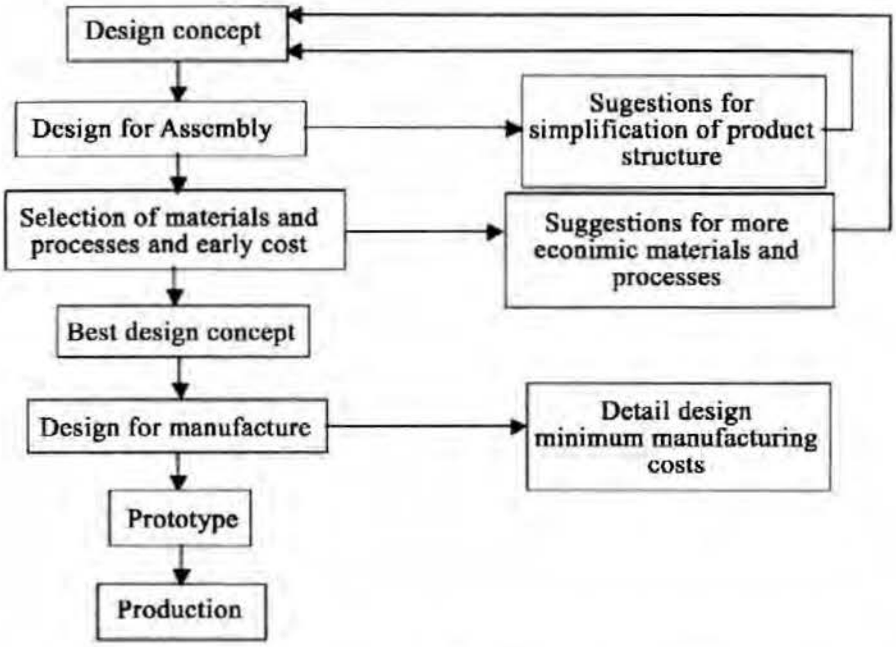


Figure 2.1: Typical steps taken in DFMA analysis using DFMA software

2.1.1 Product Design Process

Product design process is a transformation process that converts customers' needs into a product that satisfies their needs. A good design normally undergone a series of sophisticated product design process. It is the key to success of many best-selling products. Product design process can be classified into two categories: the traditional product design process and concurrent engineering.

2.1.1.1 The Traditional Linear Design Process

The traditional linear design process also known as serial engineering. It is a linear design approach in which each discipline performs its own work and then pass the results to the next discipline in a serial chain. There are no or have very less interactions between the disciplines. Traditional linear design process can also be known as "over-the-wall" design. This "over-the-wall" design separates design process and manufacturing process. This separation makes the manufacturing engineers struggle with the problems created by the designers (Boothroyd et al., 2002). This serial chain involves three main processes: ideation process, refinement process and implementation. In ideation process, problem is identified, preliminary ideas are generated using a few methods such as brainstorming, and then the preliminary design is evaluated. In refinement process, idea generated and evaluated in the ideation process are refined using modelling, design analysis and design visualisation method. Then, after all the refinement process are done, the design can be implemented. Lastly, the new developed design can be documented. Figure 2.2 illustrates the traditional linear design process.

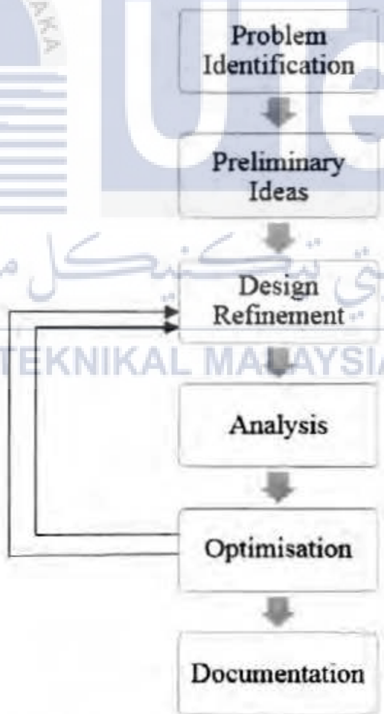


Figure 2.2: Traditional linear design process

2.1.1.2 Concurrent Design Process

Concurrent engineering is a methodology that perform task concurrently. In another words, it performs work based on the parallelisation of tasks. Youssefi (2013) stated that "concurrent design process involves the coordination of technical and non-technical functions of design and manufacturing within a business". In 1988, the definition of concurrent engineering was first introduced by the institute of defense analyse (IDA) (Winner et al., 1988). Similar with traditional linear design process, concurrent engineering also involves the same processes, which are, ideation process, refinement process, and implementation process. Ideation process consists of problem identification, preliminary idea and preliminary design. Refinement process consists of modelling, design analysis and design visualisation. Servicing, financing, marketing, producing, planning and documenting are categorised under implementation process. The difference between traditional linear design process and concurrent design process is that concurrent design process involves the interaction of all the three main processes. Figure 2.3 shows the concurrent design process.

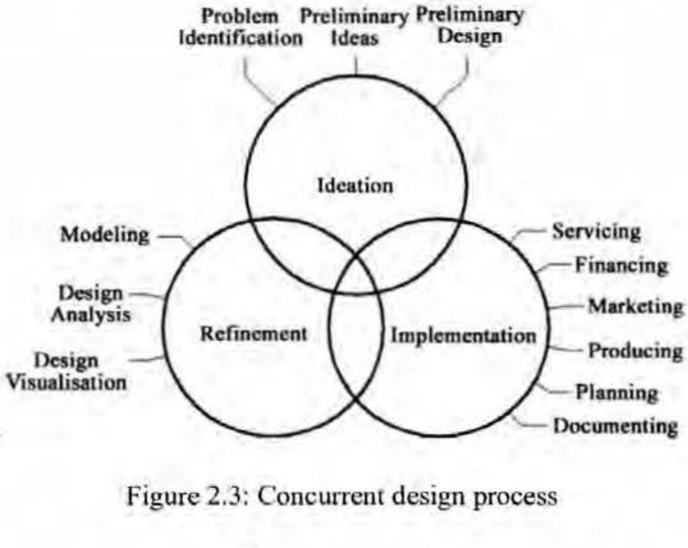


Figure 2.3: Concurrent design process

A few practices are developed from concurrent engineering, for example, DFM, DFA, Design for Serviceability (DFS), Design for Reliability (DFR) and Design for Environment (DFE). In this era of globalisation, in order to compete with companies world-wide, all the companies must produce a product at minimum cost, greatest possible quality and least lead time starting from conceptual design stage to final production, service as well as disposal stage (Youssefi, 2013).

2.1.2 DFMA Case Studies

When minimisation of part count, time of assembly and simplification of product are desired, DFMA philosophy can be used. Domestic Companies such as Allied-Signal, Motorola, Hughes Aircraft, and Mc Donnell Douglas Corporation have already implemented the DFMA philosophy throughout their product lines (Herrera, 1997). This shows that DFMA philosophy plays an important role in helping the companies to be the leading world-class competitors. In the case of Longbow Apache Helicopter, DFMA philosophy are done in two different stages: when new design requirement is established, and when optimisation is required for existing design. In the first stage, designers develop a simple design that has a minimum number of parts according to the Boothroyd-Dewhurst DFMA criteria. In the second stage, designers redesign new assemblies in order to perform design optimisation process to ease the manufacturing and installation process. This two stages will indirectly reduce the production cost and increase customers' satisfaction towards the product. The AH64D helicopter designed by Longbow Apache Helicopter has implemented DFMA philosophy in the design process. By using High

Speed Machining (HSM), a primary tool used by DFMA process in the airframe structural design area, the number of parts of the helicopter has reduced. This is mainly because HSM can produce complex geometrical parts (originally need to be fastened or welded) as one single part. In this case, complex assemblies or subassemblies can be transformed into a simple part. Thus, the assembly process can be simplified. Besides HSM, another DFMA primary tool, superplastic forming (SPF) also helps Longbow Apache Helicopter to reduce part cost, fabrication cost and assembly time. Herrera (1997), "SPF is a process that blows hot air against a sheet metal and over a tool inside an oven in order to shape the metal into part's configuration". By using SPF, complex part can be simplified by combining different complex parts into single simple part. SPF in DFMA analysis has already proven to be a savings tools by McDonnell Douglas Corporation in the military and commercial divisions. The part count in the military divisions reduced from 1744 to 1048. Significant savings in cost, weight and assembly time are also reported.

A case study of DFMA on a military test set was done by Joseph and James from Hughes Aircraft Company. A TOW military launcher test set is designed to simulate all missile functions of the family of TOW missile systems to ascertain their combat readiness through automatic testing. However, the original TOW missile test set was found to be too bulky and expensive. Therefore, Hughes Aircraft Company decided to form a DFMA team to optimise the design of the existing TOW missile test set by reducing the number of parts of the test set. Besides that, Hughes Aircraft Company hoped that the implementation of DFMA analysis in this redesign process can help them to reduce the production cost of the test set. The company gave the DFMA team members sufficient training in the principles of DFMA so that the team members can have a deeper insight on how DFMA should be implemented. During the DFMA analysis, design deficiencies were identified, alternative approaches were generated using brainstorming method. Then, all the alternative approaches were evaluated and newly developed preliminary design was identified. DFMA analysis was used to estimate the assembly and manufacturing cost of the new design. From the DFMA results, it was found that the newly developed TOW missile tester has lighter weight, with wider testing capability and more flexible usage at significantly reduced production cost. This case study shows that DFMA is a useful tool that can help designers or companies in minimising the cost of a product but on the other hand improving the quality, reliability and flexibility of a product.

A research done by Amy E. Wood, Charles D. Wood and Christopher A. Mattson demonstrated the DFMA principles, both universal and contingent using a pineapple juicer (Wood et al,. 2014). The standard DFMA principles are categorised into two categories: universal and contingent. There is a necessity to know whether the opposite of the standard DFMA principles are more suitable for the developing world. This is to ease the categorisation of the principles into universal or contingent category. Then, the contingent DFMA principles are modified so that they are appropriate for the developing world. The objective of this research done by Amy and other researchers is to redesign a pineapple juicer using DFMA principles, then validate the design with the customers in the Amazon region of Brazil (Wood et al., 2014). The modified DFMA principles are used in the design process of the pineapple juicer. The modified principles are used as a guidance in developing a requirement matrix that maps customers' needs. Then, based on the DFMA criteria, scoring matrix was tabulated. Then the DFMA principles, both universal and modified were listed to show the specified design features that were affected by the principles (Wood et al., 2014). Lastly, after several redesigns, a pineapple juicer that can extract

60% of the mass of a pineapple in just 5 minutes was developed based on the modified DFMA principles. Comparing with the first iteration of the pineapple juicer design, it can be concluded that the next pineapple juicer design had better performance, lower manufacturing and production cost, easier to use as well as to easier to manufacture. From this research, it can be concluded that DFMA principles plays an important role in the design stage of a product because it ease the manufacturing and assembly process as well as reduce the cost of the development process of the product.

2.2 Design for Manufacture (DFM)

Design for Manufacture (DFM) is an analytical process structure tool of concurrent engineering that provide design guidelines on the manufacturability of a product (Batalha, 2012). It is a set of rules to be followed by the designers at the early stage of designing process aiming at design efficiency with respect to manufacturing engineering. By applying DFM in the early stage of design, product engineers can choose among different types of material, manufacturing process and quantitatively estimate the manufacturing time as well as cost of the product. DFM can compare all kind of design plans, material plans and manufacturing plans at early design stage. Then product engineers can make revises according to the feedback information provided by DFM analysis and lastly, the most suitable design plans, material plans and manufacturing plans can be selected. The main objective of DFM is to satisfy the customer's needs in terms of reliability, functionality and quality of the product at a relatively low cost. Besides that, DFM can also increase the quality of the product (design, material, manufacturing process, service and etcetera) during the developing stages. The total cost of a product can be minimised using DFM because DFM reduces the design cost, manufacturing cost, material cost, delivery cost, technical support cost, and discarding cost. Furthermore, by using DFM in product development process, the developing cycle time (design time, manufacturing prepare time, repeatedly calculation time) can be shortened. In short, the positive effects of DFM are simpler manufacturing and assembly process, cuts down manufacturing and assembly cost, improves product quality and etcetera. Design can be defined as a problem solving process. Although design cost for a new product always takes the lowest percentage of the final product cost, the design itself affects the final cost of a new product more than any other factors. This shows that design is the most important factor in product development process due to its enormous influence on the cost and quality of a product later on.

2.2.1 DFM Case Studies

In 2004, Jeffrey W. Herrmann et al. published a research on expanding the domain of DFM into new and important areas. DFM and concurrent engineering can be accomplished through an iterative design process in which all the product engineers, personnel and marketing experts swap between identification of customers' needs, product design, and assessment of manufacturing issue (Herrmann et al., 2004).

Conceptual design is defined as a process whereby customer's needs are translated into requirements on function and performance (Herrmann et al., 2004). DFM in conceptual design means the development of several functional approaches and the propagation of those approaches through further design stages, eliminates or revises candidates as they are inferior. Quality Function Development (QFD) is the most commonly used DFM tool. QFD is used to translate customer's needs into a set of design elements. These elements can be applied top-down through Product Planning, Part Deployment, Process Planning, and Process Control. By integrating

DFM into QFD, early estimations of downstream metrics can be provided. The transformation to embodiment design can be eased, manufacturing can be taken into account at the earliest stage of design. This integration of DFM to QFD helps the designers to design components that are easier to manufactured or assembled. Embodiment design consists of material selection and manufacturing processes. It also involves a few complex problems, for example, processes of manufacturing, types of material, and sizes of component. During embodiment design, product designers will select the processes and materials of a product based on experience. By applying DFM in embodiment design, material and process selection will be simplified.

In 2002, Daniel et al. did a concurrent product case study on the Pico Radio Test Bed. This Pico Radio project (Odell et al., 2002). In order to get benefits from DFM, downstream manufacturing processes have to be identified before any design phase starts. For the case of Pico Radio Test Bed, injection molding is selected as the elementary manufacturing process due to its ability to produce complex geometries and thin wall sections. After selecting injection molding as the manufacturing process, the design for injection molding guidelines could be followed. Prototype of the design was made using Fused Deposition Modelling (FDM). By integrating DFM and FDM in the product design process, manufacturing issues can be solved easily. No redesign is needed at the later stage of the product development process. This could results in significant savings in costs, materials, tooling costs and etcetera.

2.3 Design for Assembly (DFA)

The word "assembly" in Design for Assembly (DFA) represents the addition or joining process of a few parts and sub-assemblies to form a complete product. DFA is a method that can be used to analyse the parts and sub-assemblies of a product in order to optimise the assembly process steps, to identify the relevance of the part and to estimate the time as well as cost of the assembly. By applying DFA in product development process, possible problems in the assembly process can be resolved and considered at the early stage of design. Thus, the components can be assembled in a short time with high speed, low cost and high productivity. Several criteria are considered in DFA analysis, for example, reduce part counts and types, optimise attachment methods, minimise reorientations and adjustments during assembly process, design self-align and easy locate parts, non-hazardous during assembly handling as well as minimise number of tooling. Among all the criteria, the main purpose of integrating DFA in designing process is to reduce the assembly cost by optimising the assembly process and minimising the number of parts. Although the number of parts are reduced, the application of DFA usually lead to the improvement in quality and reliability of the product. DFA should be considered at the early stage of design process because it provides a complete evaluation of product assemblability that improves the assemble process of product componets. When implementing DFA analysis, subjective judgement should be eliminated. Free association of ideas should be allowed while suggesting alternative designs. DFA provides systematic steps for the evaluation and improvement of the product assembly process. A feedback loop is used to aid the designers in measuring improvements resulting from specific design changes (Boothroyd, 2002). DFA index is a measured obtained from DFA analysis. It is a measure of assembly efficiency of a product. It is calculated by dividing the total assembly time of an ideal design with the actual total assembly time of the real-world product. DFA can be used in two ways: tool for assembly analysis, guide for assembly design. A tool for assembly analysis is the estimation of assembly possibility by analysing the factors that can affect the assembly process at the beginning of the product design stage, then, suggestion of redesign can be provided. Guide for design assembly collects knowledge and experience from the assembly experts and record them as design rules (Xie, 2003). By referring to the recorded design rules, design plan and product construction can be selected.

Although DFA is considered as a relatively recent development, it had been implemented in many companies for quite a long time. Dates back to 1960's, the original DFA method was firstly developed on automatic handling. A group of technology classification system was developed to catalogue automatic handling solutions for small parts (Woodwark, 1986). This group of technology classification system was published in an internal manufacturing producibility handbook by General Electric. This technology classification system became apparently useful to the designers because it helps to design parts that are easy to handle automatically. However, these guidelines embedded many of the principles of DFA without even actually calling it DFA or distinguishing it from the rest of the product development process (Chan et al., 2013). In the 1970's, the publication of G. Boothroyd had promoted the implementation of DFA in industries. In 1988, a major breakthrough in DFA implementation was made when Ford Motor Company announced that the Boothroyd-Dewhurst DFA software had reduce billions of dollars on Ford Taurus line of automobiles.

2.3.1 Types of Assembly

Assembly can be categorised into: manual assembly, automatic assembly and robotic assembly.

2.3.1.1 Manual Assembly

Manual assembly refers to an assembly process where all the assembly operations are done manually without any assistance of elementary and general purposed tools. There are six types of manual assembly method: bench assembly, multi-station assembly, modular assembly center, custom assembly layout, flexible assemble layout and multi-station assembly of large products. Nature of the layout of the assembly area and the method of assembly are factors that affect the part acquisition time (Boothroyd et al., 2002). Compared to automatic and robotic assembly, manual assembly is the most flexible and adaptable assembly process among all, however, the production volume is far too less compared to automatic and robotic assembly. Besides low production volume, the labour assembly time and cost for manual assembly are way too high compared to the other two types of assemblies.

2.3.1.2 Automatic Assembly

Automatic assembly refers to an assembly process that requires the help of either synchronous indexing machines or non-synchronous indexing machines. There are two types of automatic assembly process, which are fixed automation and Detroit assembly. Automatic assembly can produce a high production volume of product, however, it involves the investment of tooling for the automatic assembly process. Large investment and considerable time as well as engineering work have to be committed before the operations can begin.

2.3.1.3 Robotic Assembly

Robotic assembly refers to an assembly process that requires robotic assembly system. There are several types of robotic assembly such as, two arms robotic assembly and multi-station robotic assembly. Compared to manual assembly and automatic assembly, robotic assembly is the best assembly method among all if the product that has huge life production volume. Although it involves large investment of tooling before the operations can begin, its flexibility helps to minimise other expenses that can results in a significant savings later on.

2.3.2 Evaluation Methods for Design for Assembly

Generally, almost every different industries use different or customised DFA analysis. It is impossible to develop a standard DFA analysis that is suitable for all industries because every industries has their own requirements. However, there are a few major and most widely used DFA methods that can be used to quantify the improvements and goals of DFA. They are Boothroyd-Dewhurst's DFA method, The Lucas DFA method, Hitachi Assembly Evaluation Method (AEM) and Fujitsu Productivity Evaluation System.

2.3.2.1 Boothroyd-Dewhurst's Design for Assembly method

Boothroyd-Dewhurst's DFA method is developed by Boothroyd-Dewhurst Ins. The aims of this DFA analysis tool are to reduce the part count of a product, to ensure that the parts are easy to assemble and to determine a suitable as well as appropriate method for the assembly process of a product. In order to reduce the number of parts, DFA criteria should be applied to each part of the product so as to determine whether the part should be combined or separated from all other parts. Besides that, this method also stated that the estimation of the handling and assembly costs for each part of the product should be done using appropriate assembly process. This method focuses on an existing design that is being evaluated and improved repeatedly, for example, an assembly method will be selected for each part. Then, all the parts will be analysed based on the assembly method selected. The design will be refined in response to shortcomings identified by the analysis done. This analysis process will be repeated until a sufficient design is obtained. Tables and charts are used to estimate the manual or automatic part handling time as well as insertion time of each part. Assembly efficiency of the product can be obtained. Assembly efficiency can be defined as the ratio of ideal assembly time to actual assembly time. It is a key measure of the overall product design. In order to determine the number of theoretical minimum part count, the product needs to be analysed. All the parts have to fulfil at least one of the criteria stated by Boothroyd and Dewhurst in order to be categorised as ideal theoretical part. According to Boothroyd et al. (2002), the first criteria is, "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.)". Next, "the part must be of a different material than, or must be isolated from all other parts assembled (for insulation, electrical isolation, vibration damping, and etcetera.)". Lastly, "the part must be separated from all other assembled parts; otherwise the assembly of parts meeting one of the preceding criteria would be prevented".

2.3.2.2 The Lucas Design for Assembly method

In 1980's, Lucas Corporation in the UK developed the Lucas DFA method. Unlike Boothroyd and Dewhurst's DFA method which is based on the timing of insertion and handling motion, Lucas DFA method is a method that depends on a 'point scale' which measure the difficulties during assembly. There are three important separate and sequential analyses in The Lucas DFA: functional analysis, handling analysis, and fitting analysis. Figure 2.4 represents the relations of these three analysis.

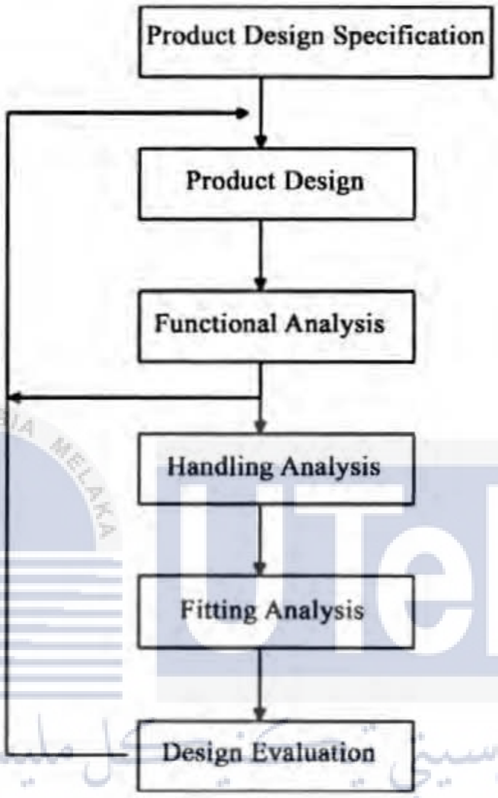


Figure 2.4: Relations of functional, handling and fitting analysis

Before the fabrication and assembly process of a product, product design specification changes customs requirements into engineering specifications. Then, this engineering specifications are used by the design engineers to perform design process. In functional analysis, only the function of the components are reviewed. The components are divided into Group A and Group B. Parts that are deemed to be essential to the product's function will be categorised into Group A; Parts that are not essential to the product's function will be categorised into Group B (Chan et-al, 2013). The functional efficiency of the design can then be obtained and it can be used to pre-screen a design before more commitment is being made. Feeding analysis analyses the problem regarding the handling parts or subassemblies. Target index can be obtained during feeding analysis. It can be calculated based on the size, weight, handling difficulties, and orientation of a part. If the target index of a component is more than 1.5, the component should be considered for redesign. 2.5 is an ideal value for target feeding index. Fitting analysis is almost similar to feeding analysis. It is divided into several subsystems including insertion, gripping and fixing analyses. The fitting ratio can be calculated by finding the ratio of fitting index to the number of essential components. Similar to feeding ratio, 2.5 is an ideal value. The fitting index of a part can be estimated based on the part's fixturing requirements, insertion resistance and vision restrictions during the assembly process.

2.3.2.3 Hitachi Assembly Evaluation Method

Hitachi AEM was developed by Hitachi Ltd. to rate the ease of automatic assembly and to improve the design quality for better producibility. When Hitachi AEM was first developed, it was used to optimise the design of a tape recorder mechanism in order to develop an automatic assembly paradigm to produce the subassemblies of the tape recorder. Product design quality will be analysed quantitatively in the early stage of the designing process. It is a method that evaluate a product based on the principle of "one motion for one part". It also focuses on the identification of the weaknesses of the design at early stage in order to facilitate design improvement. It uses two indices: assemblability evaluation score ratio (E) and assembly cost ratio

(K). E is used to determine the design quality and assembly difficulties during assembly process. E can be computed using the consideration of a simple downward motion for part insertion as an ideal reference. Penalty scores are assigned for complicated operations based on their complexity and the nature of the operation. The assemblability evaluation score of a specific part can be determined after completing a worksheet for penalty score. Then, the assemblability evaluation of all parts are combined to produce an assemblability evaluation score for the whole product assembly. On the other hand, K is used to project the elements of assembly cost. It is an indication of the improvements of the assembly cost. It is calculated by dividing the assembly cost of a modified design by the assembly cost of the original design. In order to estimate the assembly time and cost of a design, the assembly operation has to be separated into elemental components. Then, time for each elemental motion is allocated based on compiled practical observations. In short, by reducing the part count of a product, assembly operations can be simplified, and thus, assembly cost can be minimised.

2.3.2.4 Fujitsu Productivity Evaluation System

Fujitsu productivity evaluation system is a tool that is used to obtain a detailed design that can be manufactured easily and can be assembled with cost effectiveness. Different with other DFA methods, the Fujitsu productivity evaluation system is not an optimisation process after the completion of design process. It only limited to bench type manual assembly of small parts. This system consists of four subsystems, namely, assembly sequence specification subsystem, assemblability evaluation subsystem, manufacturability evaluation subsystem and design ideas as well as know-how reference subsystem. Figure 2.5 shows the four subsystems in Fujitsu Productivity Evaluation System.

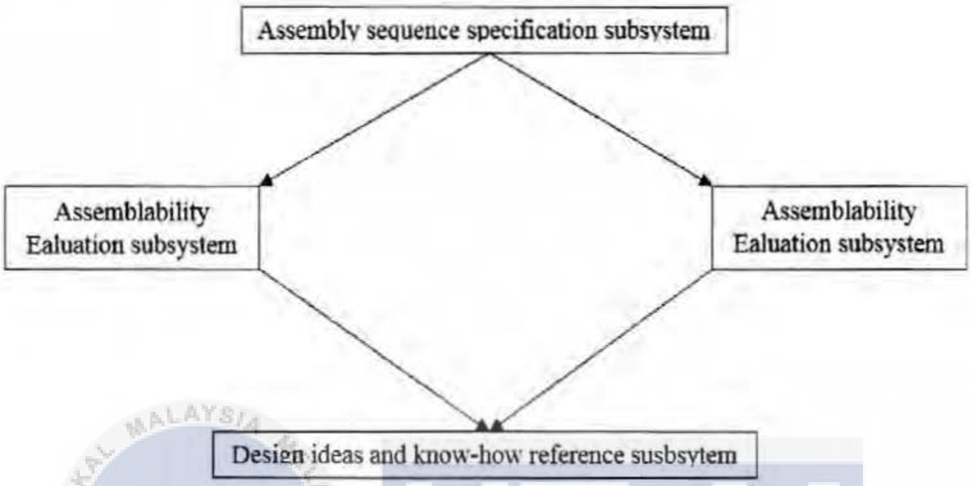


Figure 2.5: Subsystem in Fujitsu Productivity Evaluation System

In the assembly sequence specification subsystem, parts that are similar to the envisioned are selected to be used in the product, then, the assembly sequence of the parts are specified. Assemblability evaluation subsystem is a subsystem that estimates the assembly time as well as evaluates the ease of assembly. The evaluation and estimation can be done based on part handling, part insertion, targeted number of essential parts, high-cost processes and high-cost parts. Manufacturability evaluation subsystem is used to quantitatively estimate the manufacturing cost and manufacturability. This manufacturability evaluation can be done at two levels: detailed evaluation and rough evaluation.

2.3.3 DFA Case Studies

Companies worldwide have been essentially implementing DFA in their product development process for a long time. Nowadays, each and every products in Motorola Solutions' extensive portfolio is benchmarked and analysed during the design stages using Boothroyd-Dewhurst's DFA software. It helps Motorola to cut down part count and assembly time significantly. It is used to simplify the design of a product by removing and eliminating all the unnecessary parts or sub-assemblies, making the assembly process easier and faster, reducing as well as lowering the labour cost. According to Foley (2012), "DFA clearly shows which parts are required by product function and which parts can be eliminated". DFA software can illustrate the process of how to achieve significant cost reduction by identifying the opportunities for simplification of the product structure as the software steps through the process. DFA index obtained from the software is a key measure of the overall product design. It is a ratio of ideal assembly time to actual assembly time. Ideal assembly time is defined as the time of assemblage for a product that have a minimum theoretical part count. When the number of parts decrease, the actual assembly time also decrease, and therefore DFA index increase. Higher DFA index indicates product improvement. Motorola Company divided their company's extensive portfolio into a series of product families so that the DFA index family range can be calculated. Product families created enables the Motorola engineering team to calculate the DFA index of every product. The DFA index range for each family or sub-family of the product can also be calculated. Motorola also calculated the DFA index for competitive products for benchmarking purposes. DFA index is extremely useful in determining the design efficiency of a product. However, the index calculation restricted to small products with ideal components (standard symmetry, within easy reach of the assembler, snap-fit securing method and no difficulties in handling and insertion). Therefore, extra effort is needed to make highly detailed and accurate design so that the DFA index calculated is reliable.

In 2011, Boothroyd and Dewhurst's DFA software helped Motorola to save product development cost of DS9208 Scanner. In order to develop a product that has good quality and is cost efficient, design reviews should be spaced out along the new product development process. Boothroyd and Dewhurst DFA review is used while designing DS9208 Scanner and this review had supplied real-time feedback to Motorola's Design Engineering Team. The DFA review identified unnecessary parts or sub-assemblies that may be changed or eliminated from their design. This is very important because by applying DFA review, plenty of design time and resources allocation can be cut down. This could reduce the time for designing or redesigning process. DFA helps designers to identify items to be eliminated, labour reductions, cost savings, drive potential overhead cost reductions, and steer the concept to an assembly-friendly design while helping drive higher quality standards in the product (Foley, 2011). All the parts and sub-assemblies of DS9208 Scanner are analysed and reviewed using DFA software. Some parts were found to be over-designed and should be changed or eliminated. For example, in the DS9208 Scanner case, rubber gasket is identified as a part that can be eliminated. Rubber gasket is used to seal the electronic parts from dust and liquids. According to the first rule of DFA, Minimum Part Criteria, it is important to identify whether the part is really needed and can it be combined with another part and yet, perform the same function. In this case, although rubber gasket is needed in the design, it is considered as an extra part because it can be combined with other parts such as top cover or base. By combining rubber gasket with other parts, manufacturing costs can be reduced because the expensive production tool for rubber gasket can be eliminated, replacing with inexpensive tool modification of other parts. Besides that, the total number of part count of the DS9208 Scanner can be reduced and hence, total assembly time and total production cost can be reduced.

On the 12th Annual International Forum on DFMA, Richard F. Johnson presented that the Boothroyd-Dewhurst DFA method employed by Magna Seating group Value Engineering or Value Analysis team has resulting in savings in materials, costs, tooling and etcetera (Johnson, 1997). Magna Seating assigned several experienced personnel that are experts in development, manufacturing, tooling and processing. This group of personnel applied DFA technique to enhance the cost reduction efforts in their products such as seat and armrest cover. In order to produce an effective design that has the fewest parts and lowest cost, product design and engineering staffs are required. However, only experienced personnel are capable of determining the manufacturing capabilities of the plants. Therefore, Magna Seating group provides training programs to the product engineers. A small investment in training program results in more experienced personnel and hence the DFA analysis carried out later on will be more accurate and reliable. By applying DFA in the early stage of product development, false starts, redesigns, tool changes costs and the issuance of Design Change Notice can be reduced. Obviously, early analysis on new designs using DFA method is the key to the commercial success of every product. Take jump seat designed by Magna Seating for example. This jump seat originally consists of 105 separate parts, the product engineers are given eight months to redesign a new jump seat that is cheaper yet all the features and functions are maintained. Therefore, the product engineers employed DFA methods in the original jump seat design. From the analysis, it was found that the total assembly time for the original jump seat was over 1440 seconds. DFA is also used to determine which parts or components can be eliminated or combined with the other parts in order to get the total number of theoretical part count. After using all these baseline analysis, a new design was developed. The new design developed by Magna Seating had only 19 parts left and the total assembly time had reduced to 258 seconds. All the essential functions and features of the jump seat are remained. Then, the analysis was proceeded to the next phase. In this phase, the DFA analysis was conducted using the theory that any change is possible as long as the functionality of the assembly is maintained. In this phase, the number of parts had reduced to 9 parts and the assembly time is now less than 100 seconds. After the coordination of DFA with the Value Engineering or Value Analysis process, the final number of parts remained for the jump seat is 68 parts. This shows a significant change in the number of parts although it did not approach the initial 19 and 9 parts shown in the first and second phase of DFA analysis.

2.4 Hairdryer

Hairdryer is an electromechanical device that can be used to blow hot air across wet or damp hair in order to dry the water particles that stick on hair. Besides drying the hair, hairdryer can also be also used to style the hair by providing heat that can control the shape of the hairstyle. The forming of the style of hair can be done by providing heat that can accelerate the formation of temporary hydrogen bonds inside the hair strands. These hydrogen bonds provided by the hot air is the key point that allows the hair shaping to last longer. It is even more effective compared to permanent waxing product that helps in hair shaping using sulphur bonds.

2.4.1 History of Hairdryer

The first hairdryer patent was recorded in 1888. It was a design of a French hairstylist inventor, Alexandre-Ferdinand Godefroy (Gross, 2013). This complicated electromechanical device was able to send hot air through a pipe to a dome surrounding the user's head. Compared to modern hairdryers, Godefroy's invention does not have airflow. It was just a hair steamer that has a dome shape that provides heat to the women's head. However, in order not to overheat the user's head, escape valve for steam was included in Godefroy's invention. The hairdryer invented by Godefroy in 1888 was neither portable nor handheld. In the 20^{th} century, some people attached a hose to vacuum cleaners' exhaust to blow their hair. However, this action could bring dust out of the vacuum cleaner from the cleaners' exhaust, which may cause dust to stick on hair while blowing the hair. In 1926, another patent claimed that by attaching a brush to the exhaust of a vacuum cleaner, the dust and dirt escaped from the vacuum cleaner can be trapped. This can be considered to be the inceptive inspiration for the creation of the modern hairdryer.

Handheld blow dryer was invented in 1920 by the US Racine Universal Motor Company and the Hamilton Beach Company (Shelton, 2011). Although this was a handheld blow dryer, it was too heavy to be used or carried. It weighed up to approximately two pounds. It would be impossible to carry it for a long time if there is a lot of hair to be dried. This invention had a step in the right direction but still, need to be improved. This is mainly because the blow dryer invented in 1920 was prone to overheat or electrocution. Furthermore, this invention can be used up to 100 watts only. It is 20 times lesser than the wattage of the hairdryers nowadays. The limit on heat wattage may result in the longer time required to dry the hair.

Although several different hairdryers were invented and evolved after 1920, all the inventions did not have significant changes. Not until plastics had significant improvement in their properties did inventors realise hairdryers should be made of plastics. In 1951, bonnet dryer was invented and was introduced to the consumers. This soft bonnet type of hairdryer consisted of traditional motor with built-in hose attachments (Shelton, 2011). Usually, the dryer was put in a small and portable box connected to a hose. Then, one end of the bonnet was connected with the hose and the other end of the bonnet was placed on the user's head. This invention provides heat evenly to the whole head at once. Also in 1951, rigid-hood hair dryer was invented. Rigid-hood hairdryer is a hairdryer that had a hard plastic helmet that covers over the user's head. The mechanism of this hairdryer is almost similar to soft bonnet hairdryer, however, rigid-hood hairdryer has higher wattage compared to soft bonnet hairdryer, which means that this type of hairdryers can dry hair in a shorter time. Rigid-hood hairdryer can be seen frequently in the salons.

2.4.2 Fundamental Parts of a Hairdryer

There are a variety of different hairdryers available in the markets. All the hairdryers have their own distinct parts compared to the others, however, the fundamental parts of all hairdryers are still the same. There are three fundamental parts in a hairdryer, they are, heating element wire, fan and housing of hairdryer.

2.4.2.1 Heating Element Wire

Normally in almost all hairdryers, a coil of wire can be found inside the hairdryer when the hairdryer is dismantled. This metal coil is used as the heating element of a hairdryer and it is usually placed over a conduction resistant element such as plastics. This kind of resistor is known as wire-wound resistors (Hasret, 2011). This wire-wound resistor is made up of cylindrical core and metal wire. Generally, this cylindrical core is made of either plastics, ceramics or fiberglass whereas metal wire is normally made of high resistant metal. This wire-wound resistors can be categorised as the most important mechanism of a hairdryer. It is used to convert electrical energy generated by the motor into heat energy. Therefore, when air flows through it, air will becomes warmer and thus, the warm air generated can be used to dry the hair. In order to dry hair in a shorter time, hotter air should be generated. In order to generate hotter air, the heating element should be made of a material that is high in electrical resistivity and melting point. In the current hairdryer design, the maximum temperature that can be produced by the heating element is approximately 60 °C. If the temperature of the heating element is detected to be more than the maximum temperature, the electricity will be cut off by a safety cut off switch. This is to prevent the hairdryer form overheating.

2.4.2.2 Fan

When heat is generated by the heating element, a device is needed to transfer the heat from the heating element to the hair of the user. This device is known as fan. Fan of the hairdryer works as a transformation mechanism. The fan is connected to a motor. The mechanical energy of the motor will be transferred to the fan connected to it. This mechanical energy will provide rotational motion to the fan. As a result, air from the fan will be passed over to the heating element, and then blowing the heat from the heating element to the hair (Hasret, 2011). All these processes are will not occur without the rotational motion of the fan. Therefore, the material used to manufacture the fan of the hairdryer should have high temperature resistance. Besides that, the fan of the hairdryer should not be made of a high density or heavy weight material for the ease of handheld.

2.4.2.3 Housing

Housing, also known as casing of the hairdryer, is a protective layer that covers the internal electrical components such as heating elements, fan, and motor of a hairdryer. Normally, the housing of a hairdryer is designed as an inverted L-shape. All the switches are placed on the handheld part of the housing. This is to ease the users while adjusting the temperature of the hairdryer to blow dry their wet hair. Besides that, the housing provides ergonomic gripping sensation by designing the handler part of the housing in an inverted L-shape. Electrocuted caused by hairdryer had results in many accidents including fatal incidents. This endangers the life of the users. It is extremely important to create a hairdryer that is water-proof so that accidents caused by electrocution can be reduced. It is often people accidentally drop their hairdryer into the sink or bathtub. Therefore, the housing of the hairdryer should always be made of water-proof material in order to prevent short circuit or electric shock. Furthermore, the water-proof material selected should also be light in weight to ease the users.

2.4.3 Types of Hairdryer

There are several types of hairdryer that have distinct and unique functions other than drying wet hair. However in this section, the hairdryers are not categorised based on their functions. The two categories of hairdryers are foldable and non-foldable hairdryer.

2.4.3.1 Non-foldable Hairdryer

Non-foldable hairdryer are normal types of hairdryer that are used in salons or at home. They are usually bigger in size. The housing of the non-foldable hairdryer is an inverted L-shape. It is the most commonly seen hairdryer in the market before foldable hairdryer is invented. Normally, people do not opt to bring non-foldable hairdryer while travelling because it is huge and takes a lot of space if it is put in the luggage. Figure 2.6 shows the image of a non-foldable hairdryer.

Figure 2.6: Non-foldable hairdryer

2.4.3.2 Foldable Hairdryer

Unlike non-foldable hairdryer, foldable hairdryer is great for travel and is easy to store. It does not take a big space for storage. Usually, foldable hairdryer has light weight and it is not as heavy duty as non-foldable hairdryer. It is just a hairdryer that can be stored and carried easily in order to ease the users while travelling. However, there are also heavy duty foldable hairdryers available in the market. Figure 2.7 shows the image of a foldable hairdryer.

Figure 2.7: Foldable hairdryer

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, all the methods and steps that are used to obtain the outcomes of this project are discussed in detail. The methodology used to analyse the two different brands of hairdryers will be described. The explanations focus on the analysis of hairdryers using Boothroyd-Dewhurst DFMA method. The integral parts of Boothroyd-Dewhurst DFM methods such as material selection and manufacturing process will be shown in the section below. After that, the integral parts of Boothroyd-Dewhurst DFA method will be discussed. All the design guidelines, no matter design guidelines for DFMA, DFM or DFA will be listed. Before DFMA analysis, literature review on DFMA, DFM and DFA are introduced. Some history and types of the product chosen (hairdryer) are also introduced. All the information from the literature review are gathered from different journals, articles, internet sources and etcetera. In order to collect useful data for the product chosen, the product is dismantled. A detailed drawing of the product is produced. Then, the product is reassembled. These data obtained from dismantling and assembling the existing product are extremely significant for obtaining accurate and reliable DFMA results. After DFMA analysis, the existing products are optimised by improving the existing design according to the DFMA results. 3D CAD software such as CATIA V5R20 and Autodesk Inventor will be used in this project to produce all the detailed drawings, for both original and new design of the product. The project planning flow chart is shown in Figure 3.1.

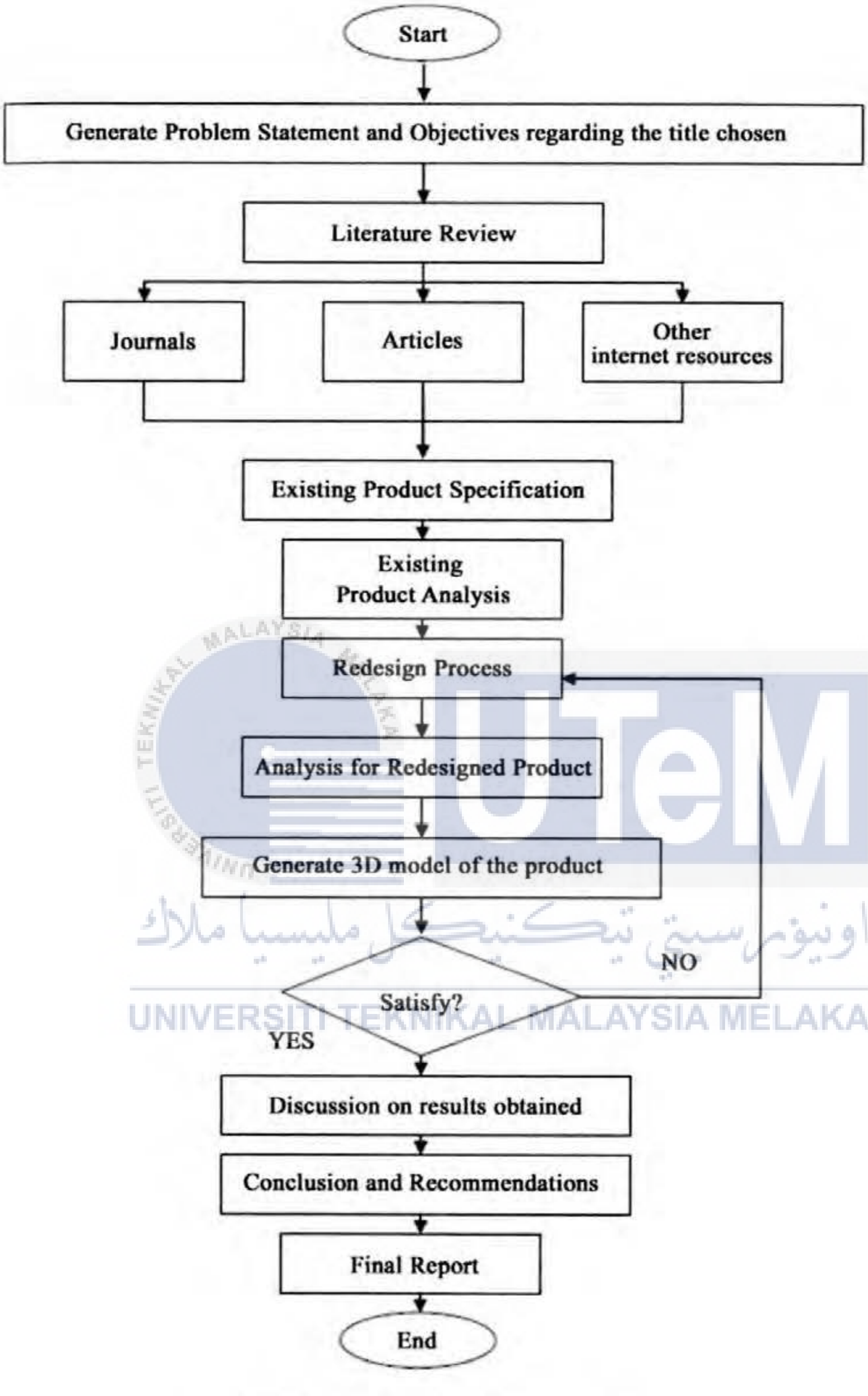


Figure 3.1: Project planning flow chart

3.2 Literature Review

Literature review is the review of a scholarly paper, case study and etcetera. It includes the synthesising of the findings of other researchers regarding a particular topic. It is a secondary source which does not present new results or new experiment works. Literature review can be done by collecting necessary information through journals, articles and other internet resources. Journals and articles are secondary resources. According to Cambridge Advanced Learner's Dictionary (2009), a journal is defined as "a serious magazine or newspaper which is published regularly, usually about a specialist subject". Conference papers are different with journals. Conference papers are articles that are written in objective to fulfil the conference requirement so that they are accepted to a conference. According to Cambridge Advanced Learner's Dictionary (2009), an article is defined as "a piece of writing on a particular subject in a newspaper or magazine". All other data gathered from internet articles, websites and etcetera are considered as other internet resources.

3.3 3D CAD Drawing

In this project, 3D CAD software such as CATIA V5R20 and Autodesk Inventor are used to produce a 3D model of the existing and new product. The existing hairdryer is disassembled. The detailed dimensions for all the components found in the existing product are measured. These measured dimensions are used to produce a 3D model of the existing hairdryer. Then, 3D models of the components are assembled together using appropriate constraints in 3D software. Detailed drawings, exploded views and assembly views for both existing and new design will be appended in the Appendix at the end of this report.

3.4 DFMA Analysis

DFMA analysis is applied to both existing and new designs. This is to ensure that the design efficiency of the existing and new design can be compared easily. Two different brands of hairdryers are chosen as the existing designs due to their availability in the market. Both of the hairdryers are analysed using DFMA analysis in order to obtain the total labour assembly time, and design efficiency of the designs. Beside manual calculations, DFMA software such as DFM Concurrent Costing 2.4 and Design for Assembly 9.3 can also be used to analyse the efficiency of a design.

As mentioned earlier, DFMA analysis is a combination of DFM and DFA. Therefore, DFMA analysis cannot be considered as a complete analysis if one of the analysis, either DFM or DFA is not carried out. In DFA analysis, appropriate assembly process, handling difficulties, insertion difficulties and etcetera have to be determined. After that, the number of minimum theoretical part count of the product can be determined based on Boothroyd-Dewhurst's criteria. Hence, the simplification of the product can be done by referring to the DFMA analysis. During DFM analysis, appropriate manufacturing process and material selection can be determined.

The results obtained from DFMA analysis can be used as guidelines to develop new design. The new design should then be analysed again using DFMA analysis so that comparisons can be made. The new design proposed should has higher design efficiency, lower assembly time and cost as well as lower manufacturing cost compared to the existing designs. Figure 3.2 shows the typical steps that are applied in DFMA studies using DFMA analysis.

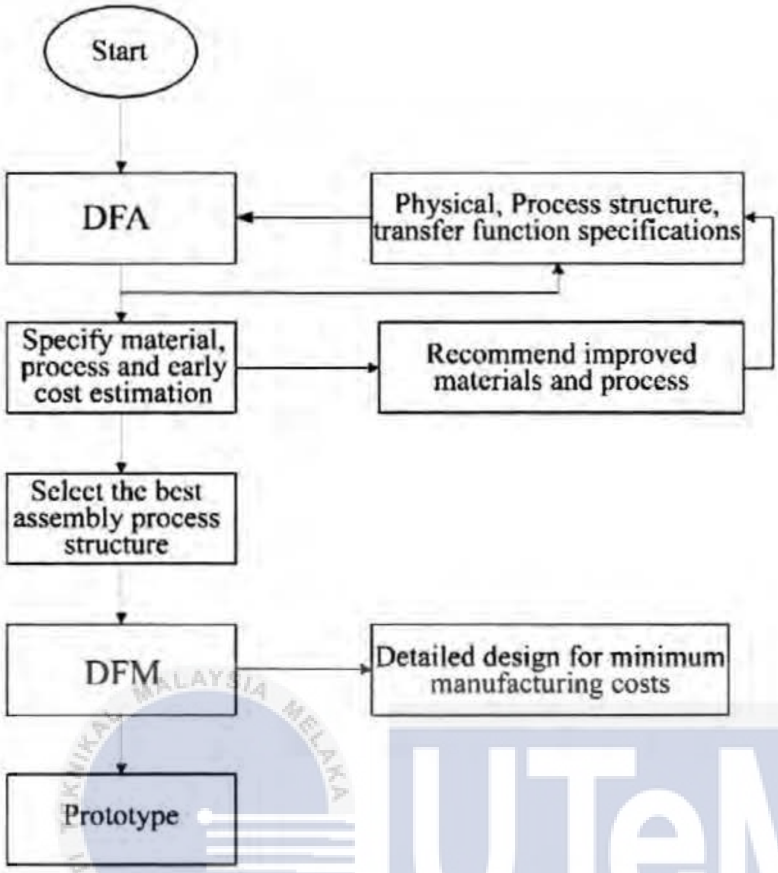


Figure 3.2: Steps taken in DFMA analysis

3.4.1 DFM Analysis

DFM analysis helps in reducing the overall part production cost. It provides suggestions in material selection and manufacturing process for the design. It is simple and easy to use. Before DFMA software is invented, designers need to refer to books or search information from the internet, which is a time consuming process. Now, by having DFMA software, information needed by the designers can be provided by DFM analysis in a short time. In order to perform DFM analysis, several steps and guidelines need to be followed so that the results obtained from the analysis are accurate and reliable. Figure 3.3 illustrates the process flow chart for DFM analysis.

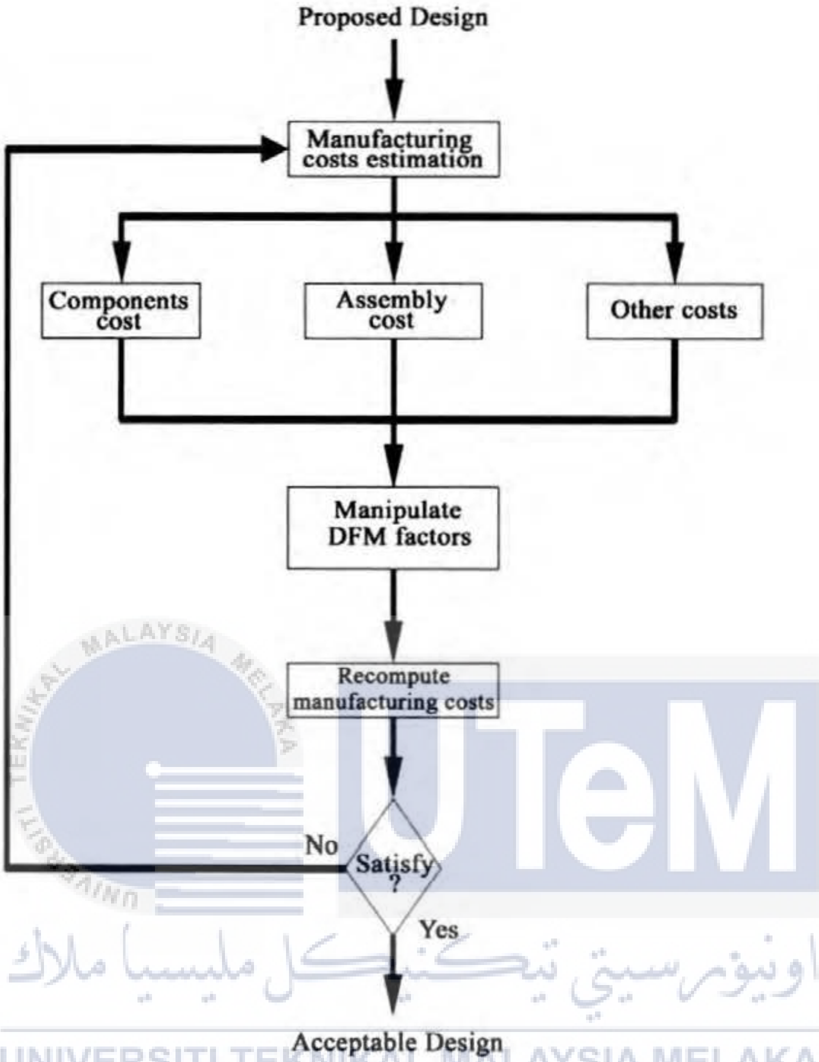


Figure 3.3: Process flow chart for DFM analysis

3.4.1.1 DFM Guidelines

In order to perform DFM analysis, designers are required to obey a set rules or guidelines. These guidelines can aid the designers in simplifying the manufacturing process and reducing the manufacturing cost of a component. These guidelines are (Chang et al., 1998):

i. Reducing the number of components can be considered as the best method to reduce manufacturing cost. Less parts implies less costs. The inventory costs, purchases, assembly costs, inspection costs and etcetera can all be reduced. A part that has no relative motion with respect to other parts, or a part that does not need to be separated from other part in order to perform its function, or a part that does not need to be fabricate using different material from other parts, can be considered as a candidate for elimination. Some manufacturing processes such as injection molding and extrusion can be used when one-piece structures are desired.

ii. By developing a modular design, manufacturing activities such as inspection, testing, assembly, redesign and etcetera can be simplified. This is most probably because modules add versatility to product update in the redesign process, help in testing before final assembly process, and encourage the use of standard components in part assembly to reduce variations in the product.

iii. In product design stages, it is encouraged to use standard parts compared to custom-made parts. This is because standard parts can reduce the product variations in the assembly. Besides that, standard parts are cheaper and easily available compared to customised parts.

iv. The objective of designing a multi-functional part is to minimise the total part count of a product. A multi-functional part combines all the required parts that has no specific movement, separation or material into one multi-functional part.

v. Design multi-use parts can reduce the variations between existing and new product designs. A multi-use part represents a part that can be used in different product for different or same functions. This multi-use part is normally a standardised part.

vi. Design for ease of fabrication. Manufacturing processes that are compatible with the materials should be chosen. Optimum combination of material and processes can reduce manufacturing costs. Finishing processes for aesthetic purposes such as painting and deburring should be avoided. Excessive tolerance and surface-finish requirement are factors that result in the increment of manufacturing as well as production costs and thus should be avoided.

vii. Feeding, handling and insertion operations of fasteners will increase the costs of manufacturing. Besides that, fasteners result in the decrement of the overall manufacturing efficiency. Therefore, fasteners should be avoided in product design. Fasteners can be replaced by snap-fits or tabs. If under some circumstances that fasteners must be used, then, some guidelines should be followed. Excessively long screw or extremely short screw should be avoided. The best choice of screw is chamfered screw because it has a high probability to be placed and fastened successfully.

viii. It is more preferable to design a product that can perform top-down assembly. All the parts should be added from one direction only. Repositioning of assembly should be avoided, assembly directions should be reduced.

ix. Maximum compliances should be included in part design and in the assembly process to avoid damage to the part if errors occur during insertion operations. Tapers and chamfers are examples of built-in compliance features.

x. Minimise handling. Handling operations consist of positioning, fixing, and orienting an assembly. These operations should be reduced. A symmetry part should be manufactured to ease the handling operations. If symmetry conditions cannot be achieved, the product should be fully asymmetry in order to avoid errors caused by confusion. Flexible parts are difficult to handle, therefore, should be avoided.

3.4.1.2 Material Selection

While designing and developing a component, systematic material selection should be taken into account as it plays an important role in ensuring the specific material meets the required properties. Material selection is useful in the development of a product, however, its usefulness is restricted at the early stage of product design when initial decisions on material and processes are made because (Boothroyd et al., 2002):

i. Detailed material property specifications may not be available in the early design process. Only general ranges of properties may have been decided upon at this stage. Therefore, the material selection procedures are restricted.

ii. The compatibleness of processes with materials is important. However, early material selection procedures are considered to be independent from the manufacturing processes that may be used later. The search for suitable materials for application during early product design can be rationalised using several approaches.

There are a few methods that can be used to perform systematic material selection. Firstly, the materials can be grouped into process compatible classes. Secondly, material selection can also be done by modifying the function of membership. Material databases should be grouped into classes regarding to the principle shape-generating processes used in the manufacturing process of every components. Grouping all the materials into different process compatible classes is better than using just one comprehensive materials database. This is because some processes and materials are incompatible and unsuitable. Besides that, shape generating processes for raw material production is unnecessary since all the components are manufactured from processed materials that have undergone the primary processes. Therefore, the separate material database should include materials such as standard metal stockforms, sand, permanent mould-casting alloys, die-casting alloys, metal powders and etcetera (Boothroyd et al., 2002). The material selection of DFM provides a more efficient procedure in providing the specifications of the supermaterial such as the best attainable properties of all the materials in the relative category.

Modelling of ambiguous or vague material constrains are the challenges that obstruct the designing of an appropriate material selection system for early design stages. Therefore, modelling the vague qualifiers using the aspects of fuzzy logic is an alternative way for the material selection system. How well an object can fit into the circumstances set by the designers can be determined using fuzzy logic. This can be done by applying the concept of membership function. One of the advantages of fuzzy logic is that it can assign different levels of accuracy or precision such as "approximately", "close to" and "more or less" to each material constrains.

3.4.1.3 Manufacturing Process

It is important to select appropriate manufacturing processes for each components of the product. The selection of suitable manufacturing process can be done by matching the required attributes of the component with the process capabilities (Boothroyd et al., 2002). Details of essential features of the geometry, properties of material, and other attributes can be tabulated in a table once the overall function of the component is determined. The attributes in the tabulated table are determined using its geometric and service conditions. They are related to the final function of the component. Generally, most of the components are not produced by just a single process. The production of component, no matter simple or complex design, requires a sequence of different processes. By producing the component using a sequence of different processes, all the required attributes of the final components can be achieved. The sequence of processes usually start with forming or shaping process, follow by material removal process and then end with finishing process. If a product has a lot of parts, the manufacturing cost of the product will be extremely high. This is because as the number of manufacturing processes increase, the manufacturing costs will also increase. However, DFMA analysis aims to simplify the design of the product and reduce the number of part count of a product. In this case, the number of manufacturing processes can also be reduced. If designers are to select a suitable manufacturing process from hundreds of processes, the selection process will be very complex. However, by referring to the observations provided by Dr. Geoffrey Boothroyd and Dr. Peter Dewhurst, the selection process can be simplified. The observations are (Boothroyd et al., 2002):

i. Several combinations of processes and materials are impossible.
ii. Several combinations of processes are impossible and, therefore, do not appear in any processing sequences.
iii. Some processes (surface treatment and heat treatment processes) affect only one attribute of the part.
iv. Sequences of processes have a natural order. Firstly, shape generation, followed by feature addition or refinement by material removal and lastly material property enhancement.

Manufacturing processes can be categorised into three categories, they are primary processes, primary or secondary processes and tertiary processes. Primary process refers to main shape-generating process of a component. In other context, primary process may refers to a process that is used to produce raw materials for manufacturing, however, this is not the case for component production. Primary process is usually the first process among the sequence of processes. The primary process chosen should be able to produce as many of the component attributes as possible. Secondary process has more functions compared to primary process. Secondary process can generate main shape of the component, form features on the component as well as refine the features on the component. It usually involves the removal of material from the component using grinding, machining or broaching process. Tertiary process comes after primary and secondary process. It is a finishing process that does not affect the geometry of the component. It usually involves surface treatment and heat treatment process that can enhance the surface finish of the components. Some of the finishing processes can also act as anti-corrosion protection to the components.

3.4.1.4 DFM Concurrent Costing 2.4 Software

DFM Concurrent Costing 2.4 software provides understanding of the manufacturing costs of the product. It also set a benchmark for the theoretical cost of a product. This software can match appropriate manufacturing process with material in order to produce a product that is cost efficient. The manufacturing costs of a product estimated by the DFM software varies with the tolerances, surface finishes and other part details specified by the users. Therefore, by choosing effective manufacturing process, material and part features in DFM software, the costs of the product can be optimised. Figure 3.4 show the user interface of DFM Concurrent Costing 2.4 software.

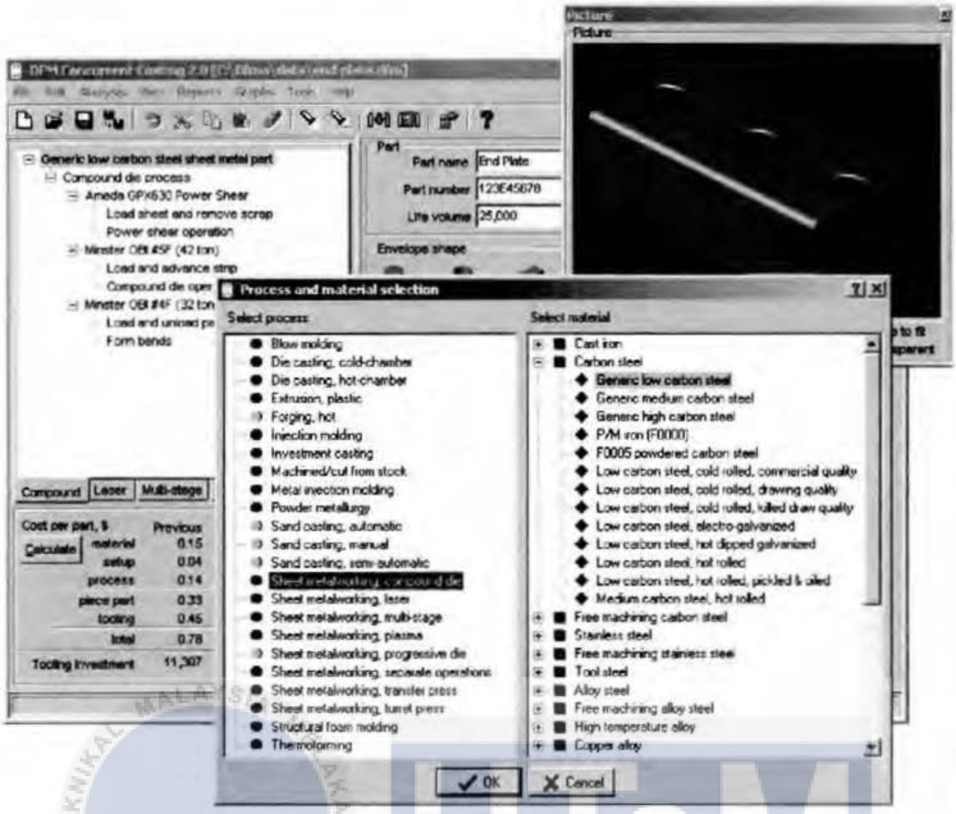


Figure 3.4: DFM Concurrent Costing 2.4

In the DFM Concurrent Costing 2.4 Software, there are columns for part name, part number and life volume. Users have to key in the required information regarding to their product in the respective columns. Then, envelop shape and dimensions of the product are required too in the DFM software. After that, a new window related to manufacturing processes and materials will pop-up. In the new window, it can be observed that there are a few colour indicators beside the processes and materials. These colour indicators indicate the compatibility of the design with the processes and materials. Yellow indicator represents process limitations or review of part shape and forming direction suggested. Orange indicator represents incomplete material data which means that analysis is impossible. Red indicator suggested that the process and material are not compatible with the design. Green indicator represents that the material and manufacturing process chosen are compatible with the design of the part. It should be noted that incompatible choice of manufacturing processes and materials must not be taken into account. After all the required information are provided, a detailed executive summary of DFM analysis can be generated. Useful graphs such as the graph of cost breakdown of the product can also be generated. Table 3.1 and Figure 3.5 show examples of executive summary and graphs generated by DFM software respectively.

Table 3.1: Example of executive summary generated from DFM

Product life volume	100,000
Batch size	12,500
Total cost, RM	4.90
Piece part cost, RM	4.24
Initial tooling investment, RM	66,241

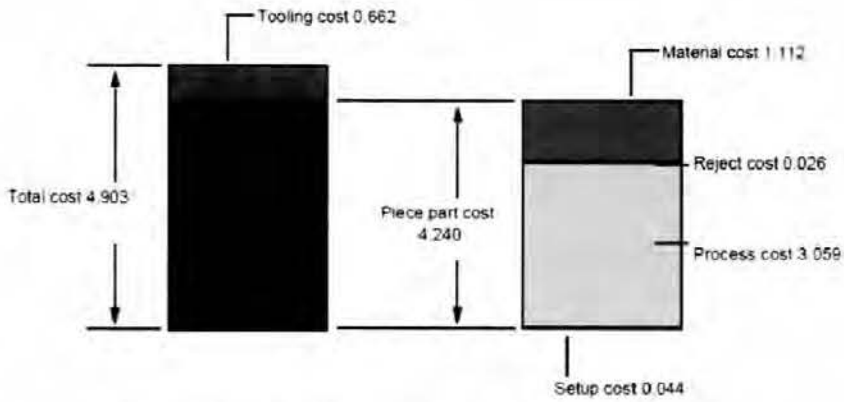


Figure 3.5: Breakdown of costing in the form of chart

3.4.2 DFA Analysis

The aim of DFA principle is to ease the assembly process of a product. DFA analysis is an analysis that analyse the design efficiency or DFA index of the product. It is also a tool that helps designers to reduce the number of parts of a product, minimise the total assembly time and as well, minimise the assembly and labour costs of a product. By using DFA analysis, the minimum theoretical part count of a product can be obtained by determining the importance of a part; whether the part can be changed, combined or eliminated. In order to perform DFA analysis, no matter manual or software analysis, several design guidelines, for example, guidelines for part handling and guidelines for insertion as well as fastening need to be followed.

3.4.2.1 Design Guidelines for Part Handling

Generally, while designing a new product, designers should attempt to obey the following guidelines (Boothroyd et al., 2002):

i. The parts designed by the designers should have end-to-end symmetry and rotational symmetry about the axis of insertion. If end-to-end symmetry cannot be achieved, the design parts should at least achieve maximum possible symmetry (see Figure 3.6 a).

ii. If under some circumstances the part cannot be made symmetric it should be obviously asymmetric to avoid confusion (see Figure 3.6 b).

iii. Parts that tend to nest or desk when stored in bulk should be provided with features that will prevent jamming (see Figure 3.6 c).

iv. Features that will allow tangling of parts when stored in bulk should be avoided (see Figure 3.6 d).

v. Parts that stick together or are too slippery, delicate, flexible, very small, or very large or that are hazardous to the handler should be avoided. Parts that are sharp, splinter easily and etcetera are some of the examples that should be avoided (see Figure 3.7).

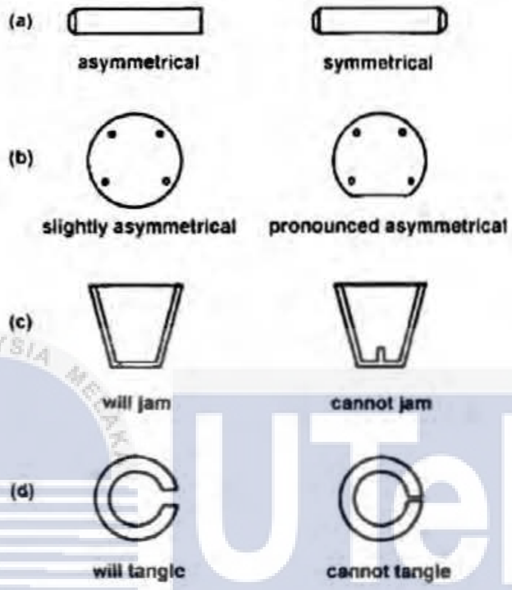


Figure 3.6: Geometrical features affecting part handling

(Source: Boothroyd et al., 2002)

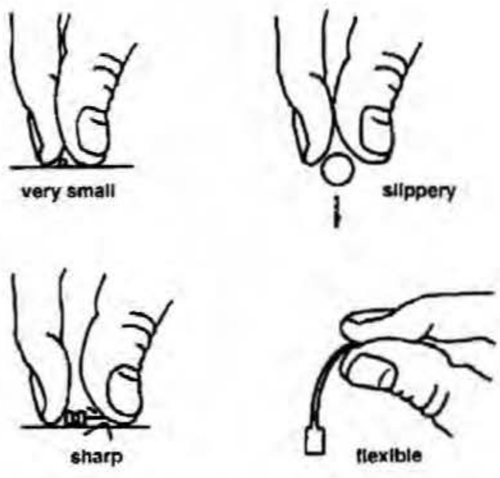


Figure 3.7: Some other features affecting part handling

(Source: Boothroyd et al., 2002)

3.4.2.2 Design Guidelines for Insertion and Fastening

For the ease of insertion and fastening, designers should attempt to obey the following guidelines (Boothroyd et al., 2002):

i. Chamfers to guide insertion of two mating parts should be provided in the design. The design should also has little or no resistance to insertion. Generous clearance should be provided, however clearances that will result in a tendency for parts to jam or hang-up during insertion should be avoided (see Figure 3.8 to Figure 3.11)

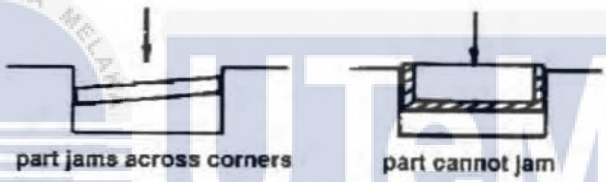


Figure 3.8: Incorrect geometry can allow part to jam during insertion

(Source: Boothroyd et al., 2002)

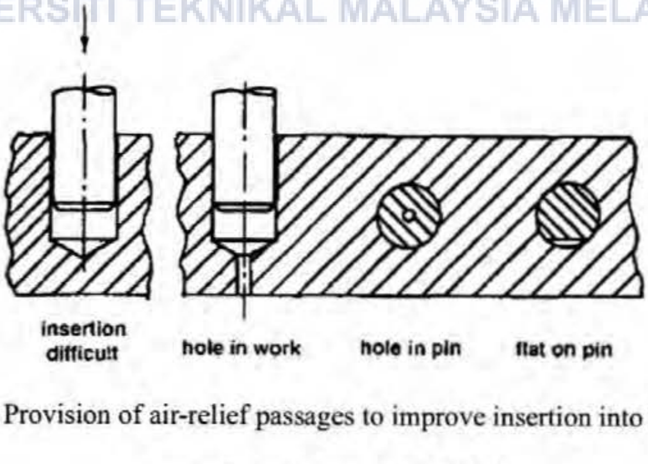


Figure 3.9: Provision of air-relief passages to improve insertion into blind holes

(Source: Boothroyd et al., 2002)

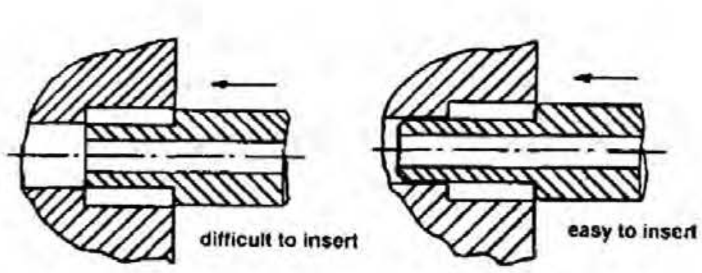


Figure 3.10: Design for ease of insertion

(Source: Boothroyd et al., 2002)

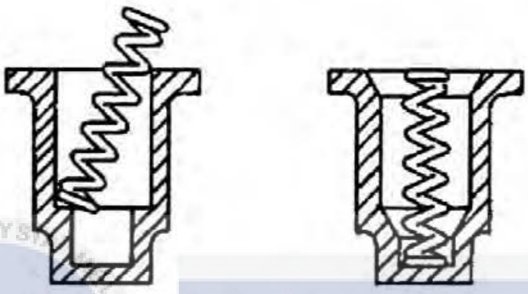


Figure 3.11: Provision of chamfers to allow easy insertion

(Source: Boothroyd et al., 2002)

ii. Common parts, processes, and methods should be standardised across all models and product lines to permit the use of higher volume processes that normally result in lower product cost (see Figure 3.12).

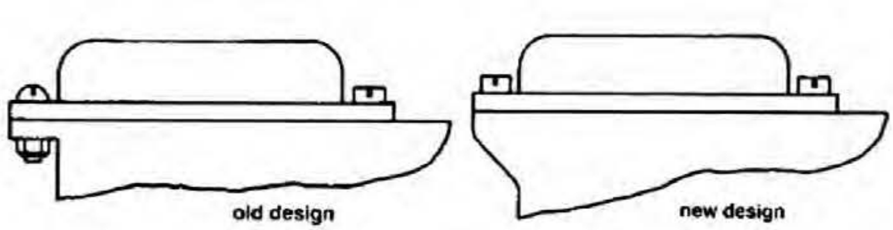


Figure 3.12: Standardise parts

(Source: Boothroyd et al., 2002)

iii. Pyramid assembly provides progressive assembly about one axis of reference. Generally, it is best to assemble from top to down part (see Figure 3.13).

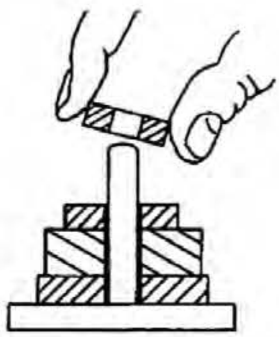


Figure 3.13: Single-axis pyramid assembly

(Source: Boothroyd et al., 2002)

iv. The necessity for holding parts down to maintain their orientation during manipulation of the subassembly or during the placement of another part should be avoided (see Figure 3.14). If under some circumstances holding down is required, the designed part should be secured as fast as possible after it has been inserted.

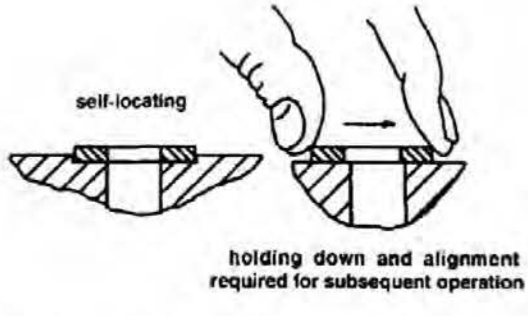


Figure 3.14: Provision of self-locating features to avoid holding down and alignment

(Source: Boothroyd et al., 2002)

v. The designed part should be located before it is released. A potential source of problems arises from a part being placed where, due to design constraints, it must be released before it is positively located in the assembly. Under these circumstances, reliance is placed on the trajectory of the part being sufficiently repeatable to locate in consistently (see Figure 3.15).

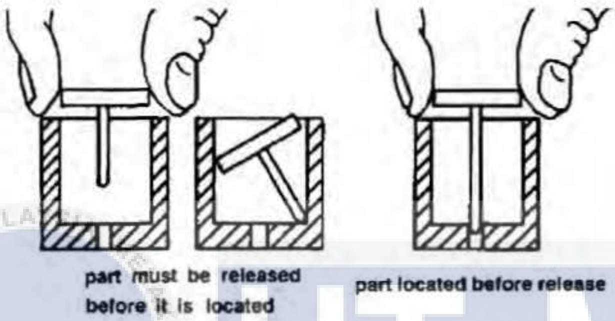


Figure 3.15: Design to aid insertion

(Source: Boothroyd et al., 2002)

vi. When common mechanical fasteners must be used, the most suitable fasteners should be chosen. The following sequence indicates the relative cost of different fastening processes (see figure 3.16).

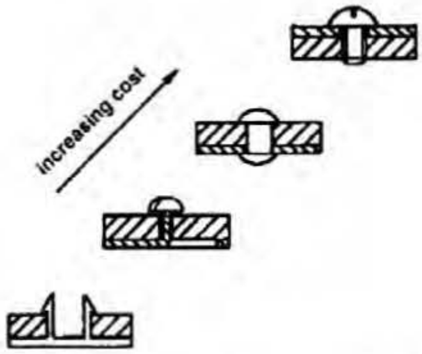
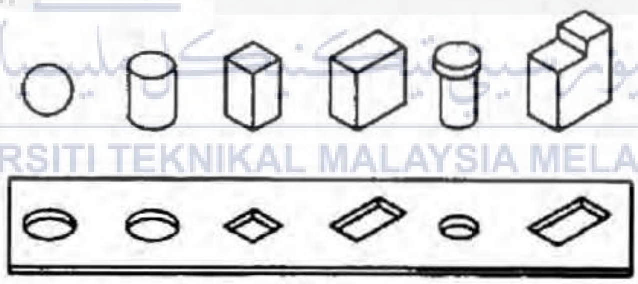


Figure 3.16: Common fastening methods

(Source: Boothroyd et al., 2002)

3.4.2.3 Alpha and Beta Symmetry

Symmetry of a part is one of the main geometrical design features that affect the handling time of the part. There are two types of symmetry for a part, namely, alpha symmetry and beta symmetry. Alpha symmetry is a geometrical design feature that depends on the angle through which a part must be rotated about an axis perpendicular to the axis of insertion to repeat its orientation (Boothroyd et al., 2002). Beta symmetry on the other hand depends on the angle through which a part must be rotated about the axis if insertion to repeat its orientation (Boothroyd et al., 2002). In short, alpha symmetry is the vertical rotation of the part and beta symmetry is the horizontal rotation of the part. The alpha and beta rotational symmetries for different parts are shown in Figure 3.17.



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

Figure 3.17: Alpha and beta symmetries rotational for various parts

(Source: Boothroyd et al., 2002)

3.4.2.4 Manual Handling, Insertion and Fastening Estimation

Partial view of the manual handling table is shown in Table 3.2. From Table 3.2, it can be seen that part features such as size and thickness are several factors that affect the manual handling time of a part. Table 3.3 shows the manual insertion and fastening table. From Table 3.3, it can be observed that part features such as the ease of alignment and positioning are important factors that affect the manual insertion and fastening time.

Table 3.2: Classification system (partial) for features that affect handling time

(Source: Boothroyd et al., 2010)

MANUAL HANDLING-ESTIMATED TIMES (s)

Key: One hand

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

Table 3.3: Features (partial) that affect insertion and fastening time

(Source: Boothroyd et al., 2010)

MANUAL INSERTION-ESTIMATED TIMES (s)

Key: Part added but not secured

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

Key: Part secured immediately

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

3.4.2.5 Design Efficiency

Design efficiency or DFA index of a proposed design is the most important measure in DFA analysis. There are two main factors that can affect the design efficiency of a design, they are, the number of parts in a design and the ease of handling, insertion as well as fastening of the design. Design efficiency can be defined as the ratio of ideal assembly time to the actual assembly time. It can also be represented using the equation:

$$E_{ma} = \frac{N_{min} t_a}{t_{ma}} \tag{3.1}$$

Where,

E_{ma} = design efficiency of the design;

N_{min} = theoretical minimum number of parts;

t_a = basic assembly time for one part;

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

Normally, t_a is estimated as 3 seconds by assuming the part has no difficulties in handling, insertion or fastening.

Theoretical minimum number of parts represents an ideal situation where all the parts are combined as one part if none of the criteria below are met. The criteria used to determine the theoretical minimum number of parts are (Boothroyd et al., 2002):

i. When the product operates in normal mode, the part moves relative to all other parts already assembled. (Small motions that can be produced by elastic hinge are not considered in this case.)

ii. The part must be made of a different material from other parts; or must be isolated from all other parts assembled (for insulation, electrical isolation, vibration damping, and etcetera).

iii. The part must be separated from all other assembled parts; otherwise the assembly of parts meeting one of the preceding criteria would be prevented.

Designers should take note that the criteria above should be implemented without taking general design and service requirements into account. As a result, fasteners should always be categorised as a candidate for elimination. After all the data required such as part handling estimation, insertion and fastening estimation as well as theoretical part count are obtained, a table for the computation of design efficiency can be tabulated. Table 3.4 shows the table for computation of design efficiency.

Table 3.4: Computation of design efficiency

Part Name	No of Items, RP	Tool Acquire Time, TA	Handling Code	Handling Time, TH	Insertion Code	Insertion Time, TI	Total Time, TA+RP*(TH+TI)	Minimum Part count, NM	Part Description
						Total	**TM**	**NM**	

3.4.2.6 DFA 9.3 Software

Design for Assembly 9.3 software implements question-and-answer interface to help the users in identifying opportunities for cost reduction in a product. DFA 9.3 software identifies all the parts that can be eliminated while maintaining all the functionalities of the product. Although the main objective of this software is to help users to reduce the number parts, it does not produce a low quality product. In fact, a DFA-based design has better functionally efficiency and is easy to assemble compared to non DFA-based design. Figure 3.18 shows the user interface of DFA 9.3 software.

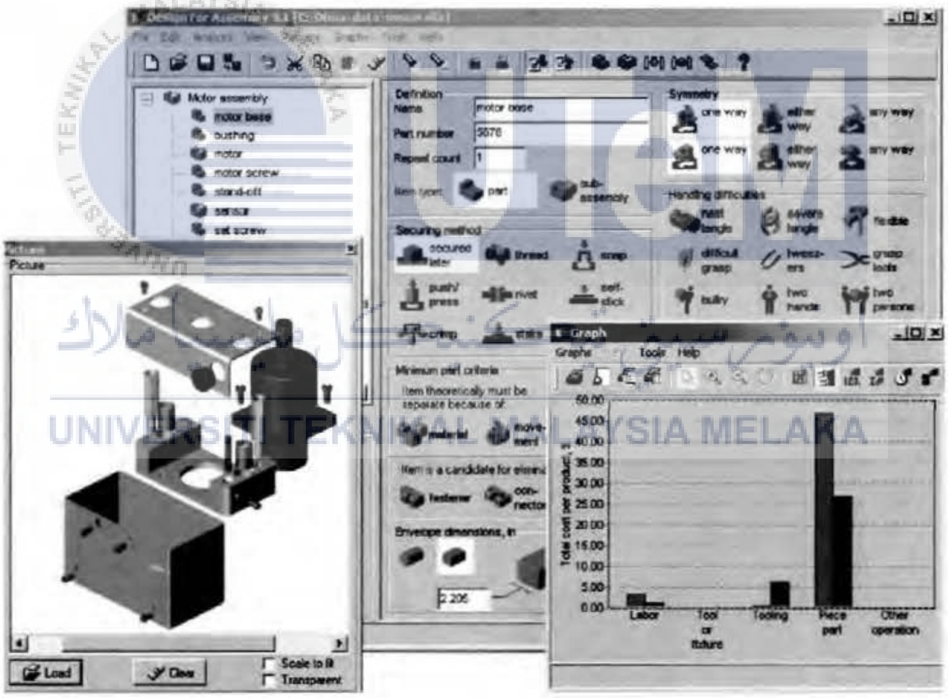


Figure 3.18: DFA user interface

Respective columns are prepared in the question-and-answer interface. The questions that need to be answered are part name, part number, life volume, repeat count, labour rate, overall plant efficiency, and envelope shape as well as dimensions. Then, assembly features such as securing method, handling and insertion difficulties need to be identified. DFA 9.3 software has a column for labour time. This column is also significant in determining the total assembly time of the product. It is important to determine the item fetching distance in order to calculate the item handling and fetching time. Table 3.5 shows example of the executive summary generated from DFA software whereas Figure 3.19 shows the chart for cost breakdown per product.

Table 3.5: DFA Executive summary

Per Product data	Entries (including repeats)	Labor Time, s	Labor Cost, RM
Component parts	44	444.97	0.75
Subassemblies partially or fully analyzed	3	54.15	0.09
Subassemblies not to be analyzed (excluded)	0	0.00	0.00
Standard and library operations	25	451.87	0.76
Totals	**72**	**950.99**	**1.60**

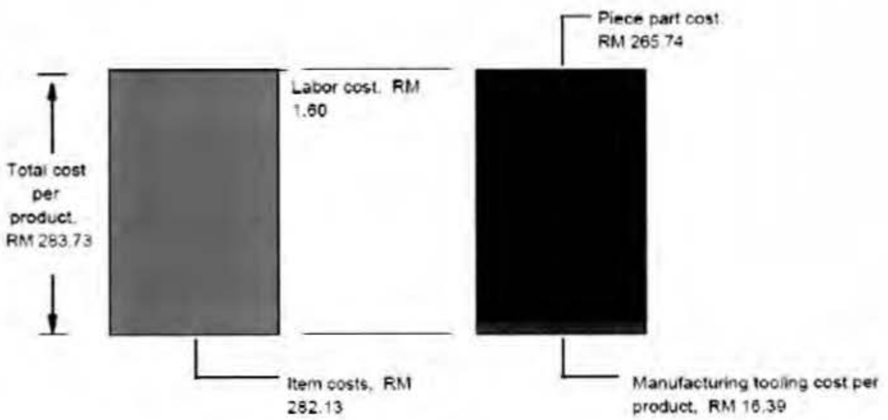


Figure 3.19: Cost breakdown per product

CHAPTER 4

DFMA ANALYSIS FOR EXISTING PRODUCTS

DFMA analysis can be done manually or automatically (software analysis). Before analysing the existing products using DFMA method, brief product case studies are carried out. Firstly, the existing products are dismantled. The number of parts of the products are calculated. Then, detailed drawing with detailed dimensions of each parts are done. These brief case studies on the products can help researchers to understand the assembly methods and manufacturing processes of the products. The DFMA method used in this project is Boothroyd-Dewhurst DFMA method. In this chapter, product descriptions for selected products are discussed. Then part list and assembly flow chart of selected products are provided. Lastly, the selected products are analysed using Boothroyd-Dewhurst DFMA method.

4.1 Product Description

In this project, the products selected for Boothroyd-Dewhurst DFMA analysis are hairdryers. The models of hairdryer selected are Elba EHD-1198G and Khind HD 1600. Both of the hairdryers are chosen due to their availability in the market.

4.1.1 Khind HD 1600 hairdryer

Khind HD 1600 hairdryer is a low cost hairdryer that can be found in most of the supermarkets. It is a non-foldable hairdryer. It is inconvenience to bring Khind HD 1600 hairdryer during vacation because it wasted a lot of space if users wish to store it in the luggage. This model of hairdryer has 2 speed and 3 temperature settings.

This model of hairdryer even provides cool air selection. If the hairdryer exceed a certain temperature, the electricity of the hairdryer will be cut-off automatically by the thermal cut-off switch. It operates at 1300W to 1600W. The product specification of Khind HD 1600 hairdryer is listed in Table 4.1.

Table 4.1: Product description of Khind HD 1600 Hairdryer

Criterion	Product Specification
Product Name	Khind HD 1600
Purpose	Dry and shape hair
Weight	0.45kg
Dimensions	82 mm x 146mm x 234 mm
Energy Consumption	1300W – 1600W
Speed Setting	2
Temperature Setting	3
Cool Air Selection	Yes
Handle	Non- foldable
Part Count	29
Retail Price	RM43.95

Table 4.1 shows the product specification of Khind HD 1600 Hairdryer. The main function of this hairdryer is to blow dry and style hair into desired shape. It weighs 0.45kg. The overall envelope dimensions of this hairdryer is 82 mm x 146mm x 234 mm. It has 2 speed, 3 temperature setting as well as cool air selection. The handle of this hairdryer is non-foldable. It needs around 1300W to 1600W to operate. There is a total of 29 parts in Khind HD 1600 hairdryer. The retail price of this model of

hairdryer is RM43.95. Figure 4.1 shows the real product of Khind HD 1600 hairdryer available in the market.

Figure 4.1: Khind HD 1600 hairdryer

4.1.2 Elba EHD-1198G hairdryer

Elba EHD-1198G hairdryer is a low cost hairdryer that can be found in most of the supermarkets and retail stores. It is a foldable hairdryer that can be easily bring along during vacations. The foldable handle eliminates space-waste. It can be stored easily due to the foldability of its handle. This model of hairdryer has 2 speed and 2 heat settings. It has a safety feature that can prevent overheat of the hairdryer. If the hairdryer exceed a certain temperature, the electricity of the hairdryer will be cut-off automatically by the thermal cut-off switch. It operates at 1200W. Table 4.2 below shows the product description of Elba EHD-1198G hairdryer.

Table 4.2: Product description of Elba EHD-1198G Hairdryer

Criterion	Product Specification
Product Name	Elba EHD-1198G
Purpose	Dry and shape hair
Weight	0.65kg
Dimensions	69 mm x 179mm x 225 mm
Energy Consumption	1200W
Speed Setting	2
Temperature Setting	2
Cool Air Selection	No
Handle	Foldable
Part Count	22
Retail Price	RM49.90

Table 4.2 shows the product specification of Elba EHD-1198G Hairdryer. The main function of this hairdryer is to blow dry and style hair into desired shape. It weighs 0.65kg. The overall envelope dimensions of this hairdryer after it is folded is 69 mm x 179 mm x 225 mm. It has 2 speed and 2 temperature setting. However, it has no cool air selection. The handle of this hairdryer is foldable. It operates at 1200W. There is a total of 22 parts in Elba EHD-1198G hairdryer. The retail price of this model of hairdryer is RM49.90. Figure 4.2 shows the real product of Elba EHD-1198G hairdryer that is available in the market.

Figure 4.2: Elba EHD-1198G hairdryer

4.1.3 Product Comparisons

Table 4.3 shows a comparison table between the specifications of Khind HD 1600 hairdryer and Elba EHD-1198G hairdryer.

Table 4.3: Hairdryers specifications comparison

Model / Specification	Khind HD 1600	Elba EHD-1198G
Product Name	Khind HD 1600	Elba EHD-1198G
Purpose	Dry and shape hair	Dry and shape hair
Weight	0.45kg	0.65kg
Dimensions	82 mm x 146mm x 234 mm	69 mm x 190mm x 225 mm
Energy Consumption	1300W – 1600W	1200W
Speed Setting	2	2
Temperature Setting	3	2
Cool Air Selection	Yes	No
Handle	Non- foldable	Foldable
Part Count	29	22
Retail Price	RM43.95	RM49.90

Table 4.3 shows the specification comparisons for both Khind HD 1600 and Elba EHD-1198G hairdryer. From this comparison table, it can be noticed that both of the hairdryer have the same general functions, which are to blow dry and style hairstyle. However, it can be seen that Khind HD 1600 has lighter weight compared to Elba EHD-1198G. Khind HD 1600 hairdryer is a non-foldable hairdryer. Elba EHD-1198G hairdryer is a foldable hairdryer. Due to the foldability of its handle, Elba EHD-1198G takes less capacity for storage. It has smaller overall envelop dimensions compared to Khind HD 1600. Both of the hairdryer have 2 speed setting. Khind HD 1600 has 3 temperature setting whereas Elba EHD-1198G hairdryer has 2 temperature setting. Khind HD 1600 hairdryer has cool air setting that can help to set the shape of hair effectively and to minimise the damage of hair. Khind HD 1600 hairdryer has a total of 29 parts whereas Elba EHD-1198G hairdryer has a total of 29 parts. The retail price of Khind HD 1600 is lower than Elba EHD-1198G hairdryer (RM43.95 and RM49.90 respectively).

4.2 Analysis of the Selected Products

Both of the selected hairdryers had gone through dismantling process. By dismantling the existing products, researchers can have better understanding regarding the assembly process of the products. Besides that, by dismantling the selected products, detailed drawing of the each parts can be produced. Total number of part of the product can also be calculated. The quantity of each item are listed in detailed in the table. A brief description of each part is also provided in the table.

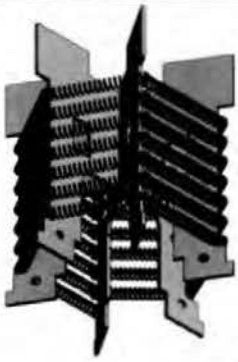
4.2.1 Khind HD 1600 Hairdryer

A detailed part list of Khind HD 1600 hairdryer is shown in Table 4.4. From Table 4.4 below, it can be noticed that Khind HD 1600 hairdryer has 29 parts in total. Among the 29 parts, 10 of them are fasteners.

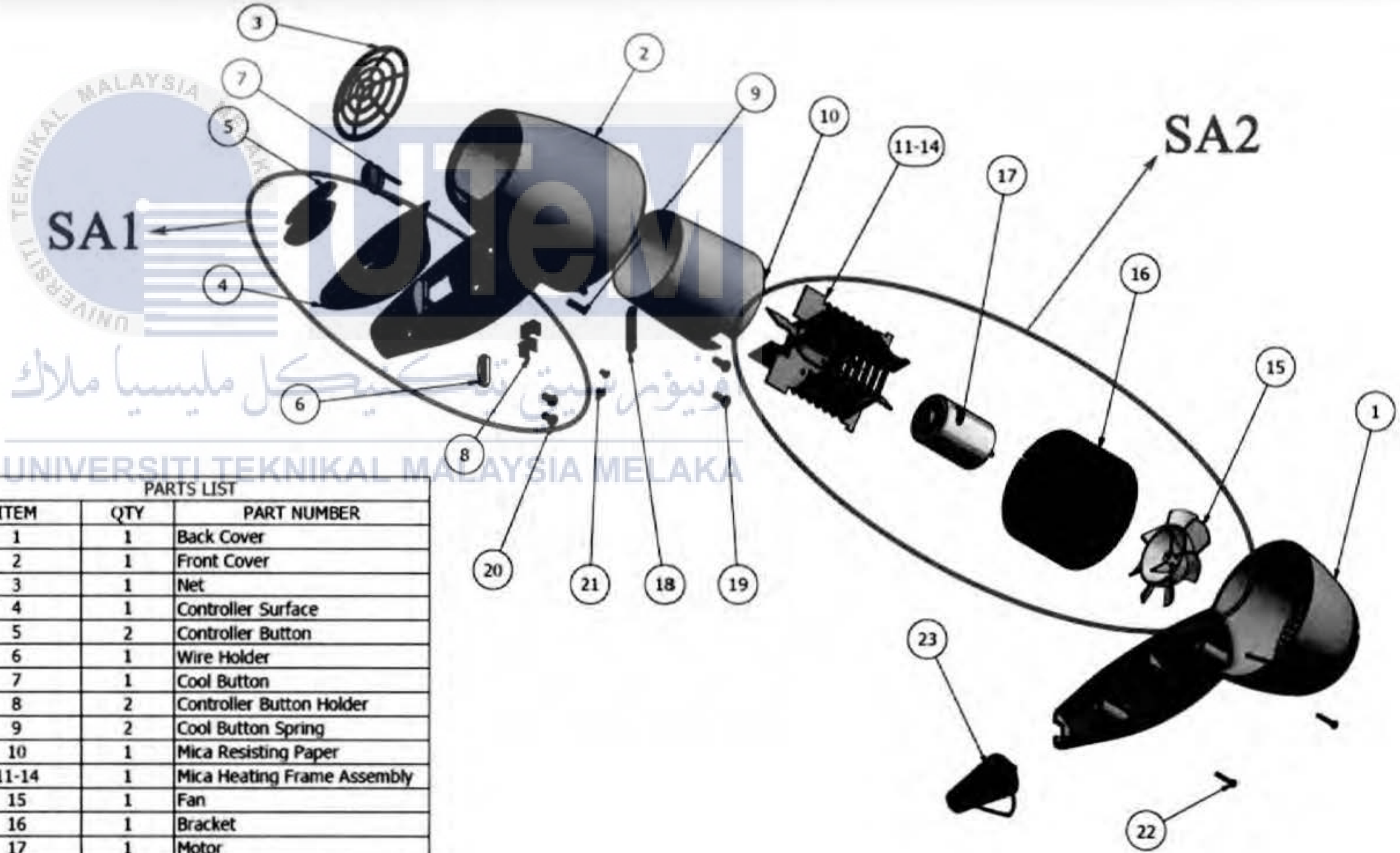
Table 4.4: Detailed part list of Khind HD 1600 hairdryer

Code	Part Name	Figure	Quantity	Description
K01	Back Cover		1	Protect electrical and mechanical components of hairdryer.
K02	Front Cover		1	Protect electrical and mechanical components of hairdryer.
K03	Net		1	Air outlet ventilation.

K04	Controller Surface		1	Guide the sliding motion of the controller button.
K05	Controller Button		2	Control speed and heat of hairdryer.
K06	Wire Holder		1	Keep the electrical wire in place.
K07	Cool Button		1	Control cool air setting of hairdryer.
K08	Controller Button Holder		2	Fix controller button.
K09	Cool Button Spring		2	Allow cool air button to return to its position.

K10	Mica Resisting Paper		1	Prevent overheating of plastic housing.
K11	Heating element		1	Produce heat.
K12	Fan		1	Blow air through heated coil.
K13	Bracket		1	Direct air into heating element.
K14	Motor		1	Provide mechanical motion.
K15	Wire Holder1		1	Fix wire in place.

K16	Screw M3 x 8 - 4.8 - H		2	Fastener.
K17	Screw M3 x 6 - 4.8 - H		4	Fastener.
K18	Screw M2x4 - 8.8 - H1		2	Fastener.
K19	Spanner Screw		2	Fastener.
K20	Wire Cord		1	Hang hairdryer for easy storage.
		TOTAL	29	



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Back Cover
2	1	Front Cover
3	1	Net
4	1	Controller Surface
5	2	Controller Button
6	1	Wire Holder
7	1	Cool Button
8	2	Controller Button Holder
9	2	Cool Button Spring
10	1	Mica Resisting Paper
11-14	1	Mica Heating Frame Assembly
15	1	Fan
16	1	Bracket
17	1	Motor
18	1	Wire Holder1
19	2	Screw M3 x 8 - 4.8 - H
20	4	Screw M3 x 6 - 4.8 - H
21	2	Screw M2x4 - 8.8 - H1
22	2	Spanner Screw

Figure 4.3: Exploded view with the labelling of sub-assemblies of Khind HD 1600 hairdryer

Figure 4.3 above shows the exploded view with the labelling of sub-assemblies of Khind HD 1600 hairdryer. From Figure 4.3, it can be seen that Khind HD 1600 hairdryer is made up of 29 parts. There are 2 sub-assemblies found in the Khind HD 1600 hairdryer. SA1 is the sub-assembly of controller; it consists of controller button holder, controller button, controller surface and screws M2x4. SA2 is the sub-assembly of mechanical part; it consists of a heating component, motor, bracket, fan and screws M3x6.

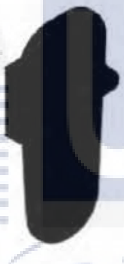
4.2.2 Elba EHD-1198G Hairdryer

A detailed part list of Elba EHD-1198G hairdryer is shown in Table 4.5. From Table 4.5 below, it can be noticed that Elba EHD-1198G hairdryer has 21 parts in total. Among the 21 parts, 4 of them are fasteners.

Table 4.5: Detailed part list of Elba EHD-1198G hairdryer

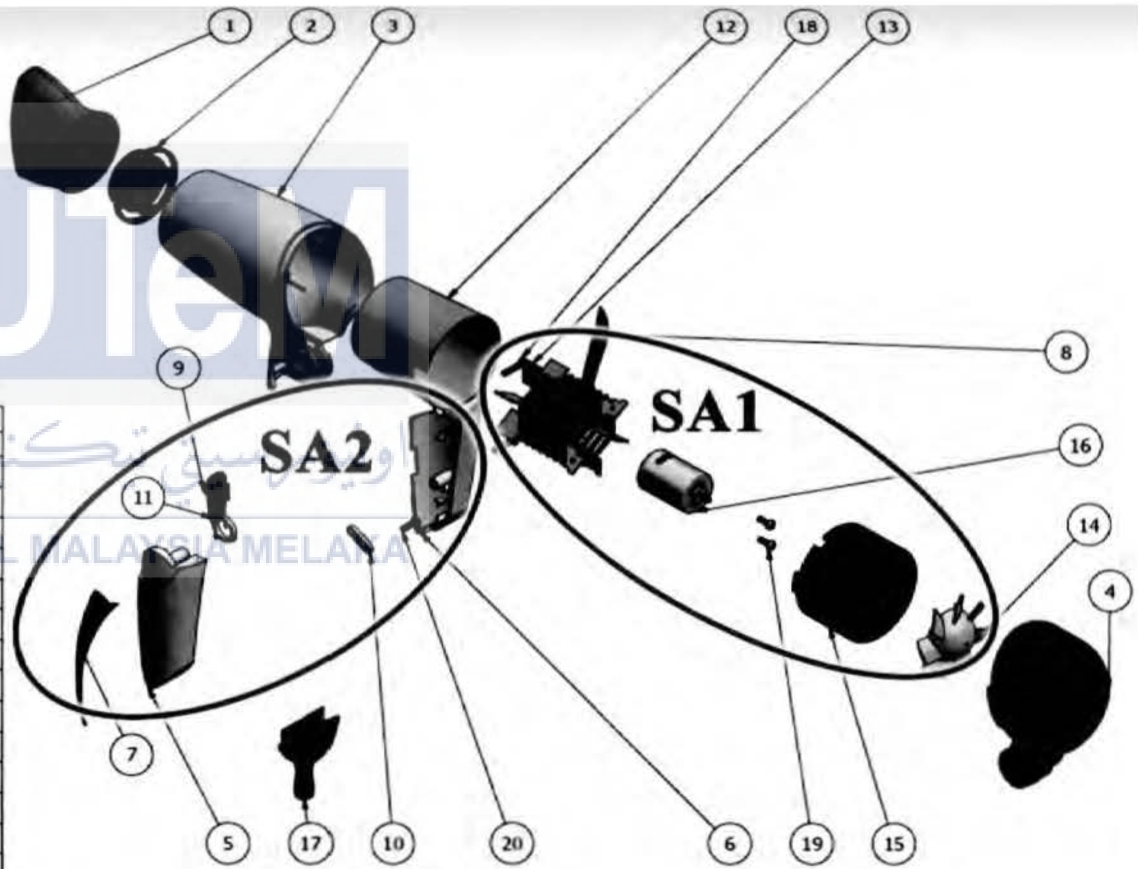
Code	Part Name	Figure	Quantity	Description
E01	Concentrator		1	Concentrate the air flow.
E02	Net		1	Air outlet ventilation.

E03	Front Body		1	Protect electrical and mechanical components of hairdryer.
E04	Back Body		1	Protect electrical and mechanical components of hairdryer.
E05	Handle		1	Protect electrical and mechanical components of hairdryer.
E06	Handle 2		1	Protect electrical and mechanical components of hairdryer.

E07	Strap		1	Aesthetics.
E08	Strap 2		1	Aesthetics.
E09	Button		1	Control speed and heat of hairdryer.
E10	Wire Holder		1	Keep the electrical wire in place.
E11	Joint		1	Provide rotary movement.

E12	Mica Resisting Paper		1	Prevent overheating of plastic housing.
E13	Heating Element		1	Produce heat.
E14	Fan		1	Blow air through heated coil.
E15	Bracket		1	Direct air into heating element.
E16	Motor		1	Provide mechanical motion.

E17	Wire Cord		1	Hang hairdryer for easy storage.
E18	Screw M3x10		1	Fastener.
E19	Screw M3x14		2	Fastener.
E20	Screw M3x8		2	Fastener.
		TOTAL	22	



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Concentrator
2	1	Net
3	1	Front Body
4	1	Back Body
5	1	Handle
6	1	Handle2
7	1	Strap
8	1	Strap2
9	1	Button
10	1	Wire Holder
11	1	Joint
12	1	Mica Resisting Paper
13	1	HeatingElement
14	1	Fan
15	1	Bracket
16	1	Motor
17	1	Wire Cord
18	2	Screw M3 x 14 - 4.8 - H
19	2	Screw M3 x 8 - 4.8 - H
20	1	Screw M3 x 10 - 4.8 - H

Figure 4.4: Exploded view with the labelling of sub-assemblies of Elba EHD-1198G hairdryer

Figure 4.4 above shows the exploded view with the labelling of sub-assemblies of Elba EHD-1198G hairdryer. From Figure 4.4, it can be seen that Elba EHD-1198G hairdryer is made up of 22 parts. There are 2 sub-assemblies found in the Khind HD 1600 hairdryer. SA1 is the mechanical sub-assembly; it consists heating component, motor, bracket, fan and screws M3x8. SA2 is the handle sub-assembly; it consists of a joint, handle, wire holder, button, Screw M3x10 and Screw M3x14.

4.3 Assembly Flow Chart of the Selected Products

After dismantling both of the hairdryers, assembly flow chart are constructed to show the assembly sequence of the product.

4.3.1 Khind HD 1600 Hairdryer

Figure 4.5 shows the assembly flow chart of Khind HD 1600 hairdryer. From Figure 4.5, it can be observed that the controller of Khind HD 1600 hairdryer is made up of 5 parts, i.e. a controller button holder, two controller buttons, a controller surface and two screws M2x4. The mechanical sub-assembly of Khind HD 1600 hairdryer is made up of 6 parts, i.e. a heating component, a motor, a bracket, a fan and two screws M3x6. All the other parts such as cool air button, front cover, back cover and etcetera are joined together with the sub-assemblies to form Khind HD 1600 hairdryer.

In order to assemble Khind HD 1600 hairdryer, firstly, the mechanical sub-assembly is inserted into the back cover. Then, the net, mica resisting paper and cool air button are inserted to the front cover respectively. All the wires and electrical components are fixed using wire holders and screws. Springs are assembled at the end of the cool air button to ensure that the cool air button can return to its original position uniformly after being pressed. Next, wire cord is inserted at the bottom, between front and back covers. Lastly, by using two spanner screws, both the front and back covers are fastened together to form a complete hairdryer assembly.

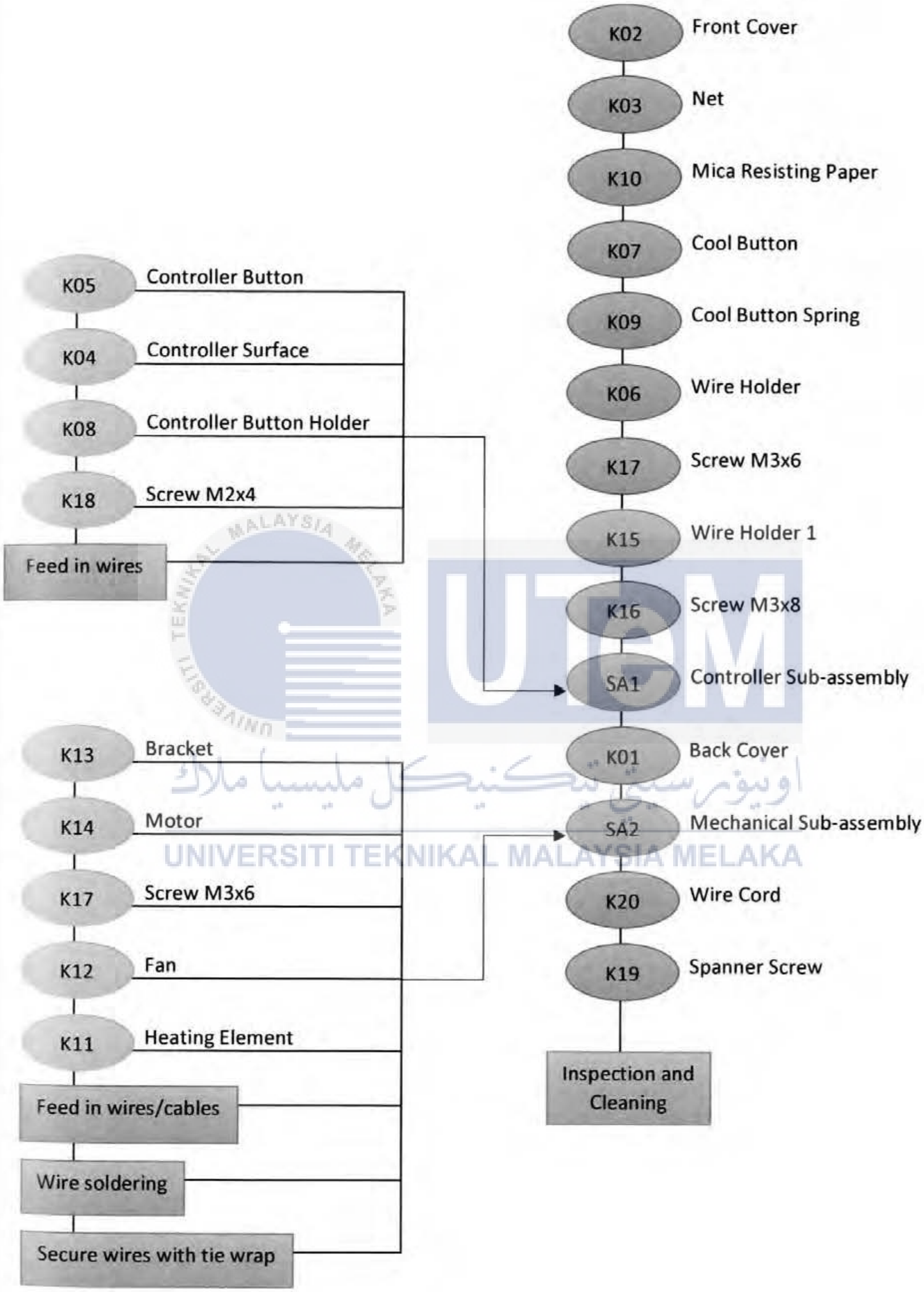


Figure 4.5: Assembly flow chart of Khind HD 1600 hairdryer

4.3.2 Elba EHD-1198G Hairdryer

Figure 4.6 shows the assembly flow chart of Elba EHD-1198G hairdryer. From Figure 4.6, it can be observed that the handle of Elba EHD-1198G hairdryer is made up of 6 parts, i.e. a joint, handle, wire holder, button, Screw M3x10 and Screw M3x14. The mechanical sub-assembly of Elba EHD-1198G hairdryer is made up of 6 parts, i.e. a heating component, motor, bracket, fan and screws M3x8. All the other parts such as front body, back body, concentrator and etcetera are joined together with the sub-assemblies to form Elba EHD-1198G hairdryer.

In order to assemble Elba EHD-1198G hairdryer, firstly, the concentrator is inserted at the outlet of the front body. Then, the net, mica resisting paper and mechanical sub-assembly are inserted into the front body. After inserted all the required components, the front body and back body are fixed together using snap-fit method. Next, the handle sub-assembly is joint with the front and back body. All the wires and electrical components are fixed using wire holders and screws. Next, wire cord is inserted at the bottom of the handle. Lastly, by using two screws, the handle and front body and back body are fastened together to form a complete hairdryer assembly.

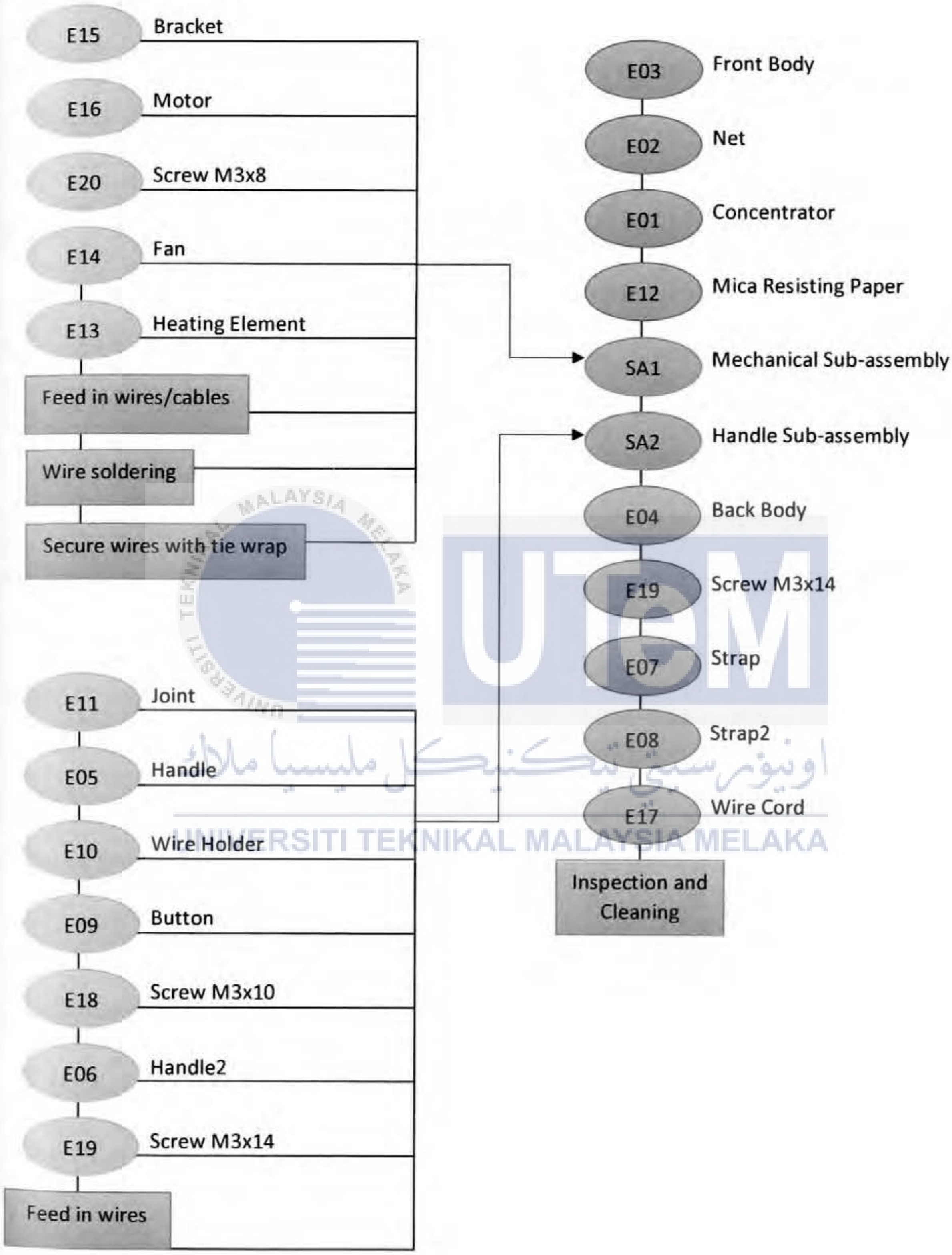


Figure 4.6: Assembly flow chart of Elba EHD-1198G hairdryer

4.4 Manufacturing Process

Appropriate manufacturing process should be selected for each parts so that the required attributes can be achieved. The manufacturing process selection should be done by matching the required attributes of each parts with various process capabilities. Most of the parts or components are not manufactured by just a single process. Normally, a sequence of different processes are required to produce a single component. By applying several processes, all the attributes required by the component can be achieved with satisfying result. Manufacturing process can be classified into three categories, i.e. primary, secondary and tertiary. When a raw material is used to produce a basic shape of the component, the process is considered as a primary manufacturing process. Primary manufacturing process can also be known as shape generating process. Sand casting, molding and deformation process are some of the examples of primary manufacturing process. Features such as keyways and thread are produced by secondary manufacturing process. Tertiary manufacturing process can also be known as finishing process. It does not change the geometry and shape of a component. It only improves the appearance of the component. Coating, painting and deburring are some of the examples of tertiary manufacturing process. Table 4.6 shows the part descriptions for DFM analysis of Khind HD 1600. Table 4.7 shows the part descriptions for DFM analysis of Elba EHD-1198G hairdryer.

Table 4.6: Part descriptions for DFM analysis of Khind HD 1600

Item	Part Name	Figure	Manufacturing Process	Material
K01	Back Cover		Injection Molding	ABS
K02	Front Cover		Injection Molding	ABS
K03	Net		Impact Extrusion	Carbon Steel
K04	Controller Surface		Injection Molding	ABS
K05	Controller Button		Injection Molding	ABS
K06	Wire Holder		Injection Molding	ABS
K07	Cool Button		Injection Molding	ABS

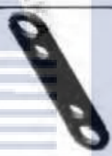
K08	Controller Button Holder		Injection Molding	ABS
K10	Mica Resisting Paper		Injection Molding	Dolomite
K12	Fan		Injection Molding	ABS
K13	Bracket		Injection Molding	ABS
K15	Wire Holderl		Injection Molding	ABS
K20	Wire Cord		Injection Molding	Polyamide

Table 4.7: Part descriptions for DFM analysis of Elba EHD-1198G

Item	Part Name	Figure	Manufacturing Process	Material
E01	Concentrator		Injection Molding	ABS
E02	Net		Injection Molding	ABS
E03	Front Body		Injection Molding	ABS
E04	Back Body		Injection Molding	Polyamide
E05	Handle		Injection Molding	ABS

E06	Handle2		Injection Molding	ABS
E07	Strap		Injection Molding	Polyamide
E08	Strap2		Injection Molding	Polyamide
E09	Button		Injection Molding	ABS
E10	Wire Holder		Injection Molding	ABS

E11	Joint		Injection Molding	ABS
E12	Mica Resisting Paper		Injection Molding	Dolomite
E14	Fan		Injection Molding	ABS
E15	Bracket		Injection Molding	ABS
E17	Wire Cord		Injection Molding	Polyamide

4.4.1 Khind HD 1600 hairdryer

From Table 4.6, it ca be seen that Part K03, net is made of carbon steel. Part K10, mica resisting paper is made of dolomite. Part K20, wire cord is made of polyamides. Other than these three parts, all the other parts are made of acrylonitrile butadiene styrene (ABS). Not all the combinations of processes and materials are possible. According to Figure 4.7 below, carbon steel is compatible with impact extrusion bulk deformation process. For thermoplastics such as polyamides, dolomite and ABS, injection molding solidification process is possible to be used as the manufacturing process. In other words, the manufacturing processes used to manufacture Khind HD 1600 hairdryer are mainly injection molding and impact extrusion.

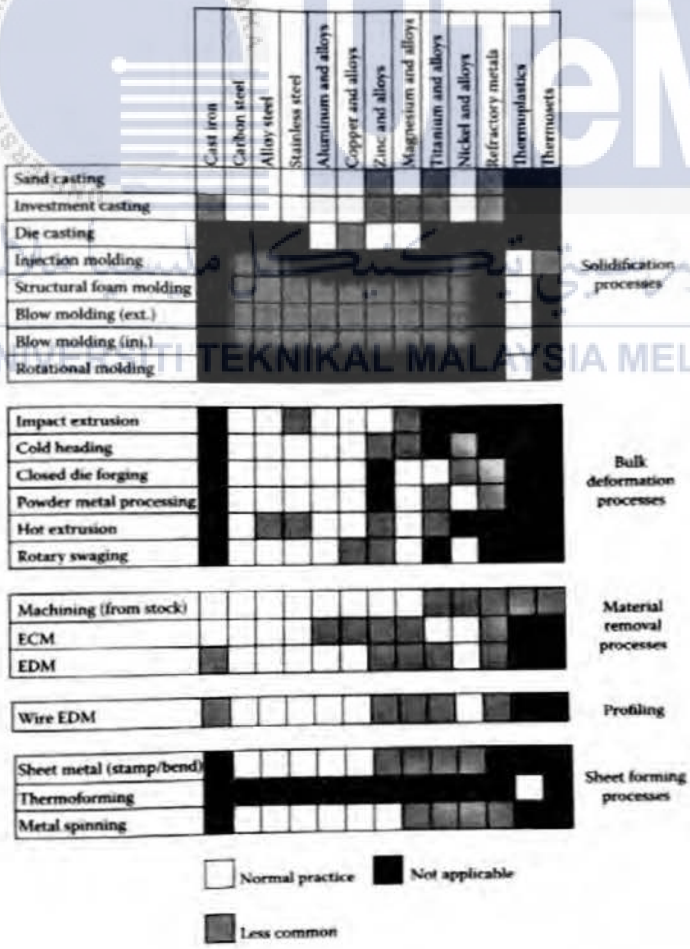


Figure 4.7: Compatibility between processes and materials

4.4.2 Elba EHD-1198G Haiedryer

From Table 4.7, it can be seen that Part E04, E07 and E08 which are back body and straps respectively are made of nylon. Part E12, mica resisting paper is made of dolomite. Part E17, wire cord is made of polyamides. Other than these parts, all the other parts are made of acrylonitrile butadiene styrene (ABS). Not all the combinations of processes and materials are possible. The manufacturing processes used to manufacture Khind HD 1600 hairdryer are mainly injection molding.

4.4.3 Injection Molding

Injection molding is a manufacturing process that produce parts in large quantities. It is normally used in mass-production industries to produce thousands or millions of similar parts in one succession. In mass-production industries, injection molding is considered as a low cost manufacturing process. Although the initial tooling cost is high, once the initial tooling cost is paid, the cost for injection molding the parts will be extremely low. Therefore, injection molding is a suitable for the mass-manufacturing of hairdryers. Injection molding one of the solidification process. It is capable of producing elegant product structures with minimal part counts. By using injection molding to fabricate the components of hairdryers, the number of total parts can be reduced. This is because injection molding can form complex shapes with fine details and accuracy. However, not all materials are possible to injection-mold. Injection molding is normally used for thermoplastic polymers such as ABS, polyamide, polycarbonate, polystyrene and etcetera. This is most probably because thermoplastic polymers will reach a state of fluidity after continuous heating. Besides thermoplastics, some thermosets and elastomers can also be used for injection molding. Injection molding is done by pouring melted thermoplastic into a steel mold with desired attributes via a hopper. When the heated thermoplastic cools, it will solidify and form the part desired.

4.4.4 Impact Extrusion

Impact extrusion is a manufacturing process that produce parts in large quantities. It is normally applied in mass-production industries to produce the same parts repeatedly. In mass-production industries, impact extrusion is considered as a low cost manufacturing process. Although the initial tooling cost is high, once the initial tooling cost is paid, the cost for impact extruding the parts will be extremely low. Therefore, impact extrusion is a suitable for the mass-manufacturing of Part K03, net of hairdryers. It is a bulk deformation process that is almost similar to extrusion. It is a process where metal slug is punched into a die using hydraulic press. The hard punch produced by hydraulic press forces the metal slug to deform and fit the punch on the inside and the die on the outside. After the metal slug is deformed to the desired shape, an ejector will eject the desired part from the die.

4.5 Process Flow before Modification

It is essential to determine the process flow for each parts of the product in DFM analysis. Process flow of a component consists of storage process, inspection process, transportation process and manufacturing process. Table 4.8 shows the lists of symbol for process flow and their descriptions.

Table 4.8: Lists of symbol for process flow and their descriptions

Symbol	Process	Description
	Storage	Permanent storage of materials.
	Inspection	Checking up to ensure quality and quantity of items.
	Transportation	Movement of workers or items.
	Operation	Complex process that often changes the attributes of items.

4.5.1 Process Flow of Injection Molding

Most of the parts in the hairdryers are manufactured using injection molding technique. Firstly, raw materials are bought from suppliers. After inspecting the quality and quantity of the raw materials, the raw materials are transported to factories for injection molding. There are three stages of operation in injection molding technique, i.e. melting raw materials, injection molding and solidifying. Each operations is accompanied by an inspection. Then, the finished parts are delivered to another section for surface finishing process. Before the part can be used or kept in storage, a final inspection on the quality and quantity is needed. Figure 4.8 shows the process flow of injection molding.

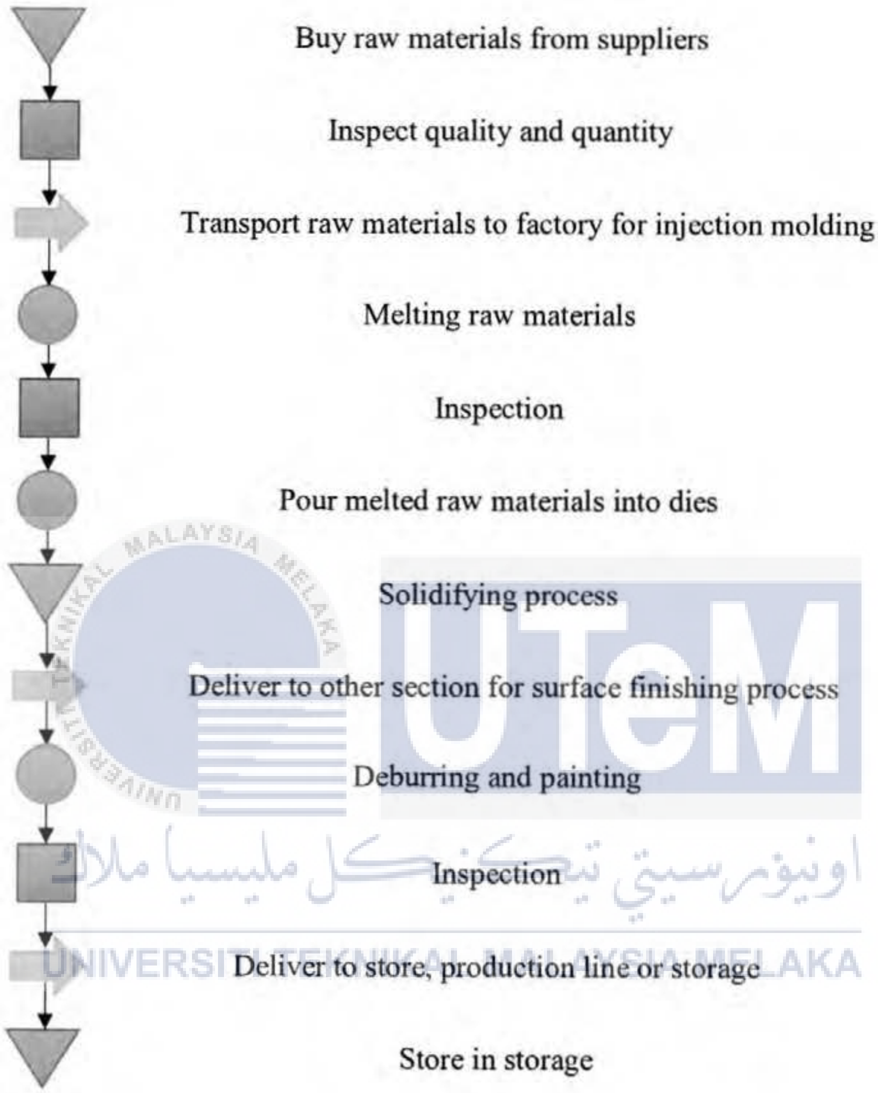


Figure 4.8: Process flow of injection molding

4.5.2 Process Flow of Impact Extrusion

Part K03, net is manufactured by impact extrusion. Firstly, raw materials are bought from suppliers. After inspecting the quality and quantity of the raw materials, the raw materials are transported to factories for impact extrusion. There are two stages of operation in impact extrusion technique, i.e. punch and counter punch. Each operations is followed by an inspection. Then, the finished parts are delivered to another section for surface finishing process. Inspection is needed before the part can be used or stored. Figure 4.9 shows the process flow of impact extrusion.

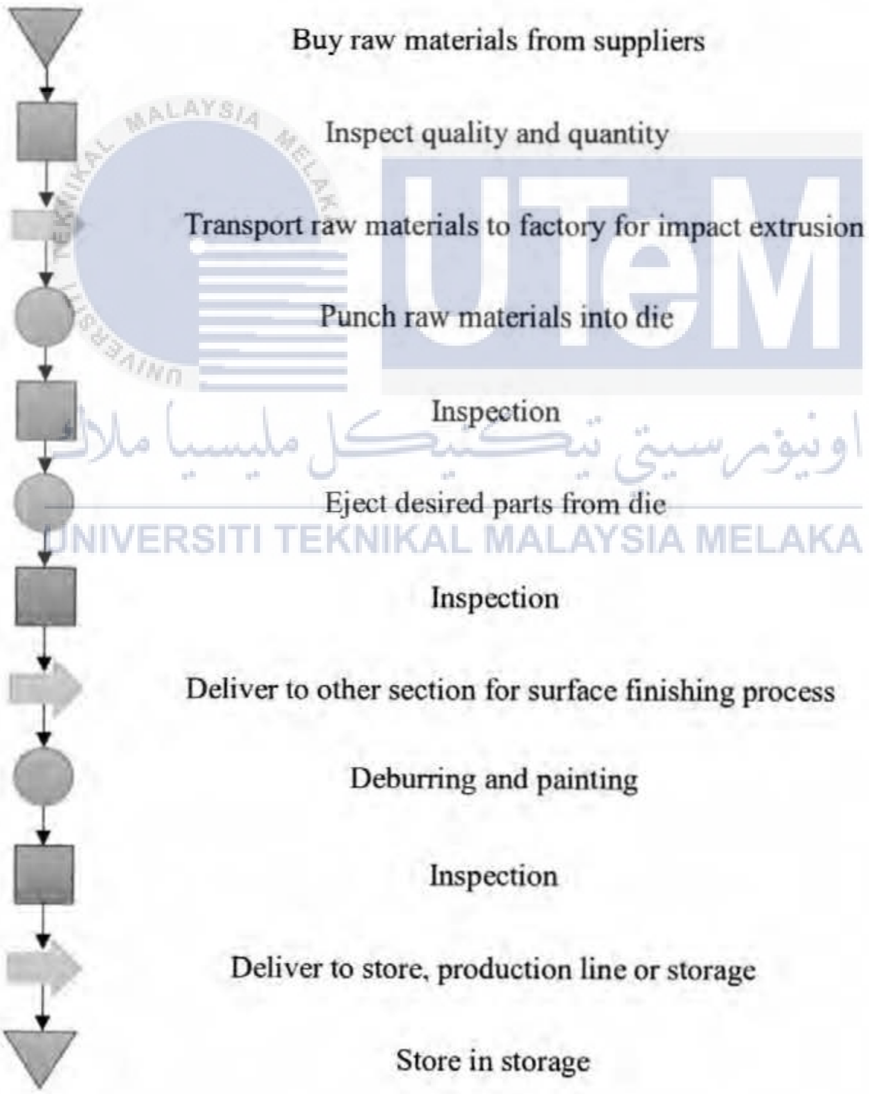


Figure 4.9: Process flow of impact extrusion

4.5.3 Process Flow of Purchased Parts

Heating element, springs and fasteners are purchased parts. After purchasing the parts from the suppliers, inspection is carried out. Then, the purchased parts are delivered to the production line for assemblage or kept in storage for future use. Figure 4.10 shows the process flow of purchased parts.

Figure 4.10: Process flow of purchased part

4.6 Theoretical Minimum Part Count

Before the design efficiency of a product is calculated, the number of theoretical part count need to be determined. Theoretical minimum part count can be determined through three criteria, i.e. movement, isolation and separation. By answering questions related to these three criteria, the number of theoretical part count of a product can be obtained. Table 4.9 shows the criteria that should be considered in estimating the theoretical minimum part count.

Table 4.9: Criteria that should be considered in estimating the theoretical minimum part count

Criteria	Description/Question
Movement	Does the part move relative to all other parts already assembled?
Isolation	Must the part be made from a different material or isolated?
Separation	Must the part be separated from all other assembled parts?

By answering three questions listed above, the importance of a part can be determined. If the answer is "Yes" for any question stated above, the part can be considered as a theoretical part. If there is a "No" for any of these questions, the part can be considered as a candidate for elimination.

4.6.1 Khind HD 1600 Hairdryer

Khind HD 1600 hairdryer consists of 29 parts in total. Among the 29 parts, if multiple instances are ignored, there are only 19 different parts. All the parts are analysed using the criteria stated above to determine the theoretical minimum part count of Khind HD 1600 hairdryer. Table 4.10 below shows the determination of theoretical minimum part count of Khind HD 1600 hairdryer.

Table 4.10: Determination of theoretical minimum part count of Khind HD 1600 hairdryer

		Criteria				
Item	Part Name	Movement	Isolation	Separation	Theoretical Part	Justification
K01	Back Cover	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
K02	Front Cover	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
K03	Net	No	No	No	✗	Can be combined with other parts.
K04	Controller Surface	No	No	No	✗	Can be combined with other parts.
K05	Controller Button	Yes	No	Yes	✓	Move to adjust speed and temperature.
K06	Wire Holder	No	No	No	✗	Can be combined with other parts.
K07	Cool Button	Yes	No	Yes	✓	Move to produce cool air.
K08	Controller Button Holder	No	No	No	✗	Can be combined with other parts.
K09	Cool Button Spring	No	No	No	✗	Use button with incorporated spring.
K10	Mica Resisting Paper	No	Yes	No	✓	Mica prevents overheating and melting.
K11	Heating element	No	Yes	Yes	✓	Produce heat. Heat source.
K12	Fan	Yes	No	Yes	✓	Rotational motion to blow hot air out.

K13	Bracket	No	No	Yes	✓	Draw and direct hot air out.
K14	Motor	Yes	Yes	Yes	✓	Mechanical part, produce energy.
K15	Wire Holder1	No	No	No	✗	Can be combined with other parts.
K16	Screw M3 x 8 - 4.8 - H	No	No	No	✗	Fastener. Can be eliminated.
K17	Screw M3 x 6 - 4.8 - H	No	No	No	✗	Fastener. Can be eliminated.
K18	Screw M2x4 - 8.8 - H1	No	No	No	✗	Fastener. Can be eliminated.
K19	Spanner Screw	No	No	No	✗	Fastener. Can be eliminated.
K20	Wire Cord	No	No	No	✗	Can be combined with other parts.
TOTAL					10	

4.6.2 Elba EHD-1198G Hairdryer

Elba EHD-1198G hairdryer consists of 22 parts in total. Among the 22 parts, if multiple instances are ignored, there are only 20 different parts. All the parts are analysed using the criteria stated above to determine the theoretical minimum part count of Elba EHD-1198G hairdryer. Table 4.11 below shows the determination of theoretical minimum part count of Elba EHD-1198G hairdryer.

Table 4.11: Determination of theoretical minimum part count of Elba EHD-1198G hairdryer

		Criteria				
Item	Part Name	Movement	Isolation	Separation	Theoretical Part	Justification
E01	Concentrator	No	No	No	✗	Can be combined with other parts.
E02	Net	No	No	No	✗	Can be combined with other parts.
E03	Front Body	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
E04	Back Body	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
E05	Handle	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
E06	Handle2	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
E07	Strap	No	No	No	✗	Can be combined with other parts.
E08	Strap2	No	No	No	✗	Can be combined with other parts.
E09	Button	Yes	No	Yes	✓	Move to adjust speed and temperature.
E10	Wire Holder	No	No	No	✗	Can be combined with other parts.
E11	Joint	No	No	No	✗	Can be combined with other parts.

E12	Mica Resisting Paper	No	Yes	No	✓	Mica prevents overheating and melting.
E13	Heating Element	No	Yes	Yes	✓	Produce heat. Heat source.
E14	Fan	Yes	No	Yes	✓	Rotational motion to blow hot air out.
E15	Bracket	No	No	Yes	✓	Draw and direct hot air out.
E16	Motor	Yes	Yes	Yes	✓	Mechanical part, produce energy.
E17	Wire Cord	No	No	No	✗	Can be combined with other parts.
E18	Screw M3x10	No	No	No	✗	Fastener. Can be eliminated.
E19	Screw M3x14	No	No	No	✗	Fastener. Can be eliminated.
E20	Screw M3x8	No	No	No	✗	Fastener. Can be eliminated.
TOTAL					10	

4.7 Design Efficiency

DFA index is an essential method used in DFA analysis to determine the design efficiency of a product. DFA index can be calculated using the following equation:

$$E_{ma} = \frac{N_{min} t_a}{t_{ma}} \tag{1}$$

Where;

N_{min} = theoretical minimum part count;

t_a = basic assembly time for one part, 3 seconds

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

Equation (1) shows the formula for calculating DFA index. t_{ma} can be determined from manual handling and manual insertion table provide by Boothroyd and Dewhurst. From the table, designers can estimate the time for manual handling and insertion based on their difficulties.

4.7.1 Khind HD 1600 Hairdryer

The design efficiency of Khind HD 1600 hairdryer can be calculated based on the equation above. Table 4.12 shows the data required to calculate the design efficiency of Khind HD 1600 hairdryer. From the table, it can be observed that the design efficiency for Khind HD 1600 hairdryer calculated based on the manual handling and insertion difficulties is 10.59%. The total assembly time for Khind HD 1600 hairdryer is estimated to be 283.18s. When the value in column C8 is smaller than the value in column C2, this means that the part can be eliminated. The theoretical number of part count determined from this analysis is 10 parts.

Table 4.12: Design Efficiency of Khind HD 1600 hairdryer

Part Name	C1	C2	C3	C4	C5	C6	C7	C8
	Total angle of symmetry ($\alpha + \beta$), deg (°)	Number of times the operation is carried out consecutively	Two-digit manual handling code	Manual handling time per part (s)	Two-digit manual insertion code	Manual insertion time per part (s)	Total Operation time, seconds (s) (C4+C6)	Figure for estimation of theoretical minimum parts
Back Cover	720	1	30	1.95	17	9.0	10.95	1
Front Cover	720	1	30	1.95	17	9.0	10.95	1
Net	360	1	10	1.50	31	5.0	6.50	0
Controller Surface	720	1	30	1.95	39	8.0	9.95	0
Controller Button	720	2	30	1.95	10	4.0	11.90	1
Wire Holder	540	1	60	4.80	12	5.0	9.80	0
Cool Button	540	1	20	1.80	00	1.5	3.30	1

Controller Button Holder	720	2	70	5.10	21	6.5	23.20	0
Cool Button Spring	180	2	42	4.35	20	5.5	19.70	0
Mica Resisting Paper	360	1	10	1.50	00	1.5	3.00	1
Heating element	360	1	10	1.50	00	1.5	3.00	1
Fan	360	1	10	1.50	10	4.0	5.50	1
Bracket	360	1	10	1.50	10	4.0	5.50	1
Motor	360	1	10	1.50	10	4.0	5.50	1
Wire Holder1	540	1	60	4.80	12	5.0	9.80	0
Screw M3 x 8 - 4.8 - H	360	2	62	5.55	39	8.0	27.10	0
Screw M3 x 6 - 4.8 - H	360	4	62	5.55	39	8.0	54.20	0
Screw M2x4 - 8.8 - H1	360	2	63	8.80	39	8.0	33.60	0
Spanner Screw	360	2	62	5.55	39	8.0	27.10	0
Wire Cord	270	1	00	1.13	00	1.5	2.63	0
Design Efficiency=(3x10)/283.18=0.1059=10.59%							TM	NM
							283.18	10

4.7.2 Elba EHD-1198G Hairdryer

The design efficiency of Elba EHD-1198G hairdryer can be calculated based on the equation above. Table 4.13 shows the data required to calculate the design efficiency of Elba EHD-1198G hairdryer. From the table, it can be observed that the design efficiency for Elba EHD-1198G hairdryer calculated based on the manual handling and insertion difficulties is 17.57%. The total assembly time for Elba EHD-1198G hairdryer is estimated to be 170.75s. When the value in column C8 is smaller than the value in column C2, this means that the part can be eliminated. The theoretical number of part count determined from this analysis is 10 parts. In another words, 12 other parts of the hairdryer can be considered for elimination or modification.

Table 4.13: Data required to calculate the design efficiency of Elba EHD-1198G hairdryer

Part Name	C1	C2	C3	C4	C5	C6	C7	C8
	Total angle of symmetry ($\alpha + \beta$), deg (°)	Number of times the operation is carried out consecutivel y	Two-digit manual handling code	Manual handling time per part (s)	Two-digit manual insertion code	Manual insertion time per part (s)	Total Operation time, seconds (s) (C4+C6)	Figure for estimation of theoretical minimum parts
Concentrator	360	1	10	1.50	30	2.0	3.50	0
Net	360	1	10	1.50	31	5.0	6.50	0
Front Body	720	1	30	1.95	00	1.5	3.45	1
Back Body	720	1	30	1.95	03	3.5	5.45	1
Handle	720	1	30	1.95	07	6.5	8.45	1
Handle2	720	1	30	1.95	07	6.5	8.45	1
Strap	720	1	33	2.51	31	5.0	7.51	0
Strap2	720	1	33	2.51	31	5.0	7.51	0
Button	720	1	30	1.95	06	5.5	7.45	1

Wire Holder	540	1	60	4.80	12	5.0	9.80	0
Joint	540	1	60	4.80	12	5.0	9.80	0
Mica Resisting Paper	360	1	10	1.50	00	1.5	3.00	1
Heating Element	360	1	10	1.50	00	1.5	3.00	1
Fan	360	1	10	1.50	10	4.0	5.50	1
Bracket	360	1	10	1.50	10	4.0	5.50	1
Motor	360	1	10	1.50	10	4.0	5.50	1
Wire Cord	270	1	00	1.13	00	1.5	2.63	0
Screw M3x10	360	1	62	5.55	39	8.0	13.55	0
Screw M3x14	360	2	62	5.55	39	8.0	27.10	0
Screw M3x8	360	2	62	5.55	39	8.0	27.10	0
Design Efficiency=(3x10)/170.75=0.1757=17.57%							TM	NM
							170.75	10

CHAPTER 5

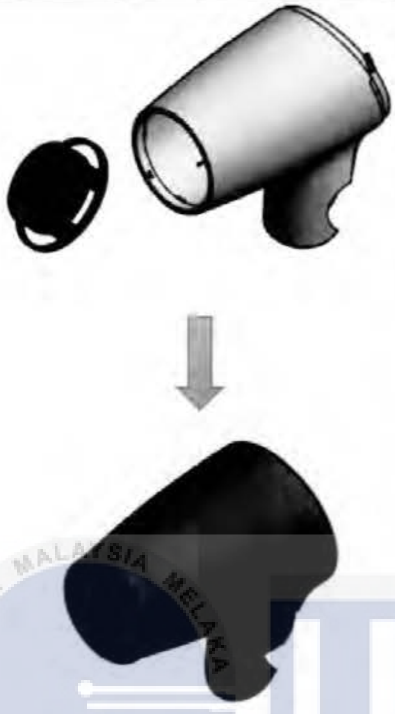
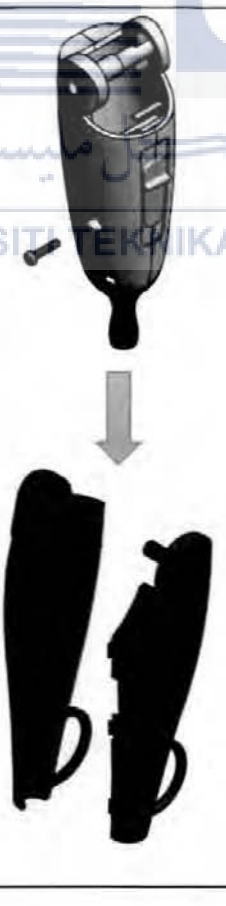
RESULTS AND DISCUSSION

In Chapter 4, DFMA analysis for the existing products, the design efficiency of both existing products are calculated. It can be seen that the design efficiency of Khind HD 1600 hairdryer is 10.95% whereas the design efficiency of Elba EHD-1198G hairdryer is 17.57%. From the comparison above, it can be concluded that the design of Elba EHD-1198G hairdryer is more efficient compared to of Khind HD 1600 hairdryer. The objective of this project is to design or improve a low cost hairdryer using DFMA analysis. In this case, the product with higher design efficiency will be selected for improvements in order to achieve even higher design efficiency. Therefore, Elba EHD-1198G hairdryer is selected for modifications and improvements.

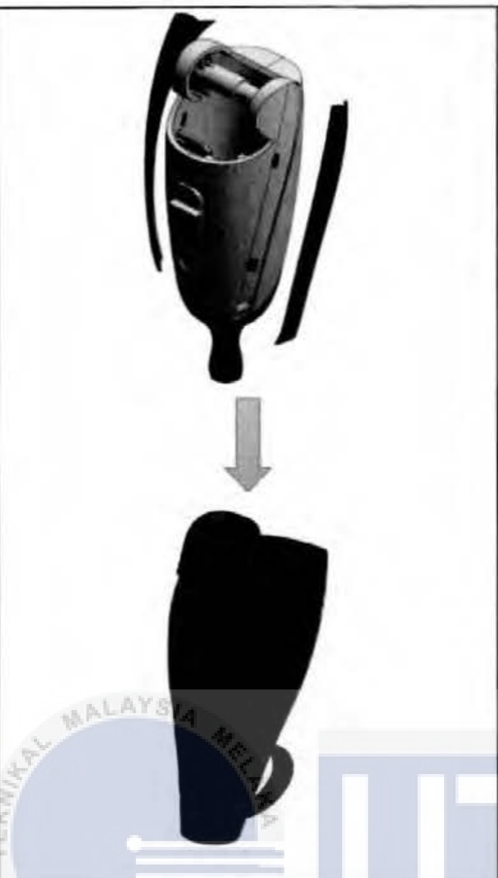
5.1 Design Improvements

The design of Elba EHD-1198G hairdryer is modified based on the DFMA analysis done in the previous chapter. Based on the DFMA analysis, some of the parts are unnecessary and can be eliminated. In the new design, a few fasteners are eliminated. Snap-fit fastening method is applied to replace fasteners because snap-fit fastening method requires less time during assembly. Next, parts that are manufactured from the same material, which have no specific movement will be combined with other parts to reduce the number of parts. Wire holder and joint are combined with the handle to reduce the number of parts. Net and front body of the hairdryer are also combined into 1 part. Besides that, some unnecessary aesthetic parts in the Elba EHD-1198G hairdryer are eliminated. Table 5.1 shows the design improvements for Elba EHD-1198G hairdryer.

Table 5.1: Design improvements for Elba EHD-1198G hairdryer

Modification	Figure	Justifications
Combine net with front body		Net and front body of Elba EHD-1198G hairdryer are made from the same material (ABS). Neither separation nor movement of net is needed for the hairdryer to operate. Therefore, net and front body can be combined as 1 part.
Apply snap-fit method to replace screw		Snap-fit fastening is cheaper compared to screw fastening. Screw requires longer assembly time compared to snap-fit.

Wire holder is combined with handle		Wire holder is a component that can keep all the wires in place. Wire holder and handle are made from the same material. Neither movement nor separation is needed. Therefore, they can be combined together.
Joint is combined with handle		Joint is a component that enables the hairdryer to have folding movement. Joint and handle are made from the same material. Neither movement nor separation is needed. Therefore, they can be combined together.

Unnecessary aesthetic parts are eliminated.		Right and left straps of Elba EHD-1198G hairdryer have no real function. Therefore, they can be eliminated.
Wire cord is eliminated		Wire cord is eliminated. However, the new designed is improved by combining the function of wire cord to the handle.

From Table 5.1 above, it can be seen that several modifications and improvements have been made to reduce the total number of parts of the hairdryer. By changing screw fastening into snap-fit fastening, total assembly time of the hairdryer can also be decrease. Thus, the design efficiency of the hairdryer can be increased.

5.2 Detailed Part List of New Design

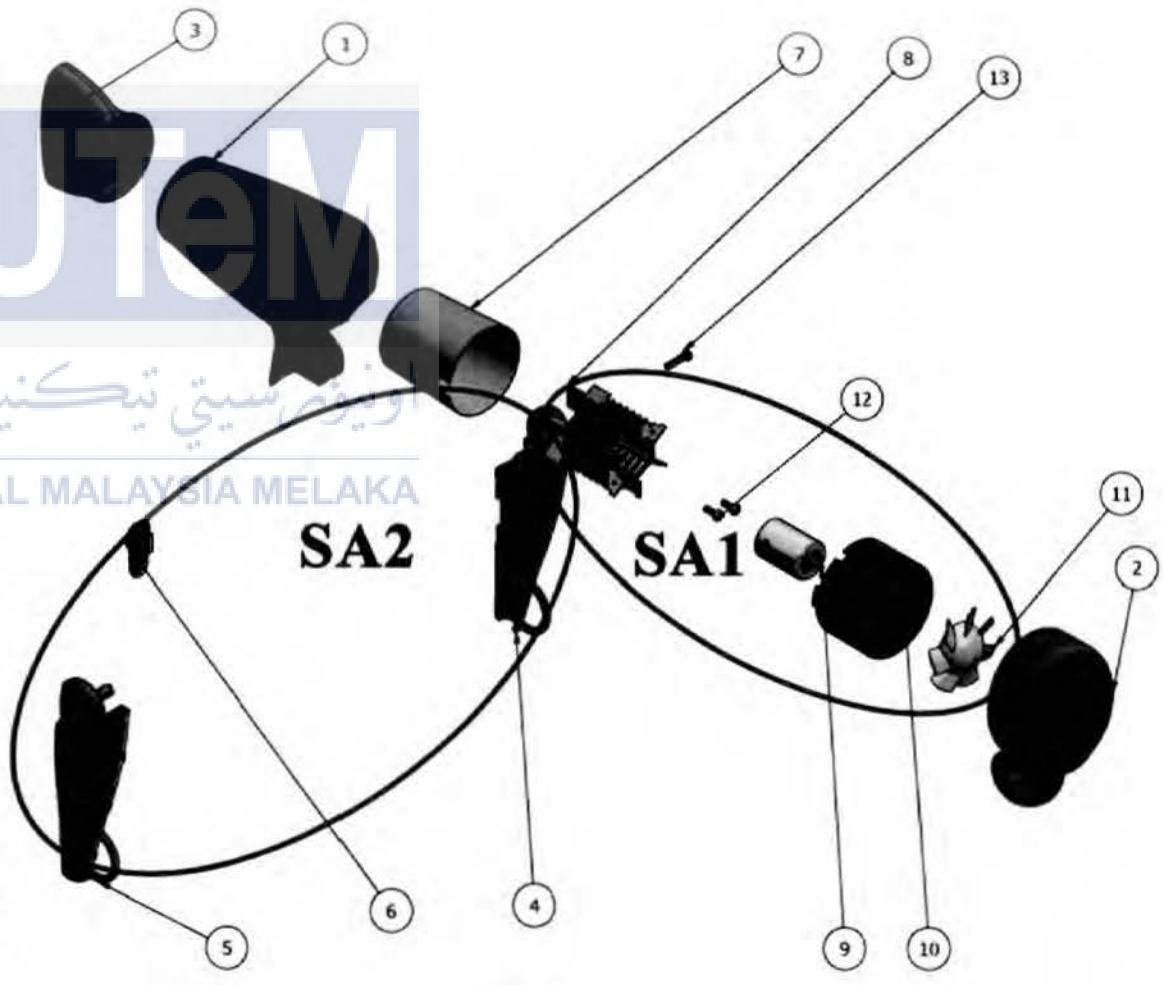
A detailed part list of the new hairdryer is shown in Table 5.2. From Table 5.2 below, it can be noticed that the new hairdryer has 14 parts in total. Among the 14 parts, only 3 of them are fasteners.

Table 5.2: Detailed Part List of New Design

Code	Part Name	Figure	Quantity	Description
N01	Front Body		1	Protect electrical and mechanical components of hairdryer.
N02	Back Body		1	Protect electrical and mechanical components of hairdryer.
N03	Concentrator		1	Concentrate the air flow.

N04	Handle1		1	Protect electrical and mechanical components of hairdryer.
N05	Handle2		1	Protect electrical and mechanical components of hairdryer.
N06	Button		1	Control speed and heat of hairdryer.
N07	Mica Resisting Paper		1	Prevent overheating of plastic housing.
N08	Heating Element		1	Produce heat.

N09	Motor		1	Provide mechanical motion.
N10	Bracket		1	Direct air into heating element.
N11	Fan		1	Blow air through heated coil.
N12	Screw M3x8		2	Fastener.
N13	Screw M3x14		1	Fastener.
		TOTAL	14	



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Front Body
2	1	Back Body
3	1	Concentrator
4	1	Handle1
5	1	Handle2
6	1	Button
7	1	Mica Resisting Paper
8	1	Heating Element
9	1	Motor
10	1	Bracket
11	1	Fan
12	2	Screw M3 x 8 - 4.8 - H
13	1	Screw M3 x 14 - 4.8 - H

Figure 5.1: Exploded view for new design

Figure 5.1 above shows the exploded view with the labelling of sub-assemblies of the new hairdryer. From Figure 5.1, it can be seen that the new hairdryer is made up of 14 parts. There are 2 sub-assemblies found in the new hairdryer. SA1 is the mechanical sub-assembly; it consists of a heating element, motor, bracket, fan and screws M3x8. SA2 is the handle sub-assembly; it consists of a handle1, handle2 and button.

5.3 Assembly Flow Chart of the New Product

Figure 5.2 shows the assembly flow chart of the improved product. From Figure 5.2, it can be seen that the new product has 14 parts. It has 2 sub-assemblies; mechanical sub-assembly and handle sub-assembly. Mechanical sub-assembly of the new hairdryer is made up of 5 parts, i.e. a heating element, motor, bracket, fan and screws M3x8. The handle sub-assembly consists of 3 components, i.e. handle1, handle2 and a button. All the other parts such as front body, back body, concentrator and mica heat resisting paper are assembled together with the sub-assemblies to form the new hairdryer.

In order to assemble the new hairdryer, firstly, the concentrator is inserted at the outlet of the front body. Then, mica heat resisting paper and mechanical sub-assemblies are inserted into the front body. All the wires are fixed at the handle part. Next, button is inserted into the handle. After inserting all the necessary electrical and mechanical component into the housing, front body and back body are fixed together using snap-fit method. Finally, a screw is used to secure front and back body as well as handle together.

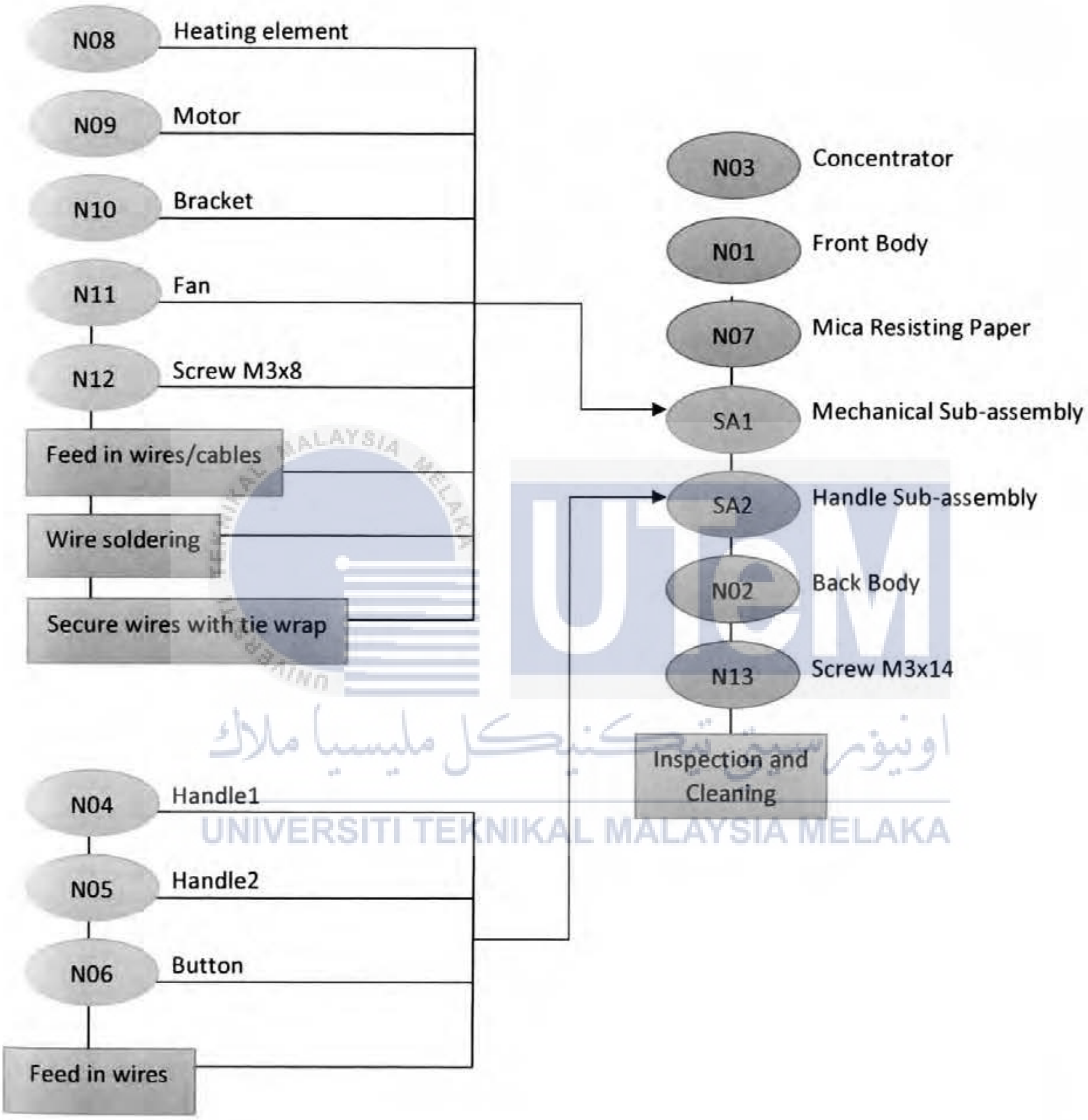


Figure 5.2: Assembly flow chart of New Design

5.4 Manufacturing Process

All the components for the new hairdryer are made of ABS plastics except mica heat resisting paper. Mica heat resisting paper is made of a heat resistance material named dolomite. Injection molding solidification process is suitable for thermoplastics such as ABS. Therefore, manufacturing process used to manufacture the new hairdryer is mainly injection molding. If all the components are fabricated using the same manufacturing process, tooling costs can be reduced. Table 5.3 below shows the part descriptions for DFM analysis of New Design. It can be seen that all the parts are manufactured by injection molding solidification process. All the components are made of ABS plastics except mica resisting paper.

Table 5.3: Part descriptions for DFM analysis of New Design

Code	Part Name	Figure	Manufacturing Process	Material
N01	Front Body		Injection Molding	ABS
N02	Back Body		Injection Molding	ABS
N03	Concentrator		Injection Molding	ABS

N04	Handle1		Injection Molding	ABS
N05	Handle2		Injection Molding	ABS
N06	Button		Injection Molding	ABS
N07	Mica Resisting Paper		Injection Molding	Dolomite
N10	Bracket		Injection Molding	ABS
N11	Fan		Injection Molding	ABS

5.5 Process Flow after Modification

Before modification, 3 sets of process are needed to manufacture or purchase the components needed for Elba EHD-1198G hairdryer. After design improvements have been made, the number of parts has reduced from 22 to 14. The types of process needed to manufacture or purchase the components for new hairdryer also reduced.

5.5.1 Process Flow of Injection Molding

All components (except electrical and mechanical components) in the hairdryers are manufactured using injection molding solidification process. Raw materials are bought from suppliers. Then, inspectors will inspect the quality and quantity of the raw materials, before they are transported to factories for injection molding. There are three stages of operation in injection molding technique, i.e. melting raw materials, injection molding and solidifying. Each operations is accompanied by an inspection. Then, the finished parts are delivered to another section for surface finishing process. Before the part can be used or kept in storage, a final inspection on the quality and quantity is needed. Figure 5.3 shows the process flow of injection molding.

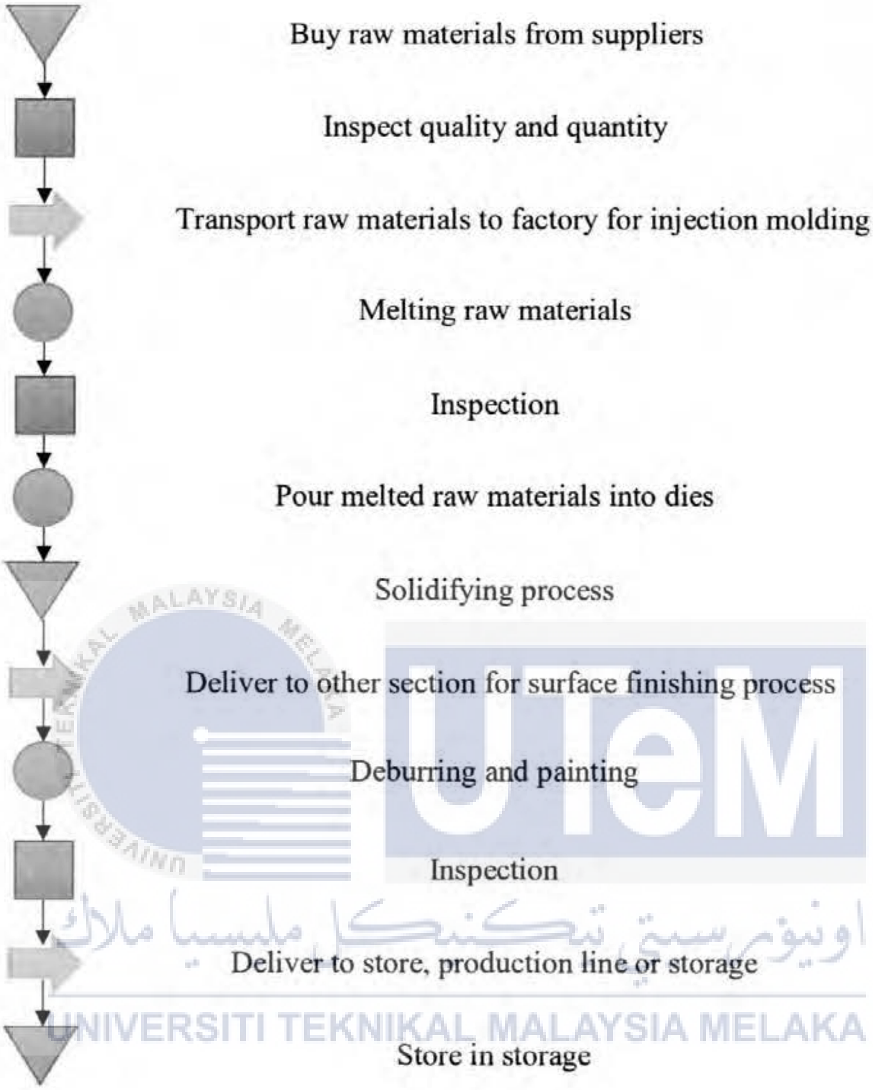


Figure 5.3: Process flow of injection molding

5.5.2 Process Flow of Purchased Parts

Heating element, motors and fasteners are purchased parts. After purchasing them from the suppliers, inspections on the quantity and quality are carried out. Then, the purchased parts are delivered to the production line for assemblage or kept in storage for future use. Figure 5.4 shows the process flow of purchased parts.

Figure 5.4: Process flow of purchased part

5.6 Theoretical Minimum Part Count

The new hairdryer consists of 14 parts. Among the 14 parts, if multiple instances are ignored, there are only 13 parts. All the parts are analysed using Boothroyd-Dewhurst criteria. Table 5.4 shows the determination of theoretical minimum part count of the new design. From Table 5.4, it can be seen that the number of theoretical minimum part count of the new design is 10 parts. In another words, there are still 4 parts that can be modified, combined or eliminated from the design.

Table 5.4: Determination of theoretical minimum part count of new hairdryer

		Criteria				
Item	Part Name	Movement	Isolation	Separation	Theoretical Part	Justification
N01	Front Body	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
N02	Back Body	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
N03	Concentrator	No	No	No	✗	Can be combined with other parts.
N04	Handle1	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
N05	Handle2	Yes	Yes	Yes	✓	Essential part. Act as base and housing.
N06	Button	Yes	No	Yes	✓	Move to adjust speed and temperature.
N07	Mica Resisting Paper	No	Yes	No	✓	Mica prevents overheating and melting.
N08	Heating Element	No	Yes	Yes	✓	Produce heat. Heat source.
N09	Motor	Yes	Yes	Yes	✓	Mechanical part, produce energy.
N10	Bracket	No	No	Yes	✓	Draw and direct hot air out.
N11	Fan	Yes	No	Yes	✓	Rotational motion to blow hot air out.

N12	Screw M3x8	No	No	No	✗	Fastener. Can be eliminated.
N13	Screw M3x14	No	No	No	✗	Fastener. Can be eliminated.
TOTAL					10	

5.7 Design Efficiency

The design efficiency of the new hairdryer can be calculated based on Equation 1 above. Table 5.5 shows the data required to calculate the design efficiency of the new hairdryer. From the table, it can be observed that the design efficiency calculated based on the manual handling and insertion difficulties is 30.03%. The total assembly time for Elba EHD-1198G hairdryer is estimated to be 99.9s. When the value in column C8 is smaller than the value in column C2, this means that the part can be eliminated. The theoretical number of part count determined from this analysis is 10 parts. In another words, 4 other parts of the new hairdryer can be considered for elimination or modification.

Table 5.5: Design Efficiency of New Hairdryer

Part Name	C1	C2	C3	C4	C5	C6	C7	C8
	Total angle of symmetry (α $+\beta$), deg (°)	Number of times the operation is carried out consecutivel y	Two-digit manual handling code	Manual handling time per part (s)	Two-digit manual insertion code	Manual insertion time per part (s)	Total Operation time, seconds (s) (C4+C6)	Figure for estimation of theoretical minimum parts
Front Body	720	1	30	1.95	00	1.5	3.45	1
Back Body	720	1	30	1.95	03	3.5	5.45	1
Concentrator	360	1	10	1.50	30	2.0	3.50	0
Handle1	720	1	30	1.95	07	6.5	8.45	1
Handle2	720	1	30	1.95	07	6.5	8.45	1
Button	720	1	30	1.95	06	5.5	7.45	1
Mica Resisting Paper	360	1	10	1.50	00	1.5	3.00	1
Heating Element	360	1	10	1.50	00	1.5	3.00	1

Motor	360	1	10	1.50	10	4.0	5.50	1
Bracket	360	1	10	1.50	10	4.0	5.50	1
Fan	360	1	10	1.50	10	4.0	5.50	1
Screw M3x8	360	2	62	5.55	39	8.0	27.10	0
Screw M3x14	360	1	62	5.55	39	8.0	13.55	0
Design Efficiency=(3x10)/99.9=0.3003=30.03%							TM	NM
							99.9	10

5.8 Comparisons between Existing and New Design

Table 5.6 below shows the comparisons between existing hairdryers (Khind HD 1600 and Elba EHD-1198G) and new product. The design efficiencies of Khind HD 1600 hairdryer and Elba EHD-1198G hairdryer are 0.1059 (10.59%) and 0.1757 (17.57%) respectively. Compared to Khind HD 1600 hairdryer, the design efficiency of Elba EHD-1198G hairdryer is much higher. In another words, the design of Elba EHD-1198G hairdryer is better and more efficient. In terms of manufacturing and assembly operations, the design of Elba EHD-1198G hairdryer is much superior. Therefore, in order to achieve an even better design after modification, the more superior product (Elba EHD-1198G hairdryer) is chosen for improvement.

From Table 5.6 below, it can be seen that the Khind HD 1600 hairdryer has 29 parts in total whereas Elba EHD-1198G hairdryer has 22 parts in total. After modification, the number of parts reduce from 22 to 14. The new design has 8 parts lesser than the existing Elba EHD-1198G hairdryer. When the number of parts decrease, the total assembly time will also decrease. The decrease in the total number of parts and the total assembly time will increase the design efficiency of the product. Hence, total manufacturing cost can be reduced.

From DFMA analysis, the design efficiency of the new product is 0.3003 or 30.03%. The design efficiency of the new product is very high compared to both the existing products. For the new design, a few of the components are combined together to reduce the number of parts. Screw fasteners are eliminated and replaced with snap-fit fasteners. By replacing screws with snap-fits, the number of parts and total assembly time can be reduced tremendously, and thus, the design efficiency will be higher. Besides that, some aesthetic parts that have no real function are also eliminated from the existing design. From Table 5.6, it can be seen that the total assembly has reduced from 170.75s to 99.9s whereas the total number of parts has reduced from 22 to 14. The decrement in total assembly time as well as number of parts have contributed to the increment of the design efficiency of the new product.

Table 5.6: Comparisons between existing and new products

Item	Existing Products		New Design
	Khind HD 1600	Elba EHD-1198G	
Figure			
Design Efficiency (DFA Index)	0.1059	0.1757	0.3003
Total number of Parts	29	22	14
Theoretical Min. Part Count	10	10	10
Total Assembly Time (s)	283.18	170.75	99.9

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

As indicated earlier, the aims of this project are to analyse the design efficiency and to make comparisons between two different brands of low cost hairdryer. This project also intended to suggest improvements for a new hairdryer design that has higher design efficiency.

This project focuses on how to improve the design efficiency or DFA index of the hairdryer. Two different brands of hairdryer available in the market are selected for comparisons. Both of the hairdryers are dismantled. Detailed drawing of each components in the hairdryers are produced using 3D CAD software, Autodesk Inventor. Then, the design of the existing hairdryers are analysed using DFMA analysis. After comparisons have been made, the hairdryer with higher design efficiency is selected for modification. Then the new design is analysed again using DFMA analysis to determine its design efficiency.

From the DFMA analysis that has been done, one of the most significant findings is that Elba EHD-1198G hairdryer has higher design efficiency compared to Khind HD 1600 hairdryer, the design efficiencies for both of the hairdryers are 0.1757 and 0.1059 respectively. This finding shows that the design of Elba EHD-1198G hairdryer is better and more efficient compared to Khind HD 1600 hairdryer. Therefore, in order to redesign a product that has high design efficiency, Elba EHD-1198G hairdryer is selected for modifications. Then, a new hairdryer design is produced and analysed using DFMA analysis. From the DFMA analysis, it can be concluded that the design efficiency of the new product is the best among the 3 hairdryers. The new hairdryer design has a design efficiency of 0.3003. The total assembly time of the new hairdryer also reduced from 170.75s to 99.9s. The total number of parts of the new hairdryer design has also reduced from 22 parts to 14 parts.

Elba EHD-1198G hairdryer has 22 parts in total. Out of the 22 parts, only 10 of them are theoretical parts. Theoretical parts are parts that fulfil Boothroyd-Dewhurst's criteria regarding movement, material and separation. The design efficiency of a product can be calculated using Equation 1. By reducing the total number of parts and total assembly time, the design efficiency of a product can be increased. By applying this concept during the modification of the new hairdryer, some of the unnecessary parts in the existing design are either changed or eliminated. Screw fasteners are eliminated and replaced with snap-fit fastening method. By replacing screws with snap-fits, the number of parts can be reduced, the total assembly time can be reduced, the manufacturing cost can also be reduced. Thus, the design efficiency can be increased. Some other parts which have no specific or significant functions are also eliminated. All the components are manufactured using injection molding solidification process. As a result, tooling cost and manufacturing can be reduced.

Although this project has fulfilled its objectives, there are some unavoidable limitations. The estimation of manufacturing cost for the new hairdryer design is not covered in this project. This project only suggests the methods on how to improve the design efficiency and how to design a low cost hairdryer. Besides that, electrical components are not taken into consideration during the analysis and redesign process.

This project is important as it provides ideas and methods on how to design a low cost hairdryer. The findings shows that by reducing the total number of parts of a product, the total assembly time of a product can also be reduced. Thus, the design efficiency of a product will be higher. The design will be more efficient. The more efficient the design is, the less expensive the manufacturing cost of the product will be.

Future studies should focus on the cost estimation of the manufacturing cost of the product after modifications and improvements have been made. Future researchers can also implement other design methods such as reliability design, benchmarking and etcetera in order to produce a low cost as well as efficient design.

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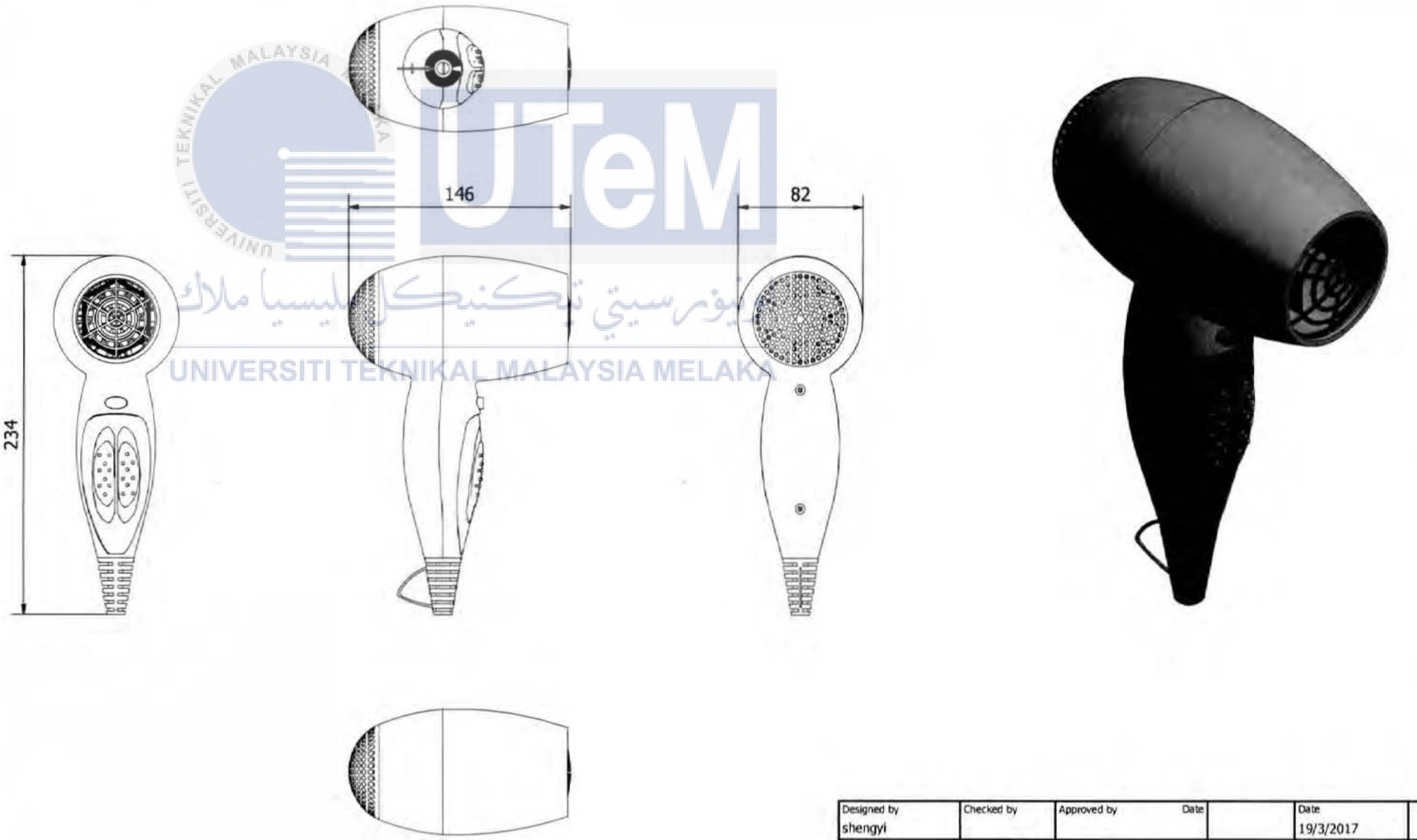
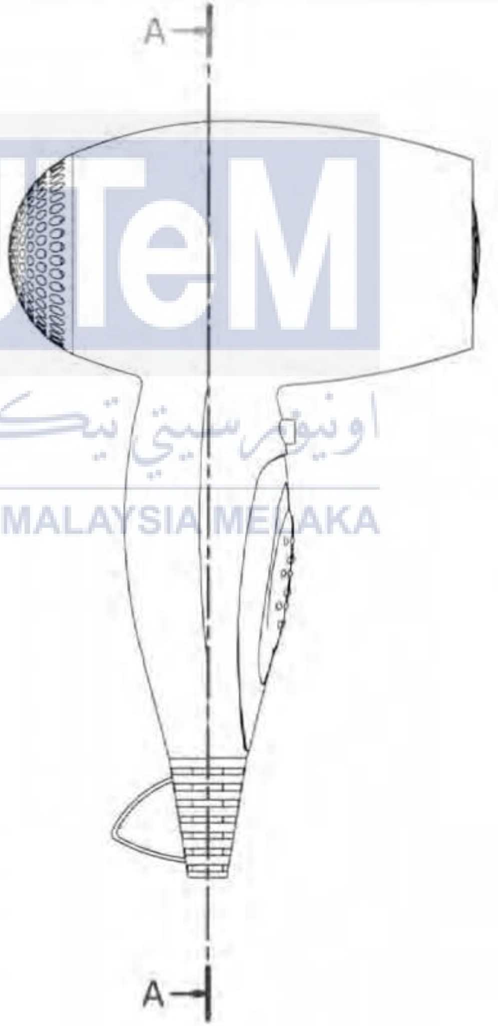


Designed by	Checked by	Approved by	Date	Date
shengyi				19/3/2017

Universiti Teknikal Malaysia Melaka	Assembly View		
	Khind HD1600	Edition	Sheet 1 / 23



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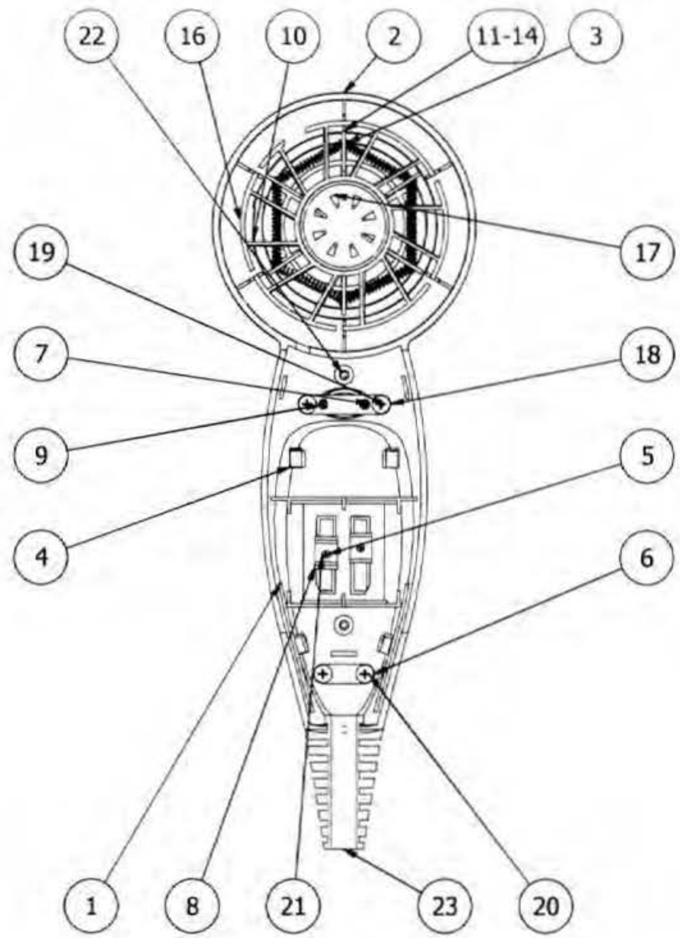
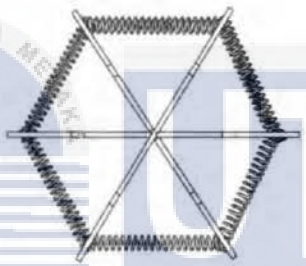


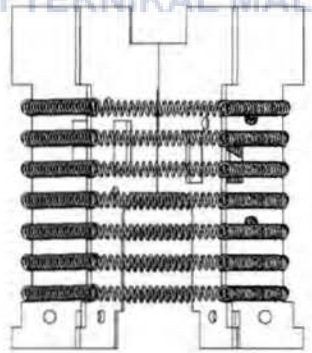
PARTS LIST

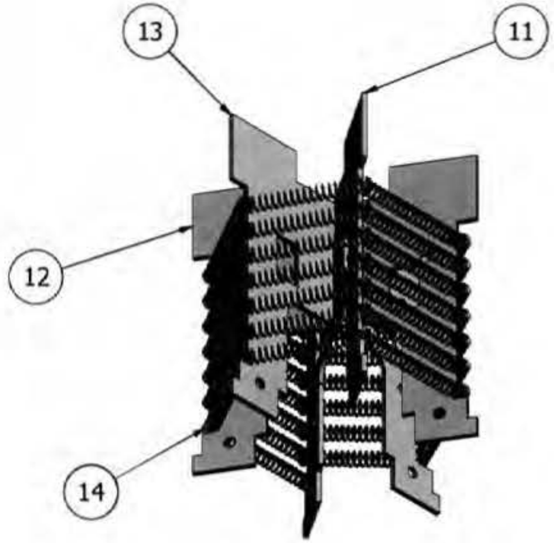
ITEM	QTY	PART NUMBER
1	1	Back Cover
2	1	Front Cover
3	1	Net
4	1	Controller Surface
5	2	Controller Button
6	1	Wire Holder
7	1	Cool Button
8	2	Controller Button Holder
9	2	Cool Button Spring
10	1	Mica Resisting Paper
11-14	1	Mica Heating Frame Assembly
15	1	Fan
16	1	Bracket
17	1	Motor
18	1	Wire Holder1
19	2	Screw M3 x 8 - 4.8 - H
20	4	Screw M3 x 6 - 4.8 - H
21	2	Screw M2x4 - 8.8 - H1
22	2	Spanner Screw
23	1	Wire Cord

Designed by	Checked by	Approved by	Date	Date
shengyi				19/3/2017

Universiti Teknikal Malaysia Melaka	BOM		
	Khind HD1600	Edition	Sheet 2 / 23

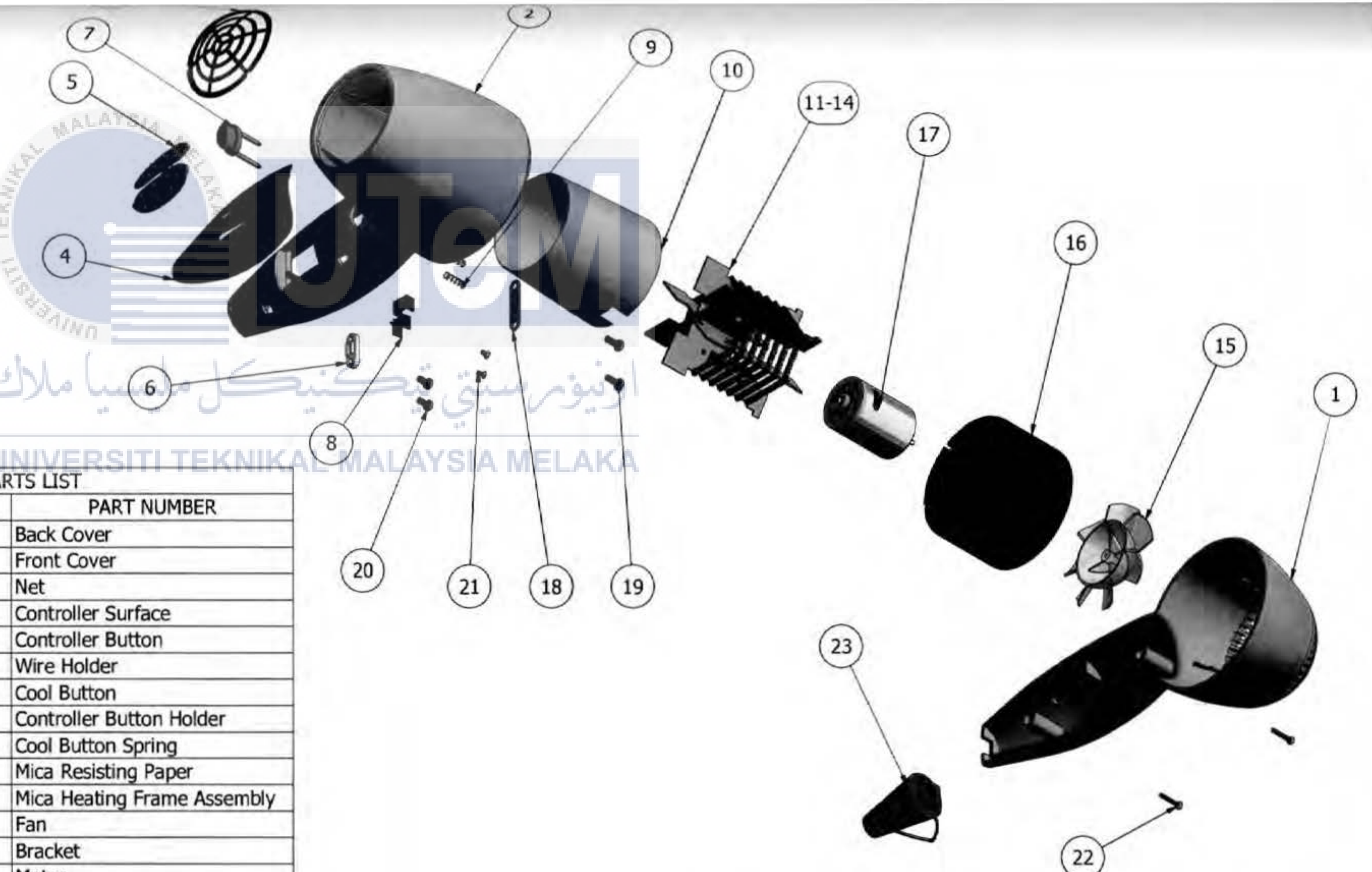






PARTS LIST		
ITEM	QTY	PART NUMBER
11	1	Mica Heating Frame1
12	1	Mica Heating Frame2
13	1	Mica Heating Frame3
14	3	Heating element

Designed by	Checked by	Approved by	Date	Date
shengyi				19/3/2017
Universiti Teknikal Malaysia Melaka		Mica Heating Element Assembly		
		Khind HD1600	Edition	Sheet 3 / 23

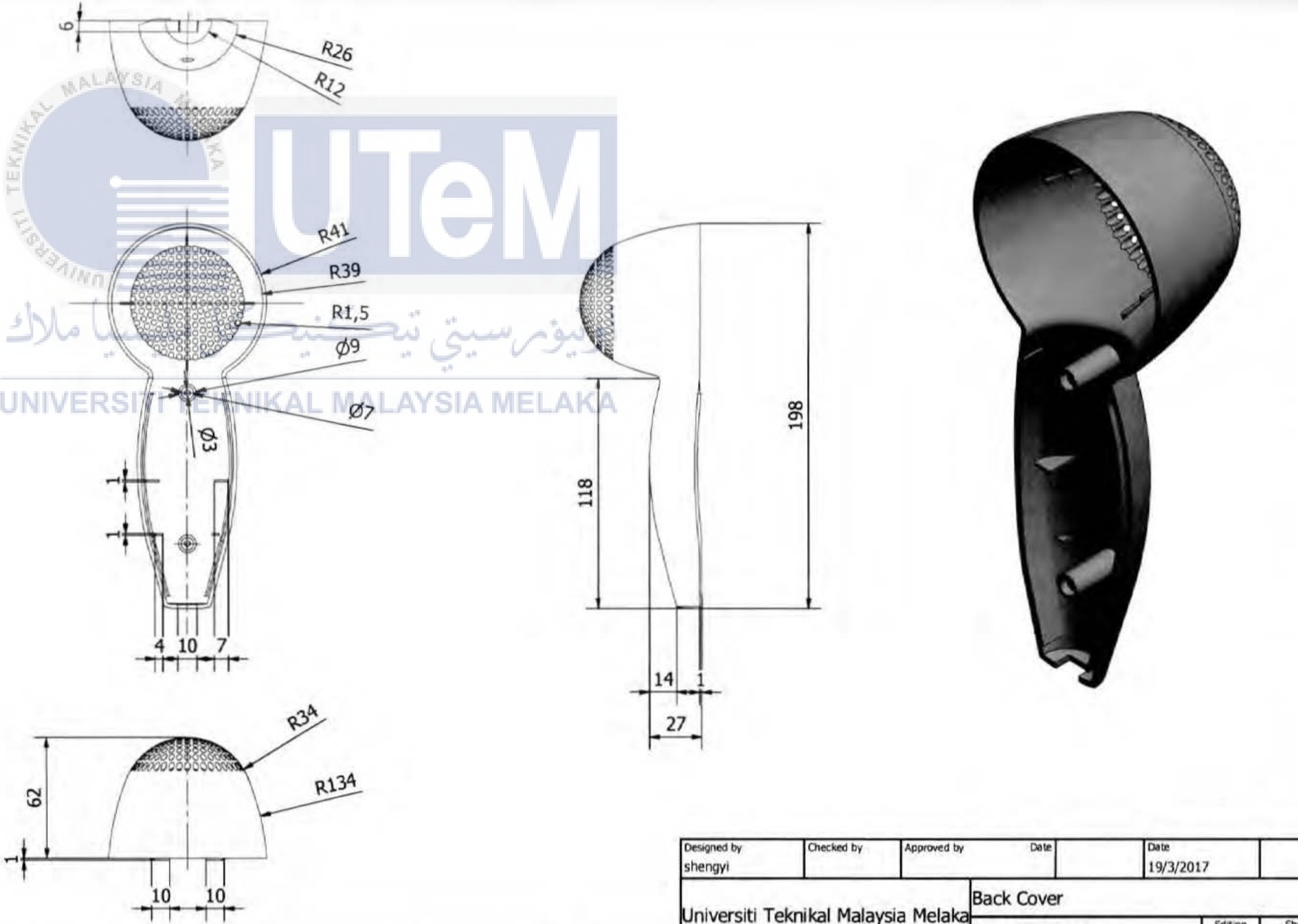


PARTS LIST

ITEM	QTY	PART NUMBER
1	1	Back Cover
2	1	Front Cover
3	1	Net
4	1	Controller Surface
5	2	Controller Button
6	1	Wire Holder
7	1	Cool Button
8	2	Controller Button Holder
9	2	Cool Button Spring
10	1	Mica Resisting Paper
11-14	1	Mica Heating Frame Assembly
15	1	Fan
16	1	Bracket
17	1	Motor
18	1	Wire Holder1
19	2	Screw M3 x 8 - 4.8 - H
20	4	Screw M3 x 6 - 4.8 - H
21	2	Screw M2x4 - 8.8 - H1
22	2	Spanner Screw
23	1	Wire Cord

Designed by	Checked by	Approved by	Date	Date
shengyi				19/3/2017

Universiti Teknikal Malaysia Melaka	Exploded View		
	Khind HD1600	Edition	Sheet 4 / 23



Designed by	Checked by	Approved by	Date	Date	
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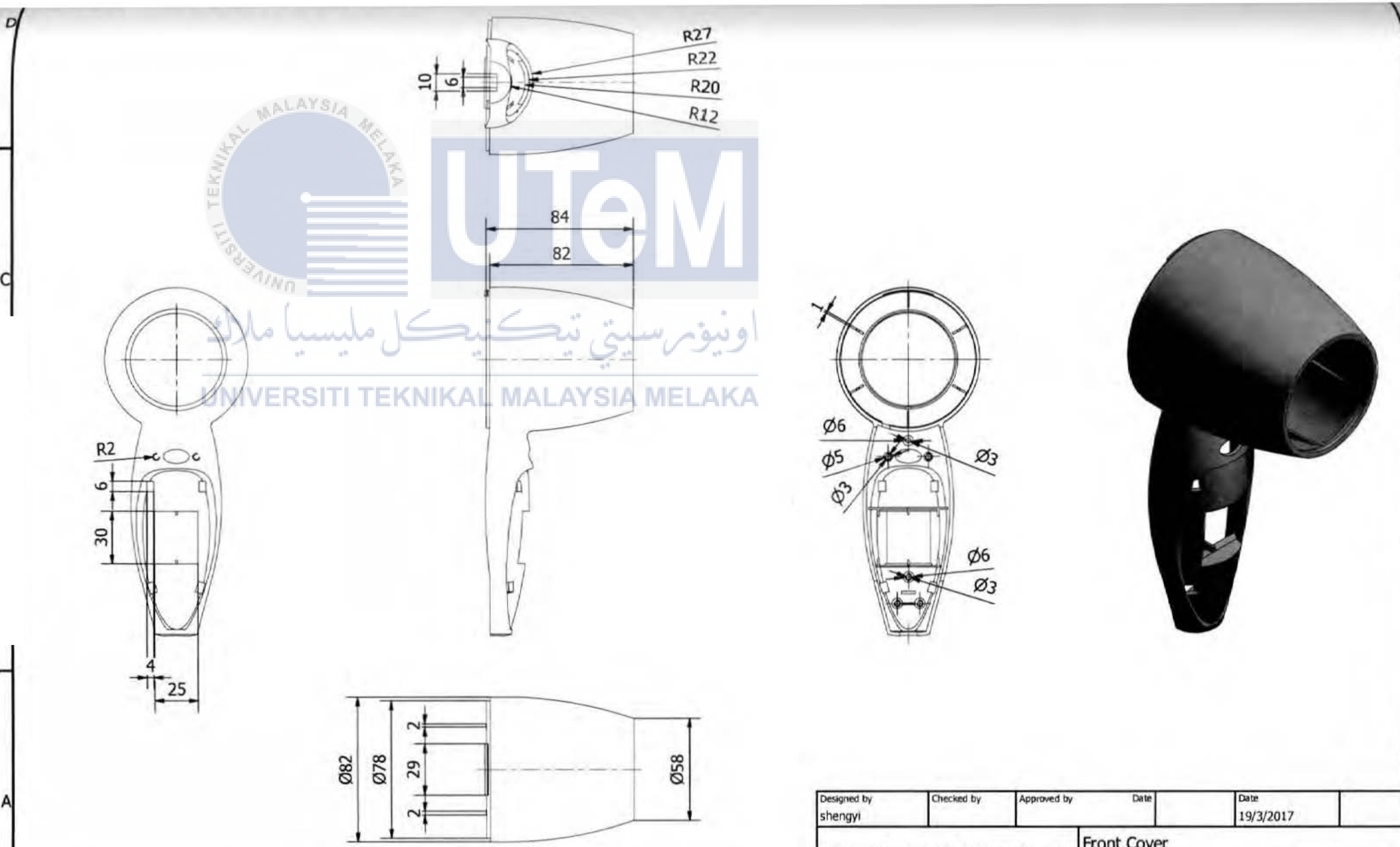
Universiti Teknikal Malaysia Melaka		Back Cover			
		Khind HD1600		Edition	Sheet 5 / 23



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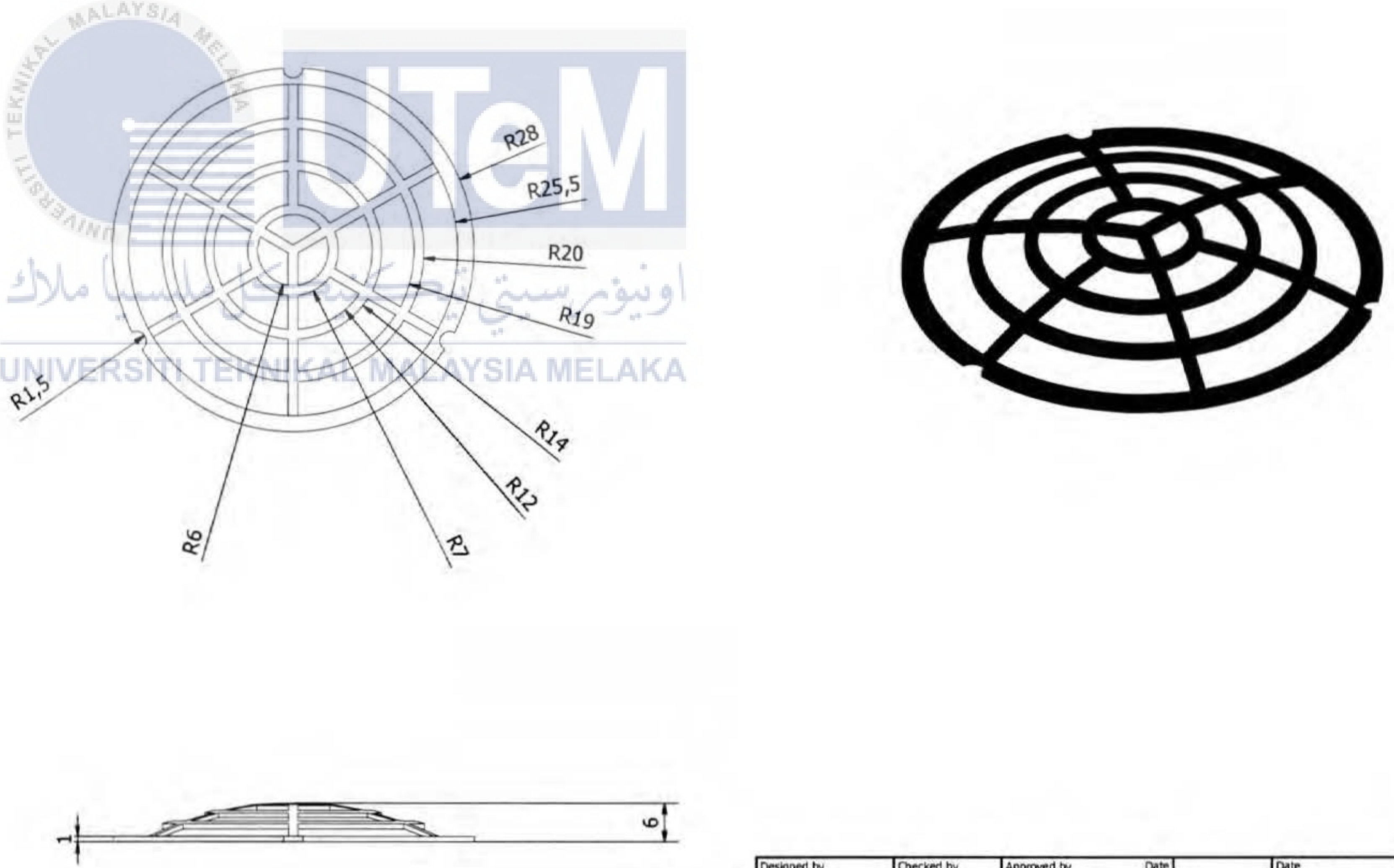
Universiti Teknikal Malaysia Melaka	Front Cover			
	Khind HD1600		Edition	Sheet 6 / 23



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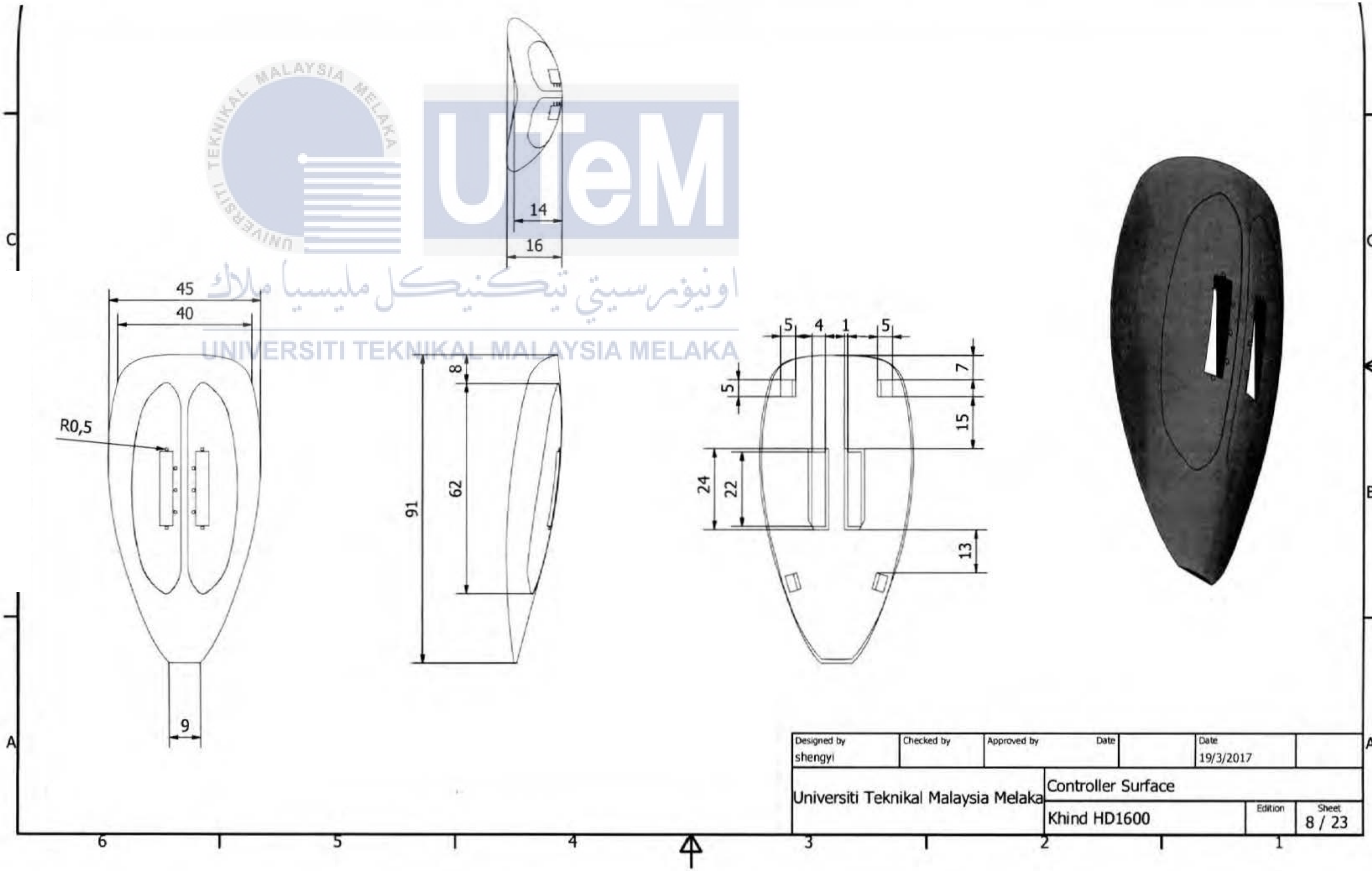
Universiti Teknikal Malaysia Melaka	Net			
	Khind HD1600		Edition	Sheet 7 / 23



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Universiti Teknikal Malaysia Melaka
Controller Surface
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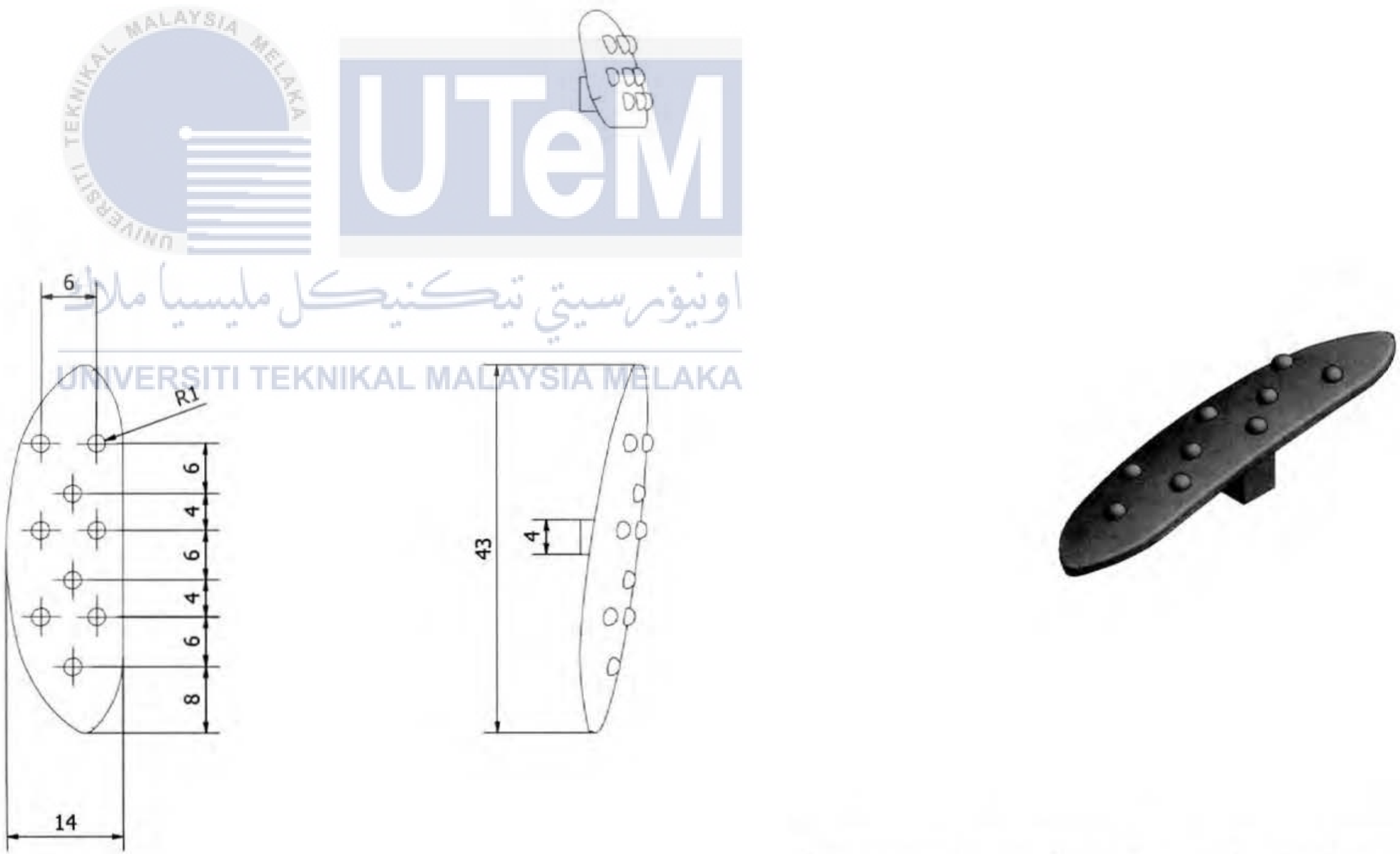
Sheet
8 / 23



Designed by	Checked by	Approved by	Date	Date
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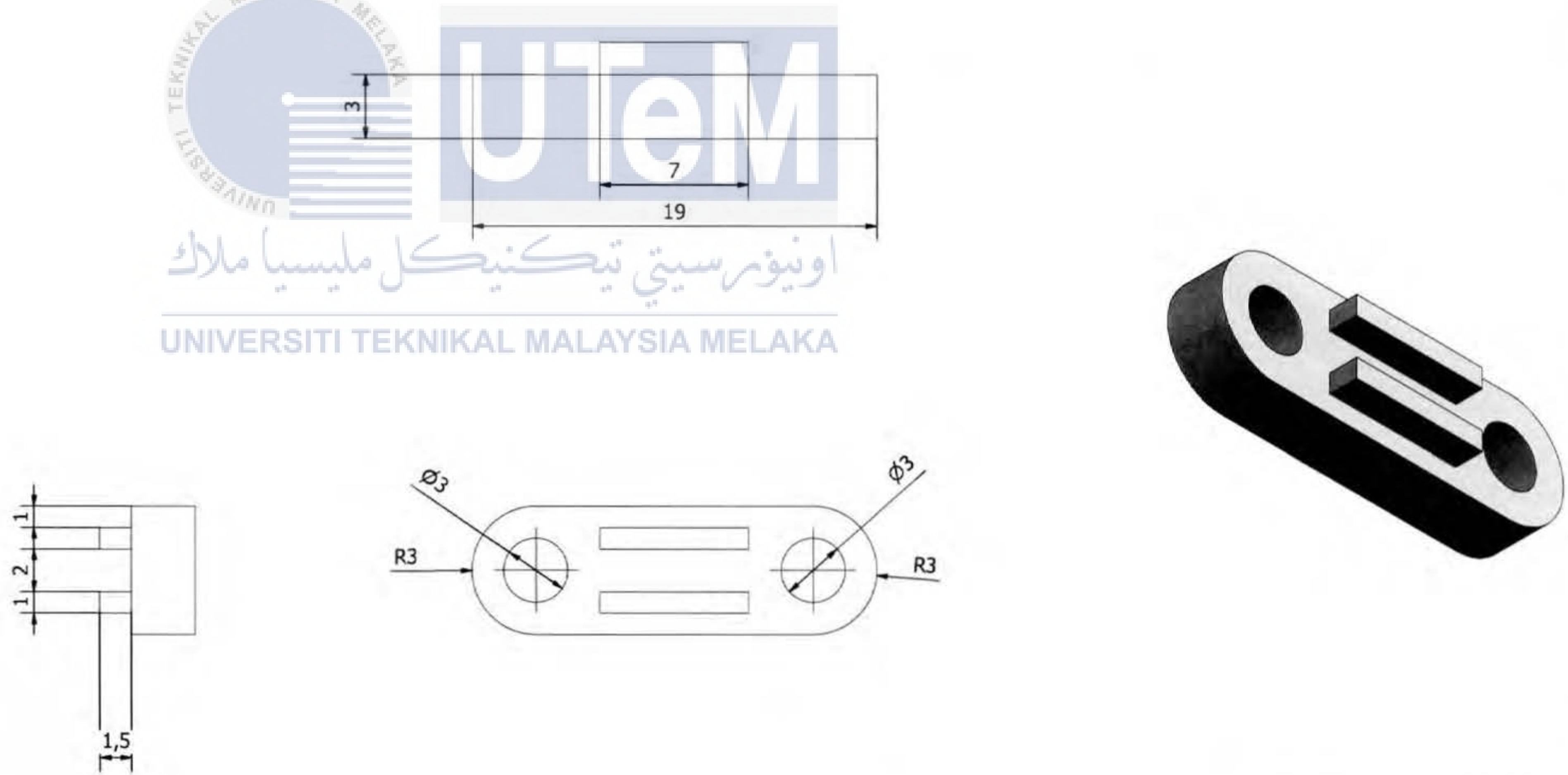
Universiti Teknikal Malaysia Melaka	Controller Button			
	Khind HD1600		Edition	Sheet 9 / 23



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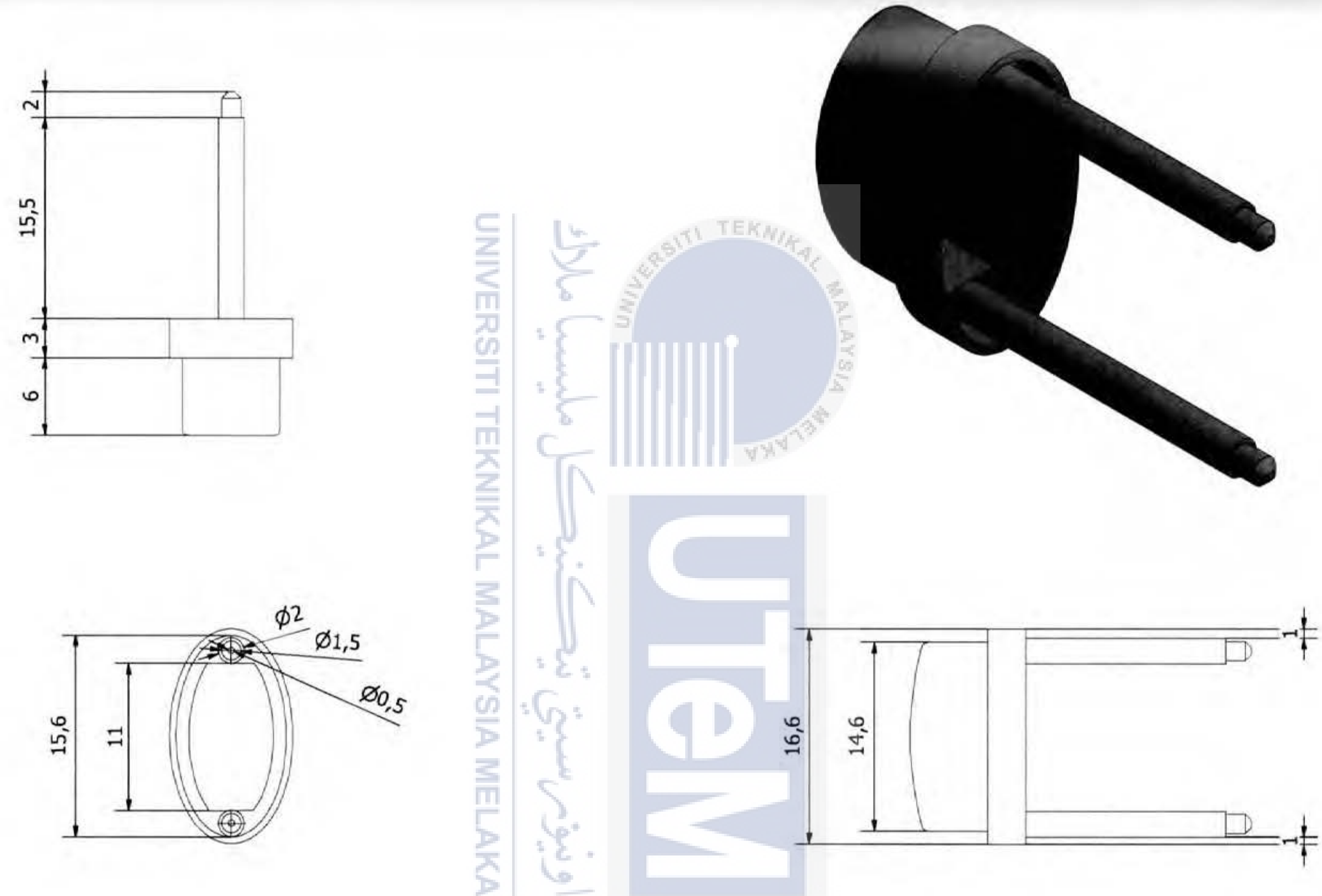
Universiti Teknikal Malaysia Melaka			Wire Holder		
			Khind HD1600	Edition	Sheet 10 / 23



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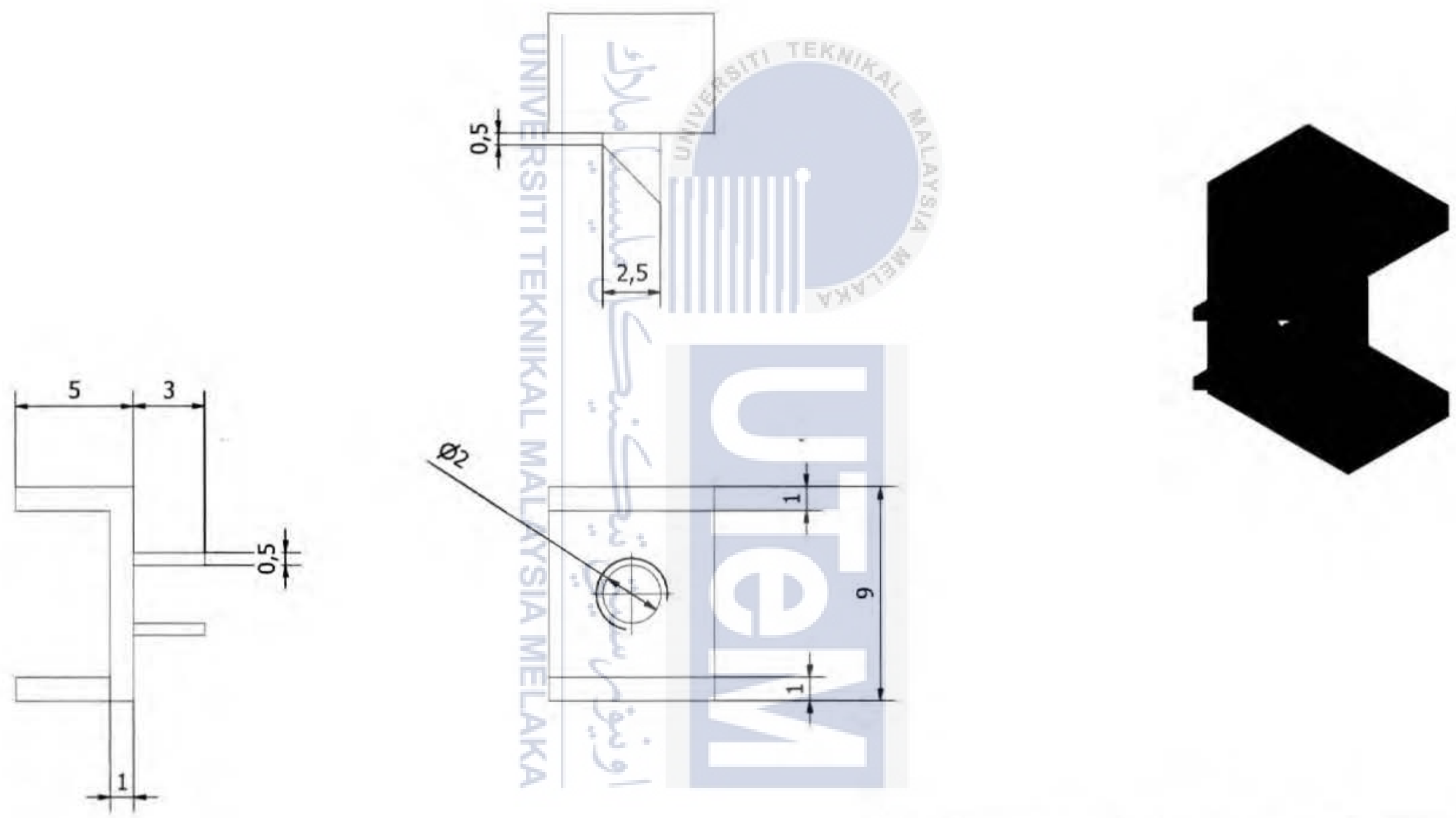
Universiti Teknikal Malaysia Melaka	Cool Button			
	Khind HD1600		Edition	Sheet 11 / 23



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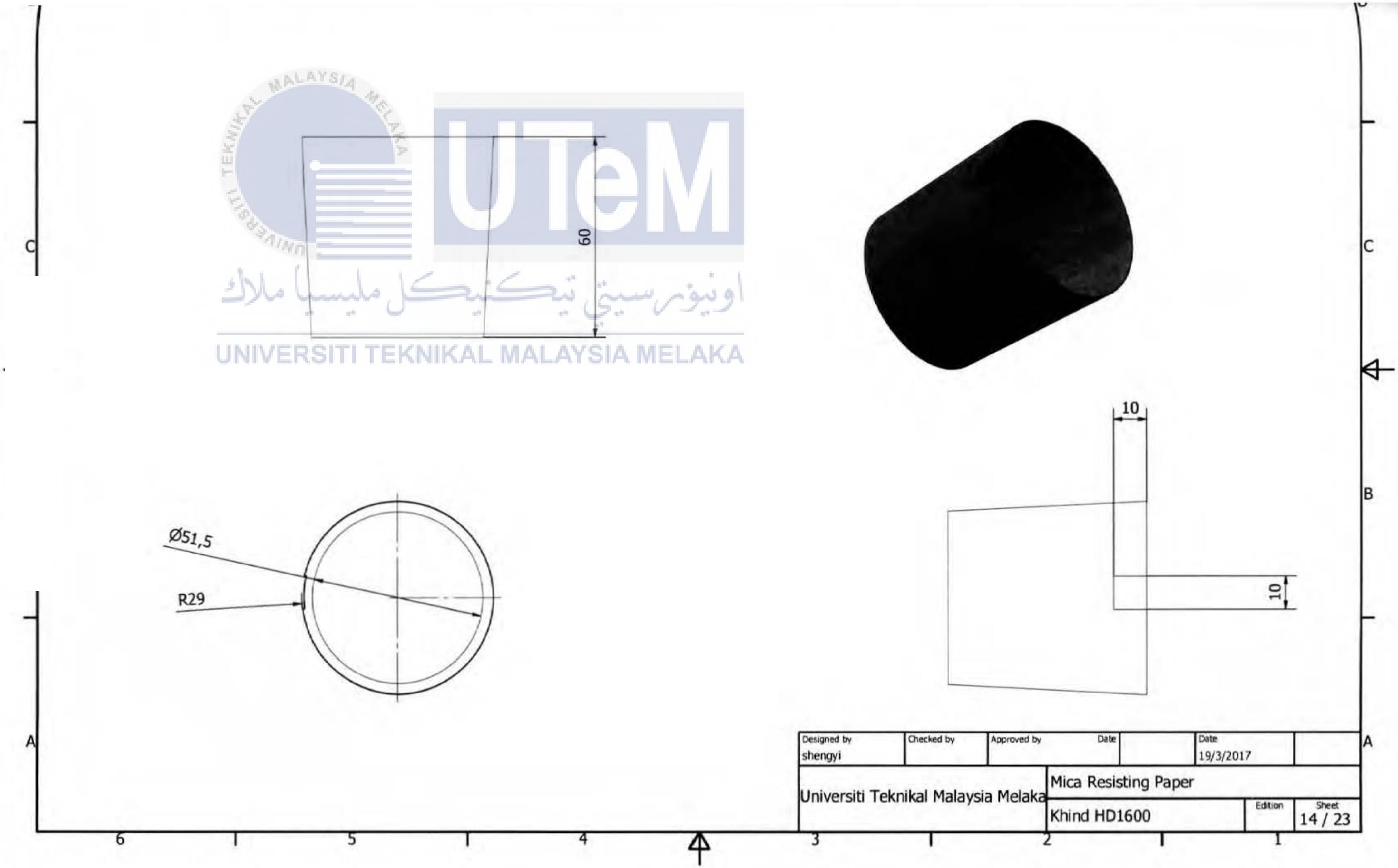
Universiti Teknikal Malaysia Melaka	Controller Button Holder			
	Khind HD1600		Edition	Sheet 12 / 23

Designed by	Checked by	Approved by	Date	Date	
shengyi				19/3/2017	
Universiti Teknikal Malaysia Melaka			Cool Button Spring		
			Khind HD1600	Edition	Sheet 13 / 23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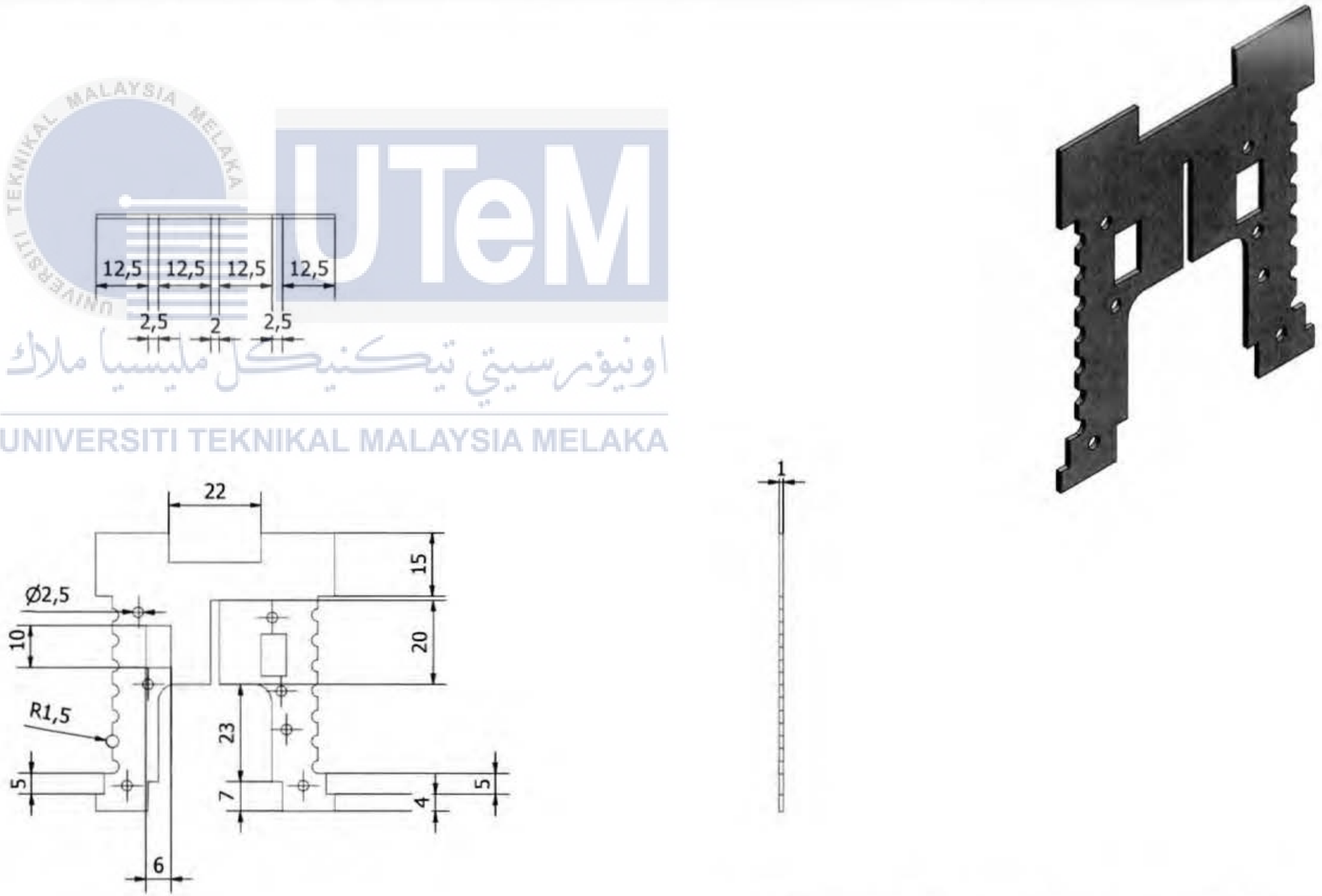
Universiti Teknikal Malaysia Melaka
Mica Resisting Paper
Khind HD1600
Edition
Sheet
14 / 23



Designed by	Checked by	Approved by	Date	Date	
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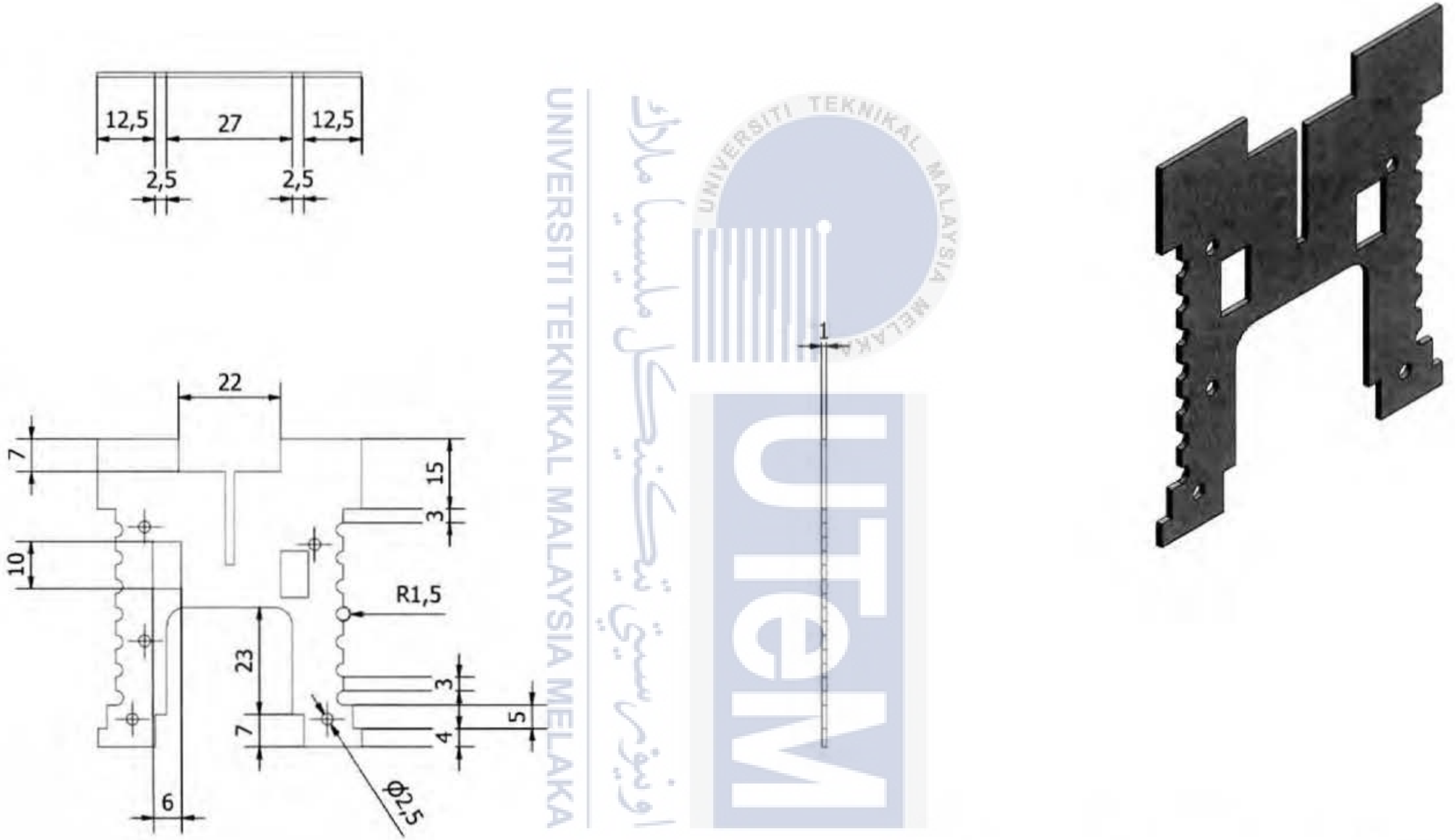
Universiti Teknikal Malaysia Melaka			Mica Heating Frame 1		
			Khind HD1600	Edition	Sheet 15 / 23



Designed by	Checked by	Approved by	Date	Date
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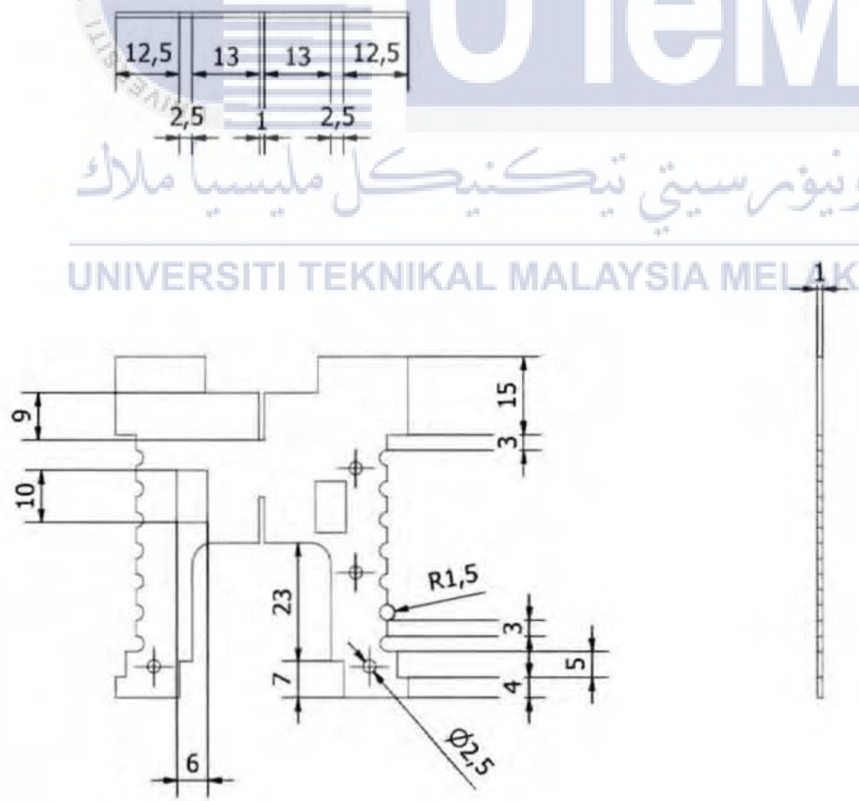
Universiti Teknikal Malaysia Melaka	Mica Heating Frame 2			
	Khind HD1600		Edition	Sheet 16 / 23



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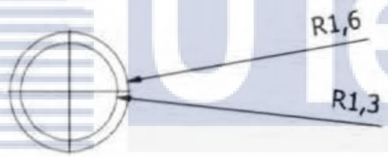
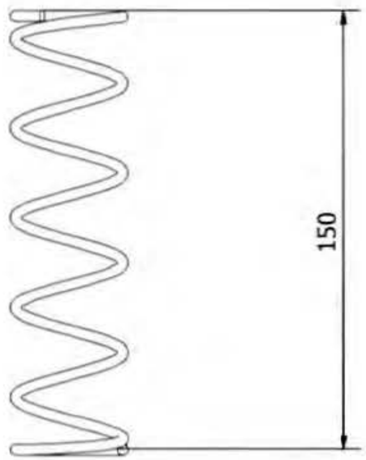
Universiti Teknikal Malaysia Melaka	Mica Heating Frame 3				
	Khind HD1600			Edition	Sheet 17 / 23





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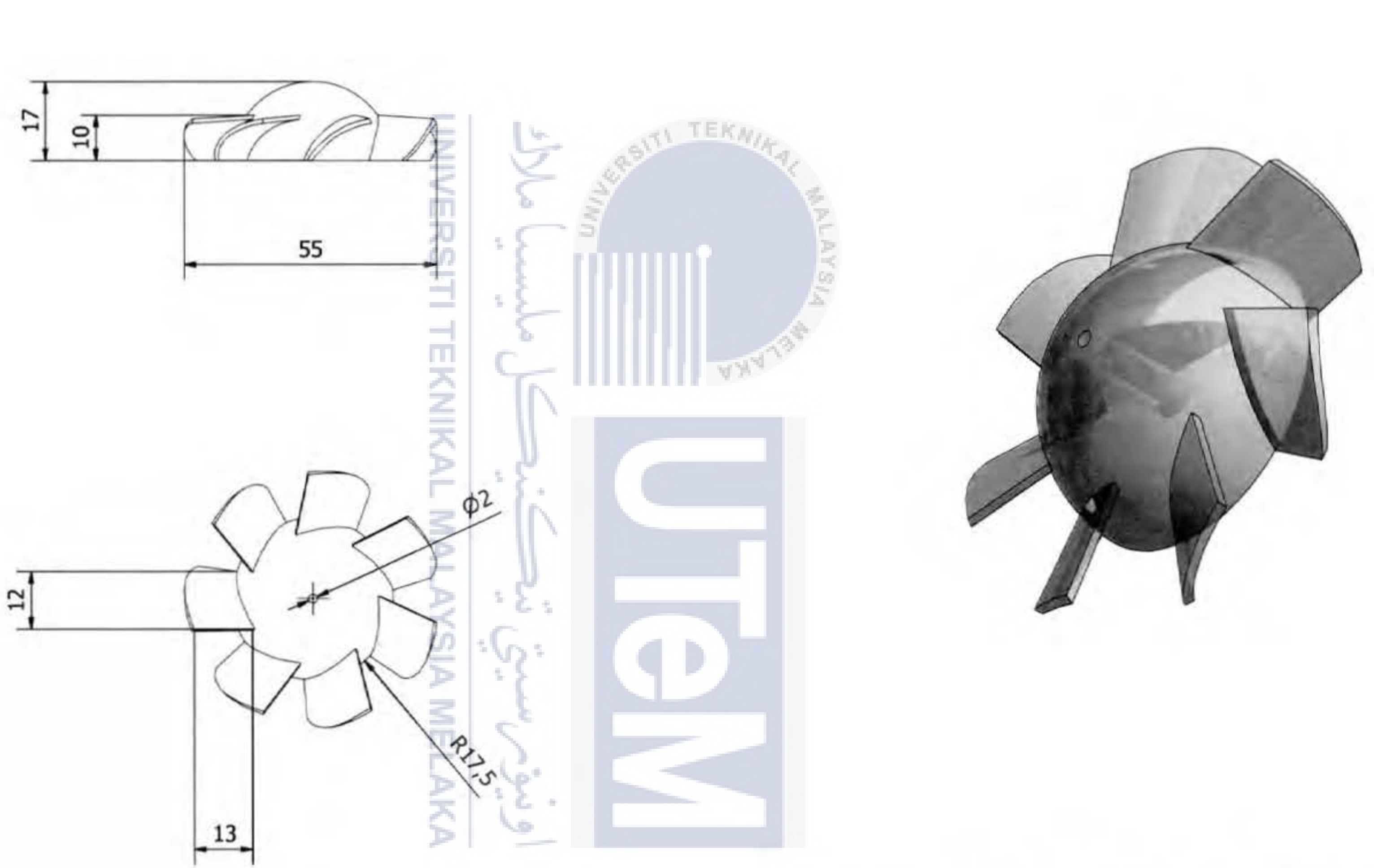
Universiti Teknikal Malaysia Melaka			Heating Element		
			Khind HD1600	Edition	Sheet 18 / 23



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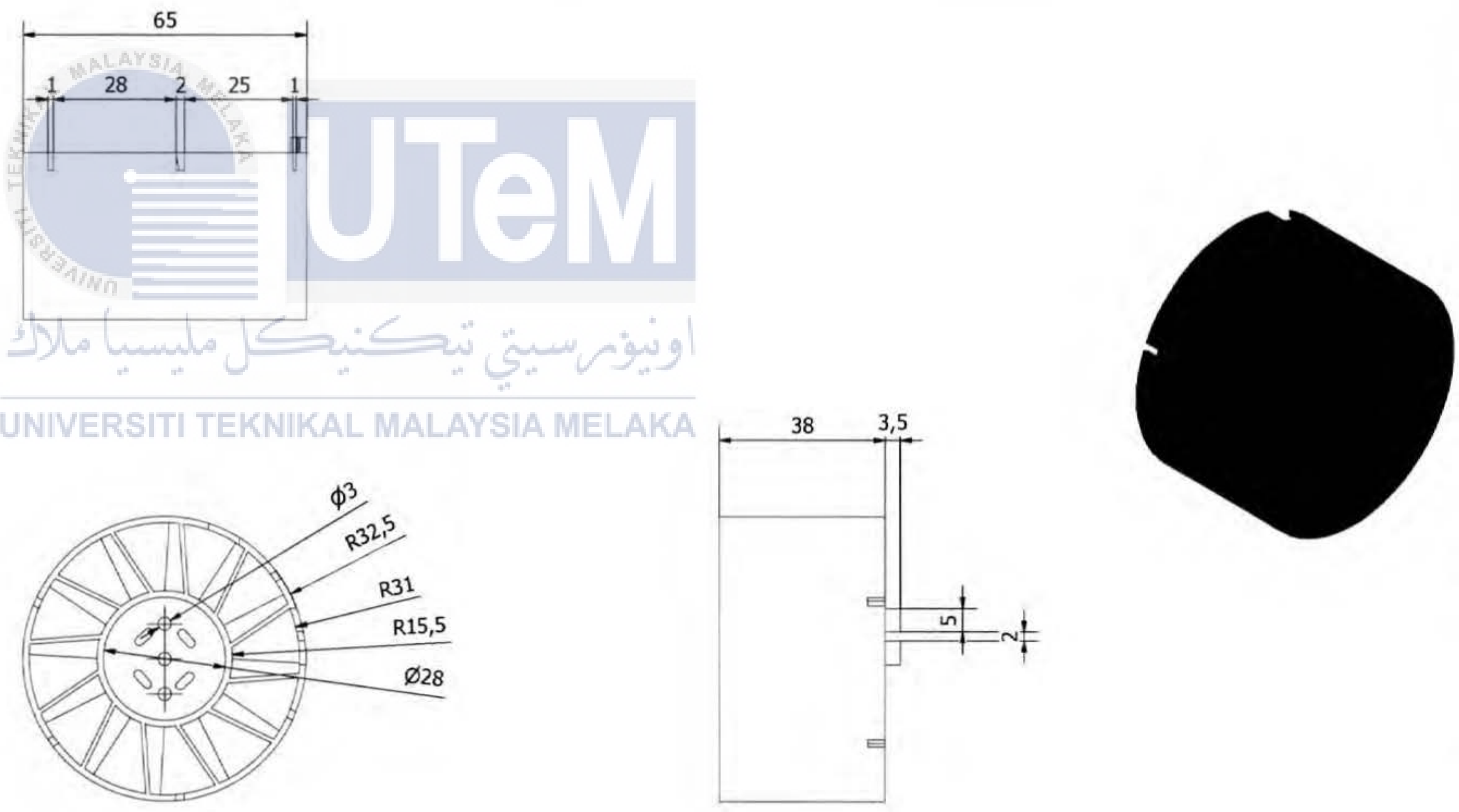
Universiti Teknikal Malaysia Melaka	Fan			
	Khind HD1600		Edition	Sheet 19 / 2



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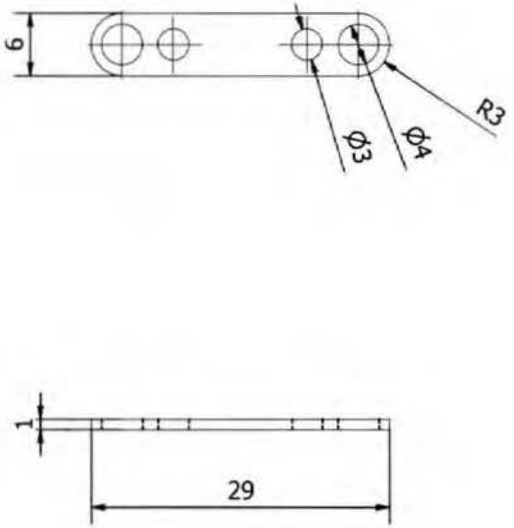
Universiti Teknikal Malaysia Melaka		Bracket			
		Khind HD1600		Edition	Sheet 20 / 23

Part 17-Motor

Part 18-Wire Holder1



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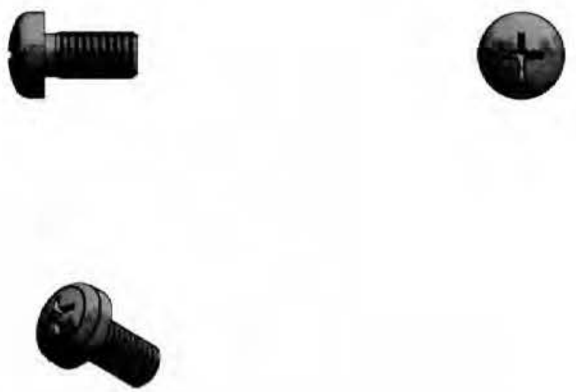
shengyi				19/3/2017
Universiti Teknikal Malaysia Melaka	Motor & Wire Holder 1			
	Khind HD1600		Edition	Sheet 21 / 23

Part 21- Screw M2 x 4

Part 22-Spanner Screw



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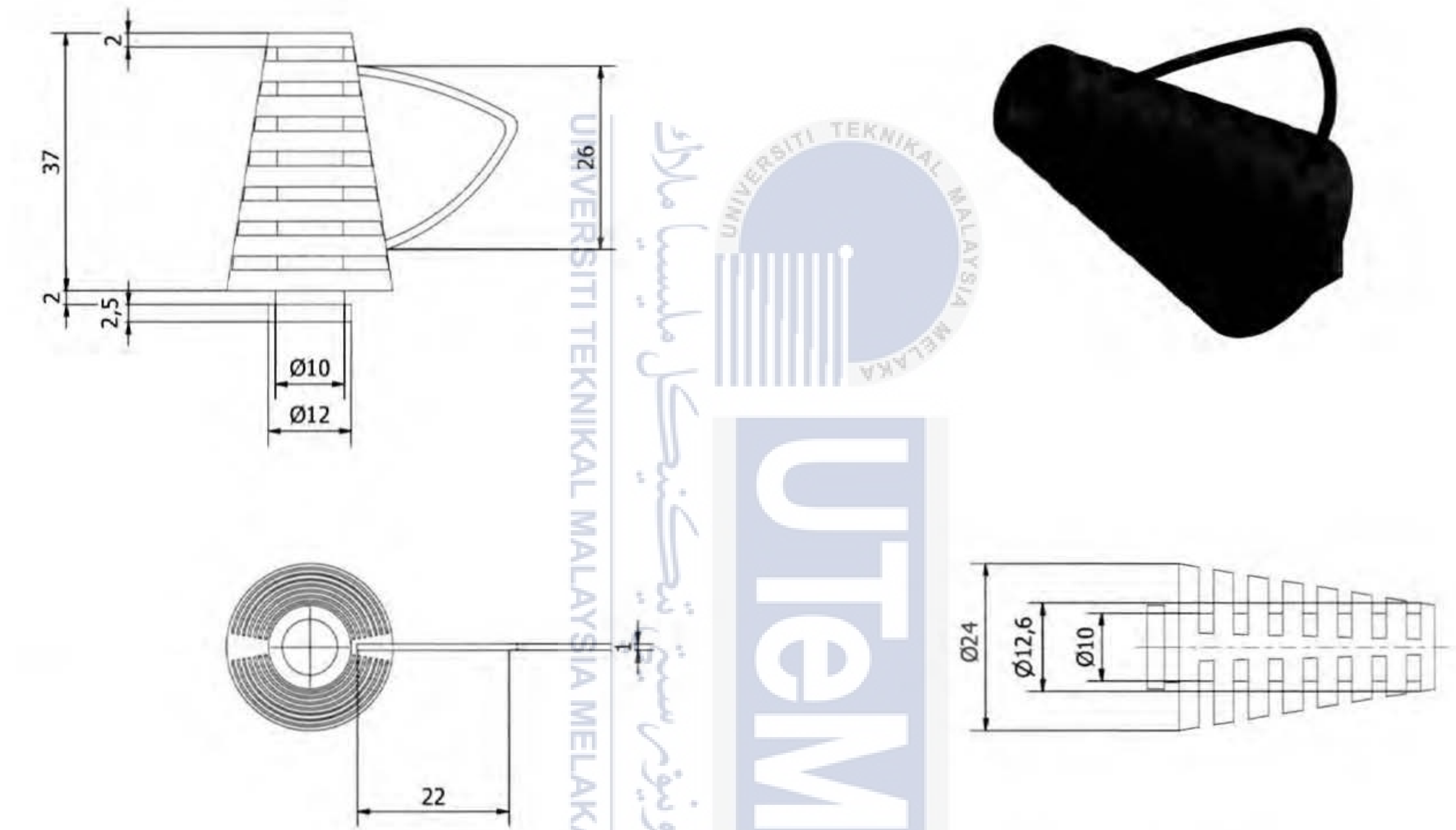
Universiti Teknikal Malaysia Melaka		Screws			
		Khind HD1600		Edition	Sheet 22 / 23



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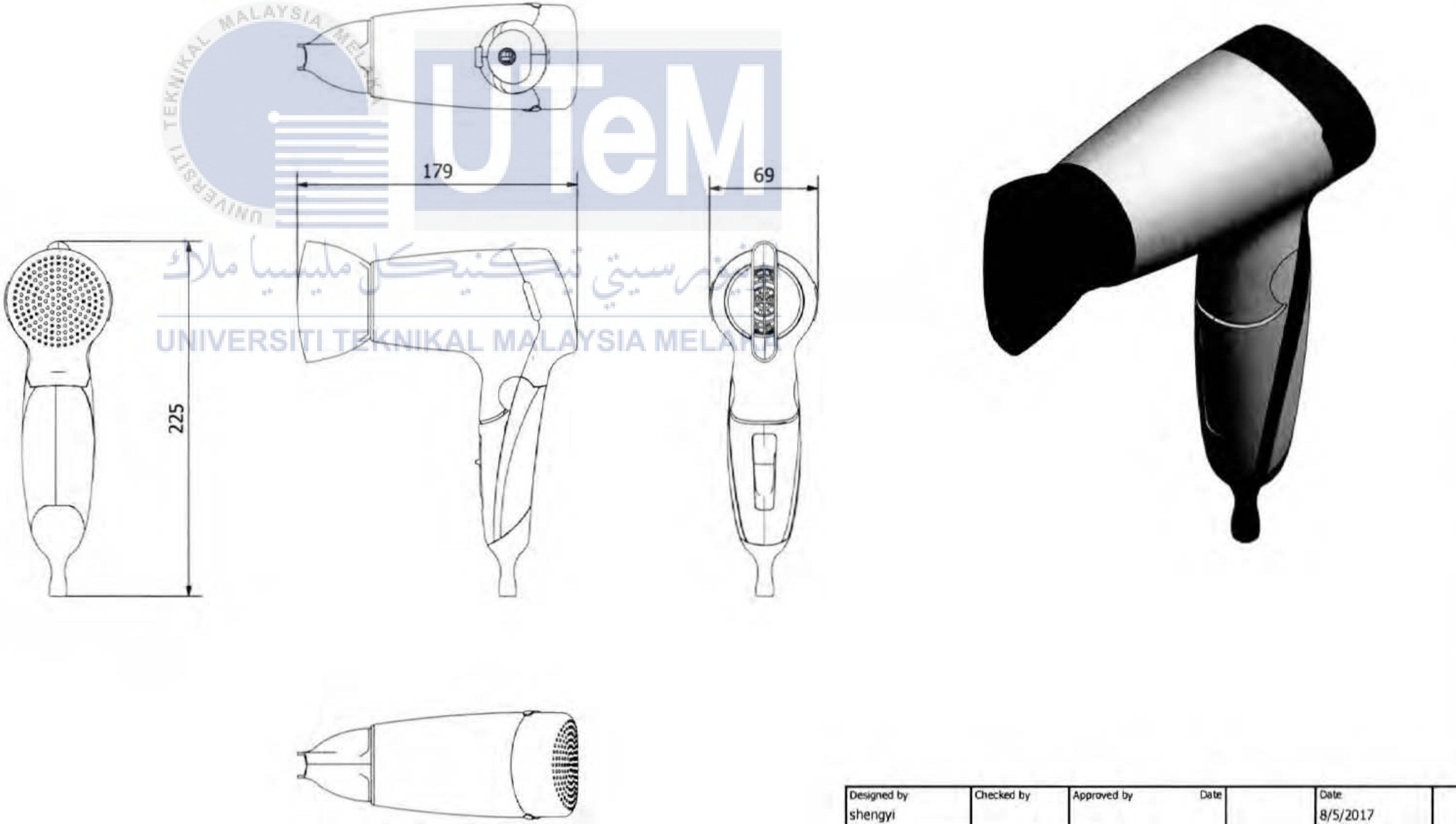
Universiti Teknikal Malaysia Melaka		Wire Cord		
		Khind HD1600	Edition	Sheet 23 / 23



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shengyi				8/5/2017	
Universiti Teknikal Malaysia Melaka	Elba EHD-1198G Hairdryer				
	Elba Hairdryer Drawing			Edition	Sheet 1 / 21

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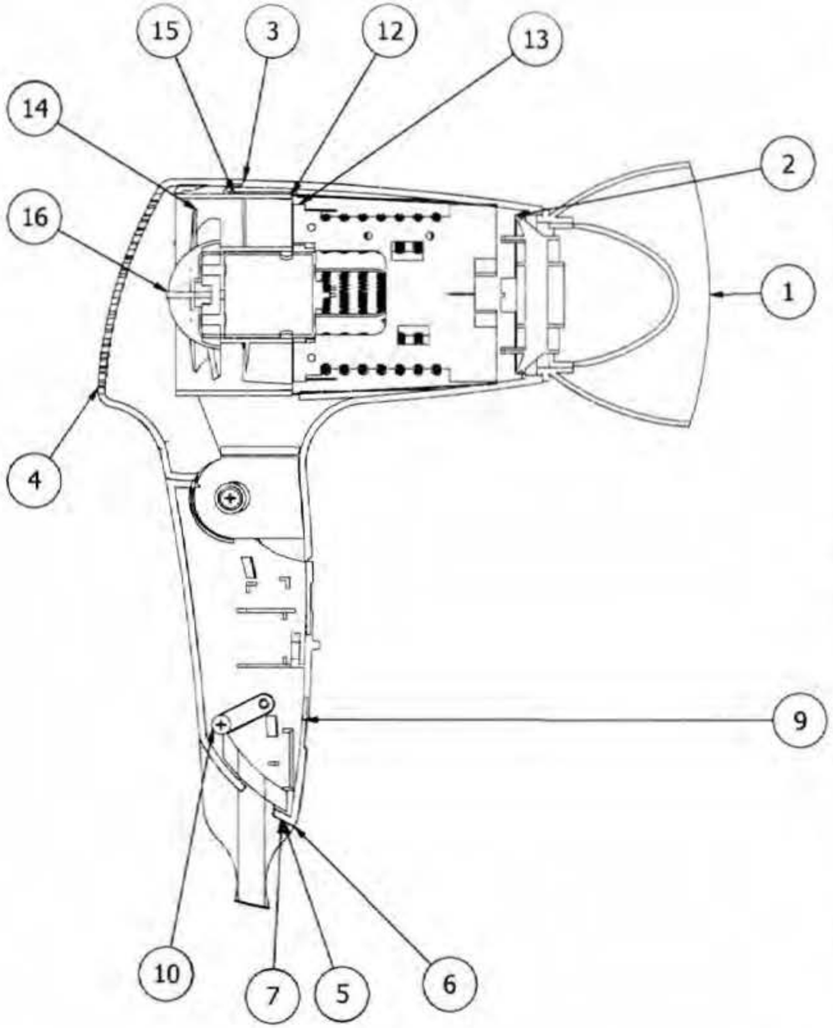
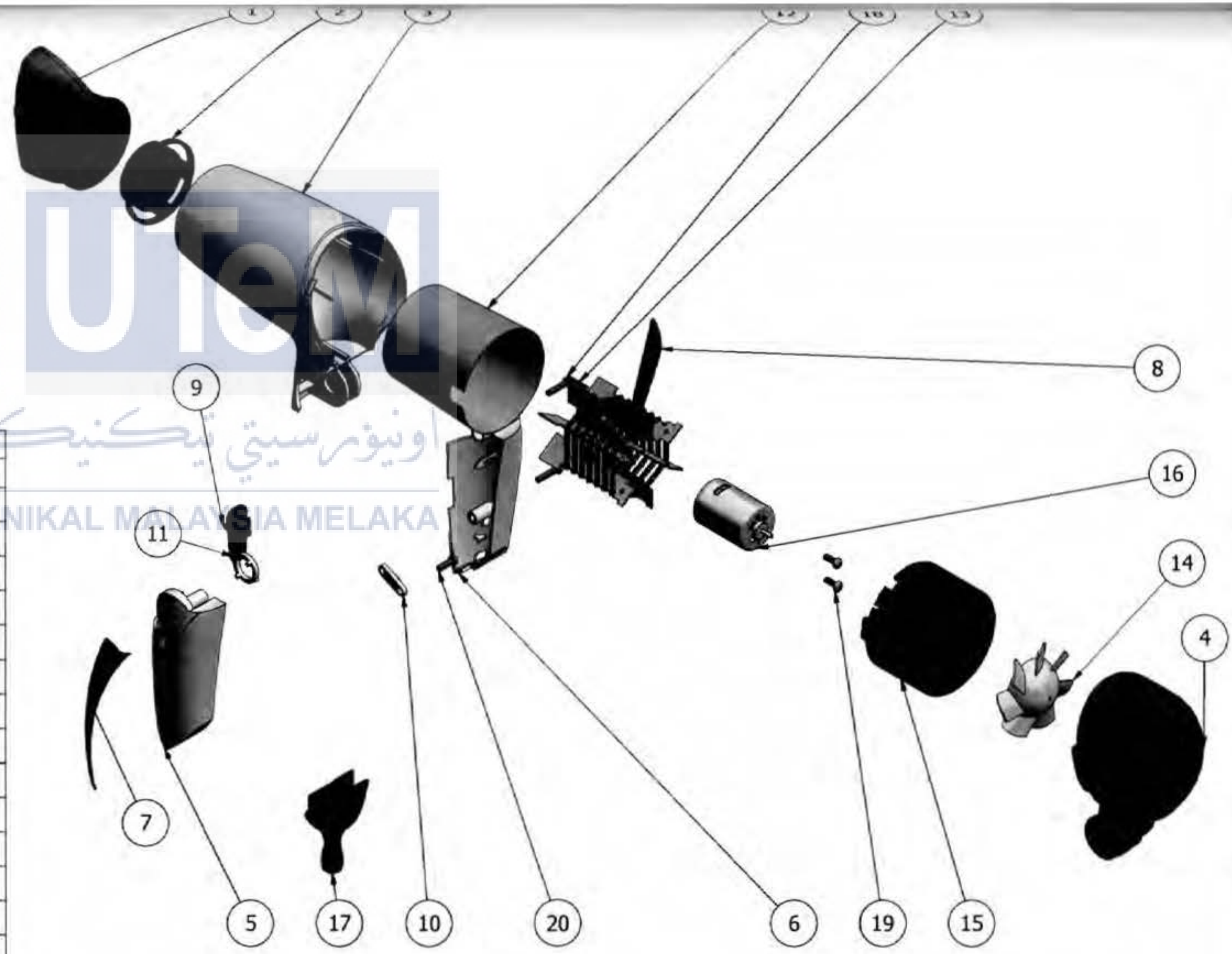


PARTS LIST

ITEM	QTY	PART NUMBER
1	1	Concentrator
2	1	Net
3	1	Front Body
4	1	Back Body
5	1	Handle
6	1	Handle2
7	1	Strap
8	1	Strap2
9	1	Button
10	1	Wire Holder
11	1	Joint
12	1	Mica Resisting Paper
13	1	HeatingElement
14	1	Fan
15	1	Bracket
16	1	Motor
17	1	Wire Cord
18	2	Screw M3 x 14 - 4.8 - H
19	2	Screw M3 x 8 - 4.8 - H
20	1	Screw M3 x 10 - 4.8 - H

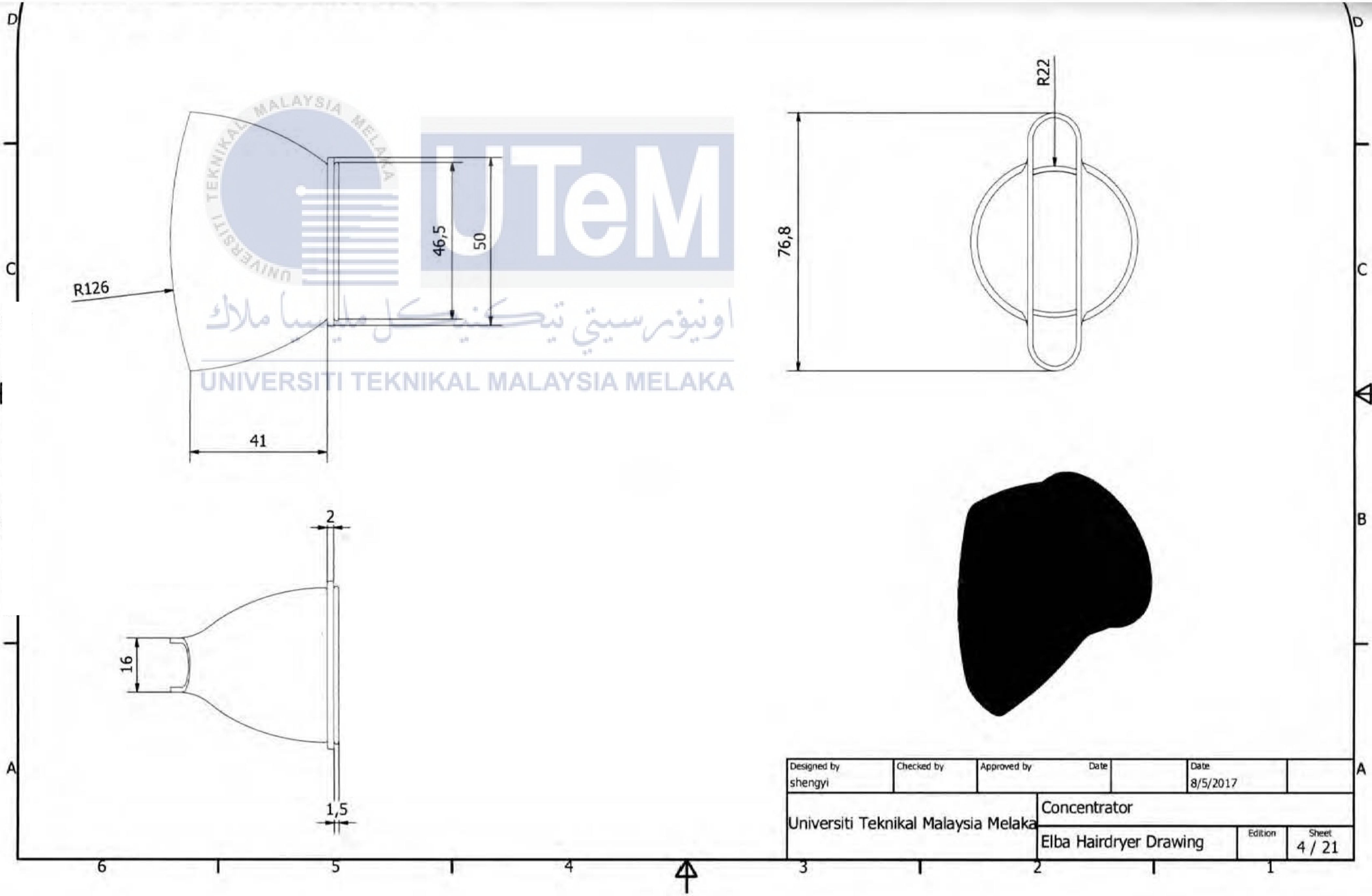
Designed by	Checked by	Approved by	Date	Date
shengyi				8/5/2017
Universiti Teknikal Malaysia Melaka	Elba EHD-1198G Hairdryer Sectional View			
	Elba Hairdryer Drawing		Edition	Sheet 2 / 21



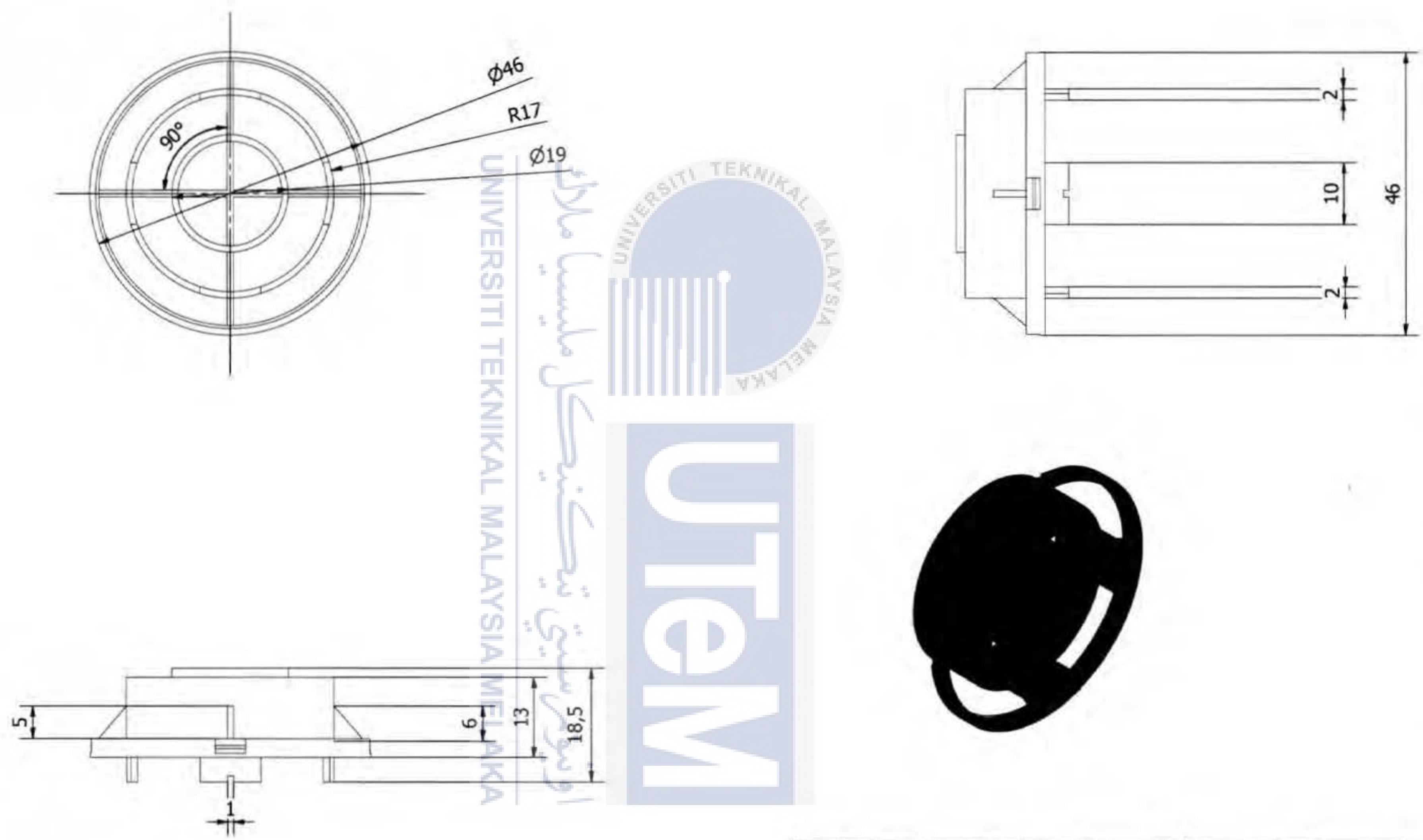
PARTS LIST

ITEM	QTY	PART NUMBER
1	1	Concentrator
2	1	Net
3	1	Front Body
4	1	Back Body
5	1	Handle
6	1	Handle2
7	1	Strap
8	1	Strap2
9	1	Button
10	1	Wire Holder
11	1	Joint
12	1	Mica Resisting Paper
13	1	HeatingElement
14	1	Fan
15	1	Bracket
16	1	Motor
17	1	Wire Cord
18	2	Screw M3 x 14 - 4.8 - H
19	2	Screw M3 x 8 - 4.8 - H
20	1	Screw M3 x 10 - 4.8 - H

Designed by	Checked by	Approved by	Date	Date	
shengyi				8/5/2017	
Universiti Teknikal Malaysia Melaka			Elba EHD-1198G Hairdryer Exploded View		
			Elba Hairdryer Drawing	Edition	Sheet 3 / 21



Designed by	Checked by	Approved by	Date	Date	
shengyi				8/5/2017	
Universiti Teknikal Malaysia Melaka	Concentrator				
	Elba Hairdryer Drawing			Edition	Sheet 4 / 21



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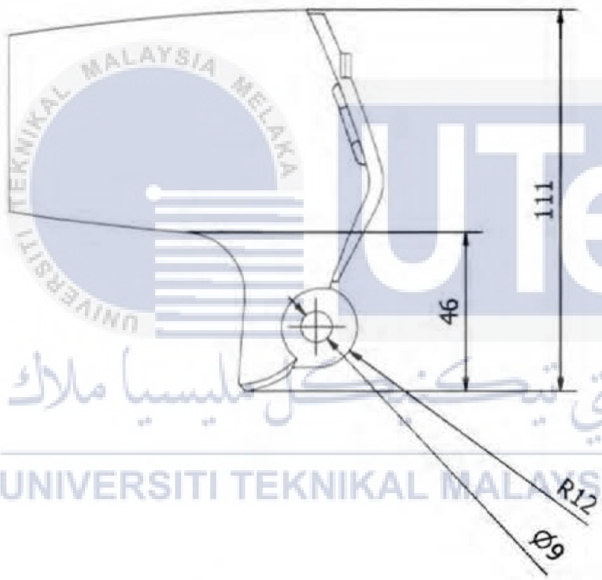
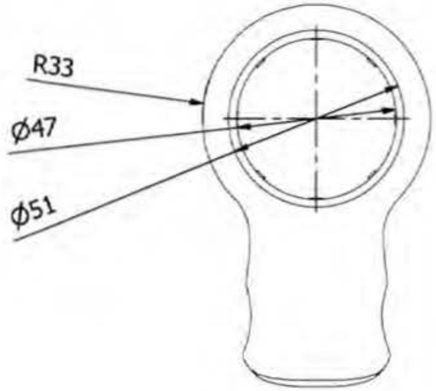
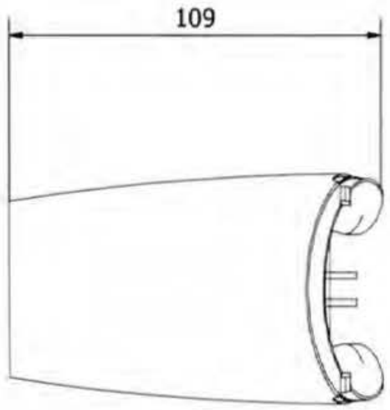
	Elba Hairdryer Drawing			Edition	Sheet 5 / 21







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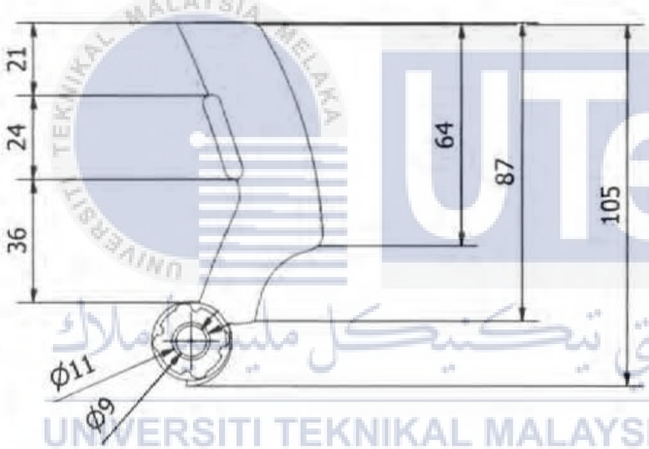
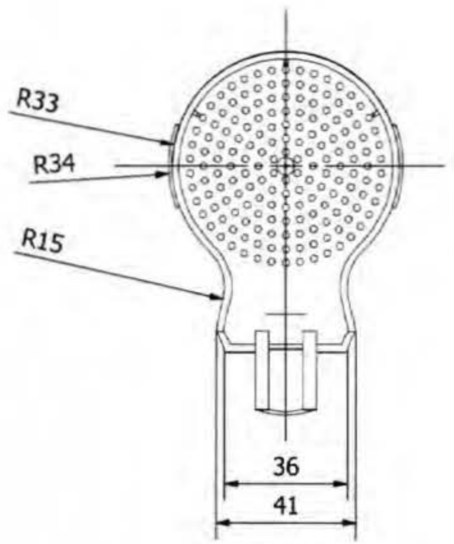
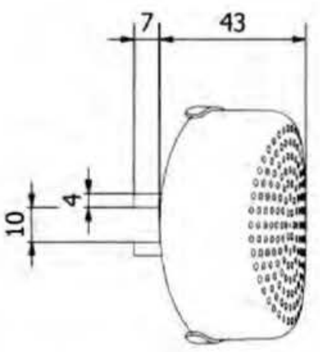
Universiti Teknikal Malaysia Melaka			Front Body		
			Elba Hairdryer Drawing	Edition	Sheet 6 / 21







Designed by	Checked by	Approved by	Date	Date	
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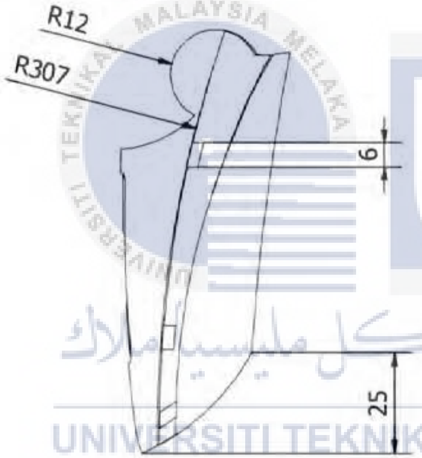
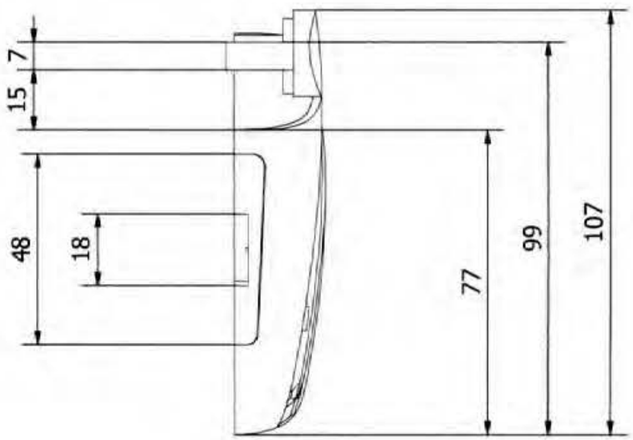
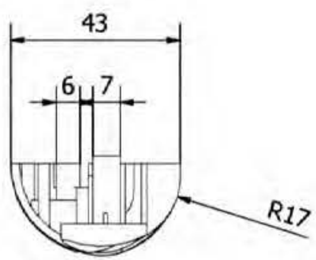
Universiti Teknikal Malaysia Melaka		Back Body			
		Elba Hairdryer Drawing		Edition	Sheet 7 / 21







Designed by	Checked by	Approved by	Date	Date	
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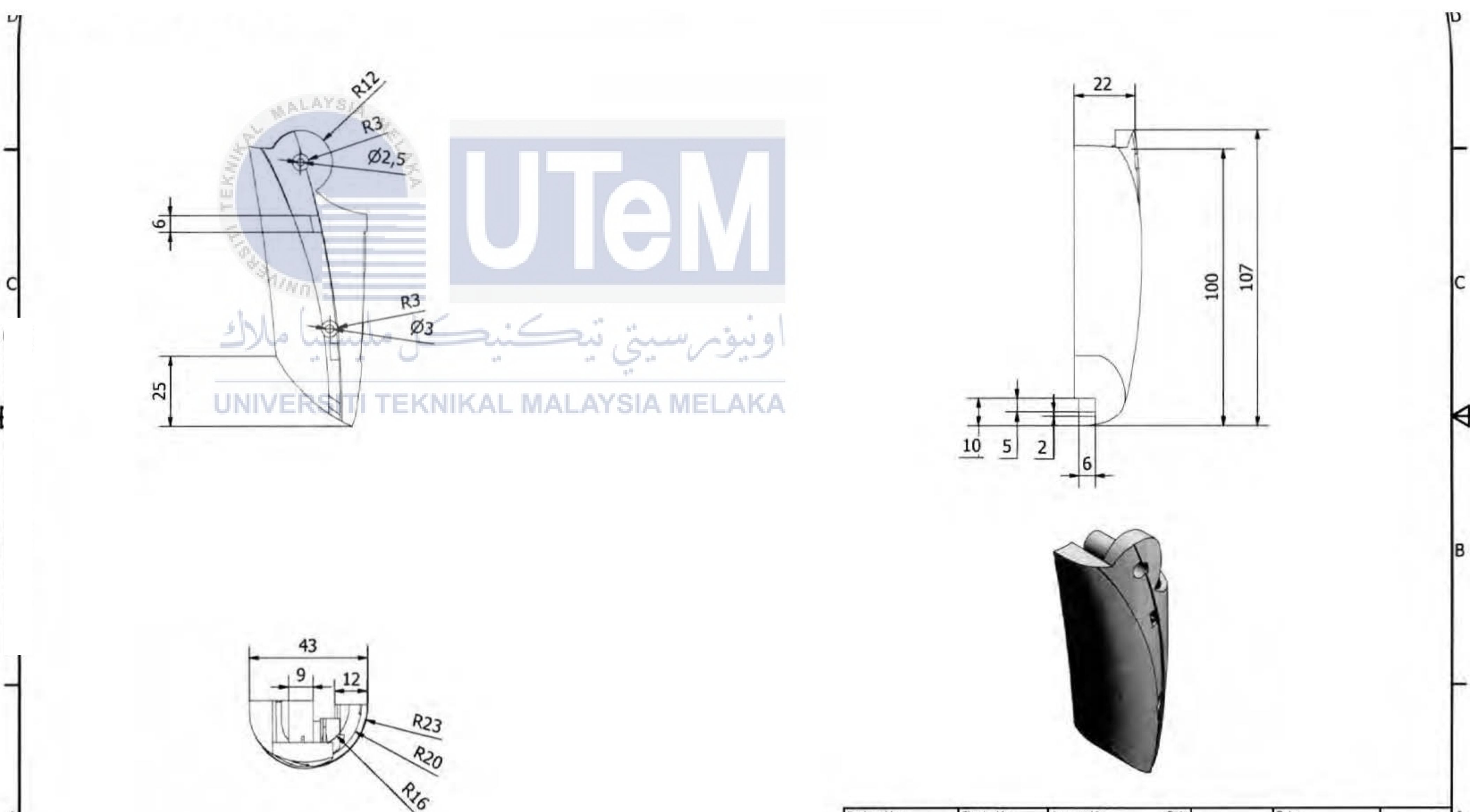
Universiti Teknikal Malaysia Melaka	Handle				
	Elba Hairdryer Drawing			Edition	Sheet 8 / 21



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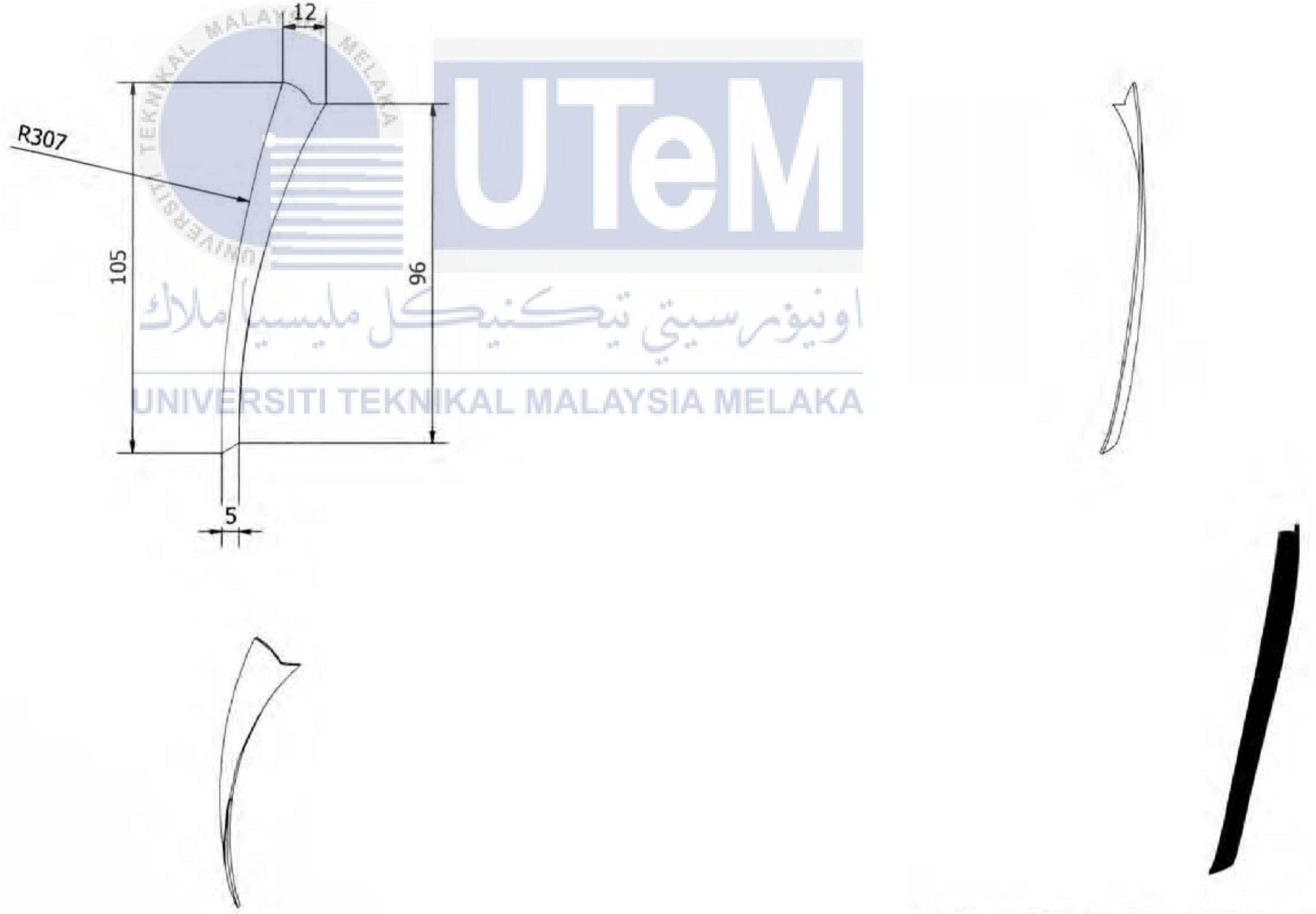
Universiti Teknikal Malaysia Melaka	Handle2			
	Elba Hairdryer Drawing		Edition	Sheet 9 / 21



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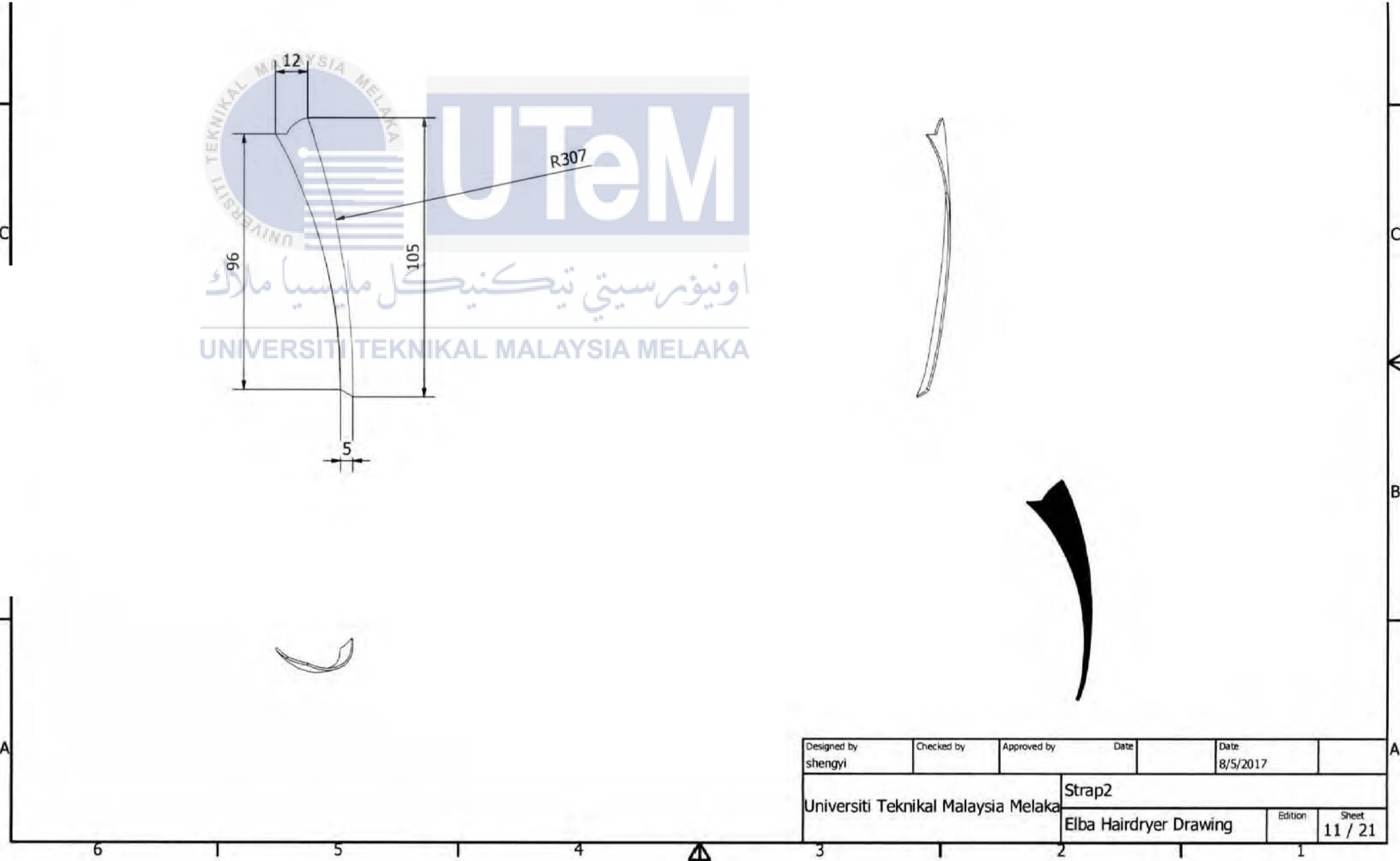
Universiti Teknikal Malaysia Melaka	Strap			
	Elba Hairdryer Drawing		Edition	Sheet 10 / 21



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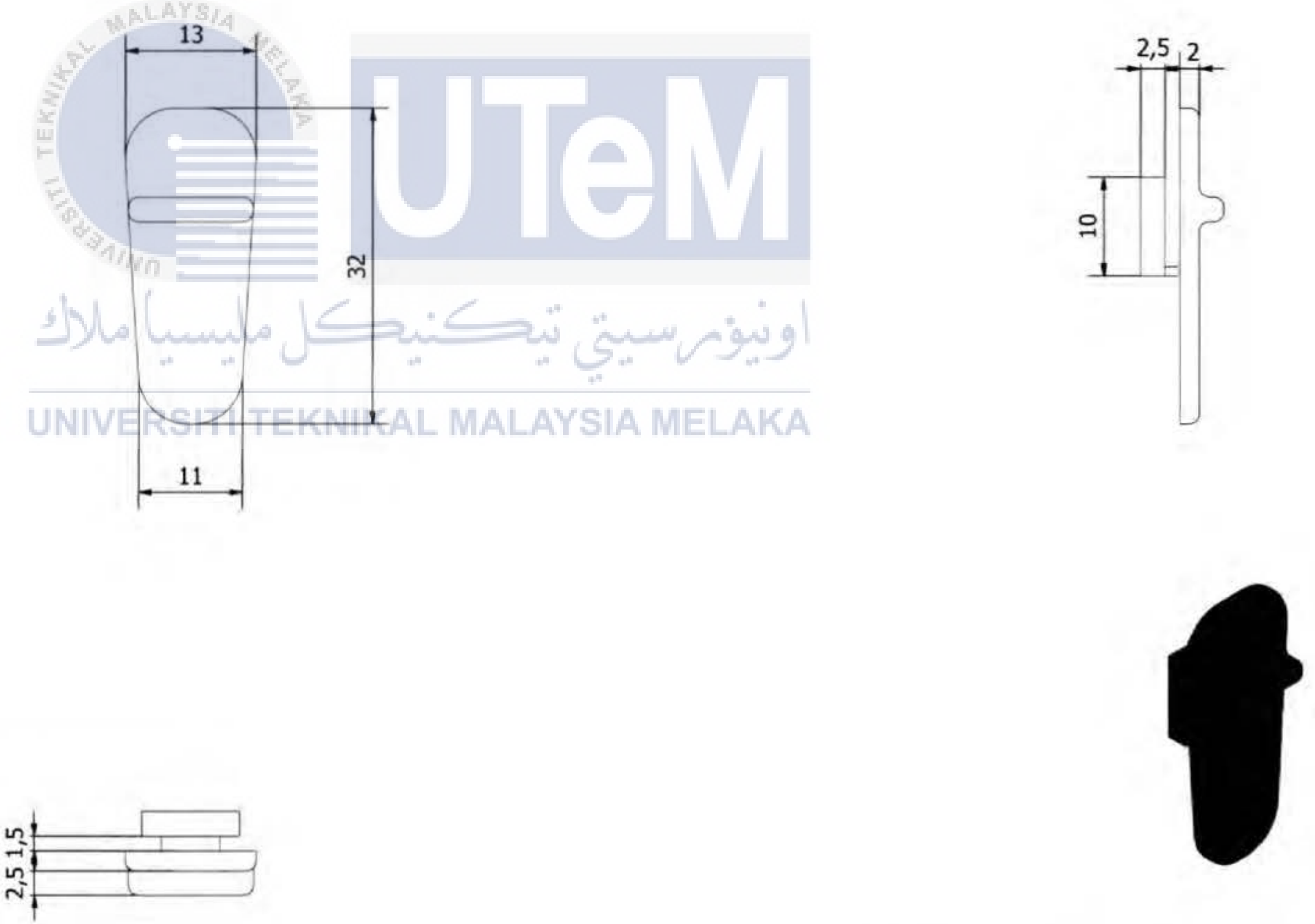
Universiti Teknikal Malaysia Melaka			Strap2		
			Elba Hairdryer Drawing	Edition	Sheet 11 / 21



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Universiti Teknikal Malaysia Melaka	Button			
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shengyi				8/5/2017	
Universiti Teknikal Malaysia Melaka	Wire Holder				
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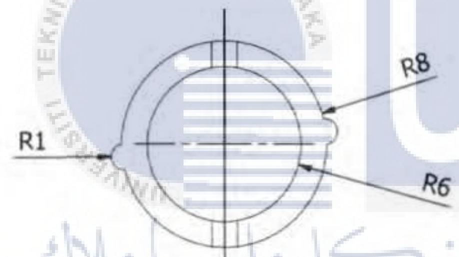

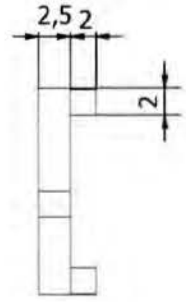

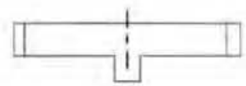

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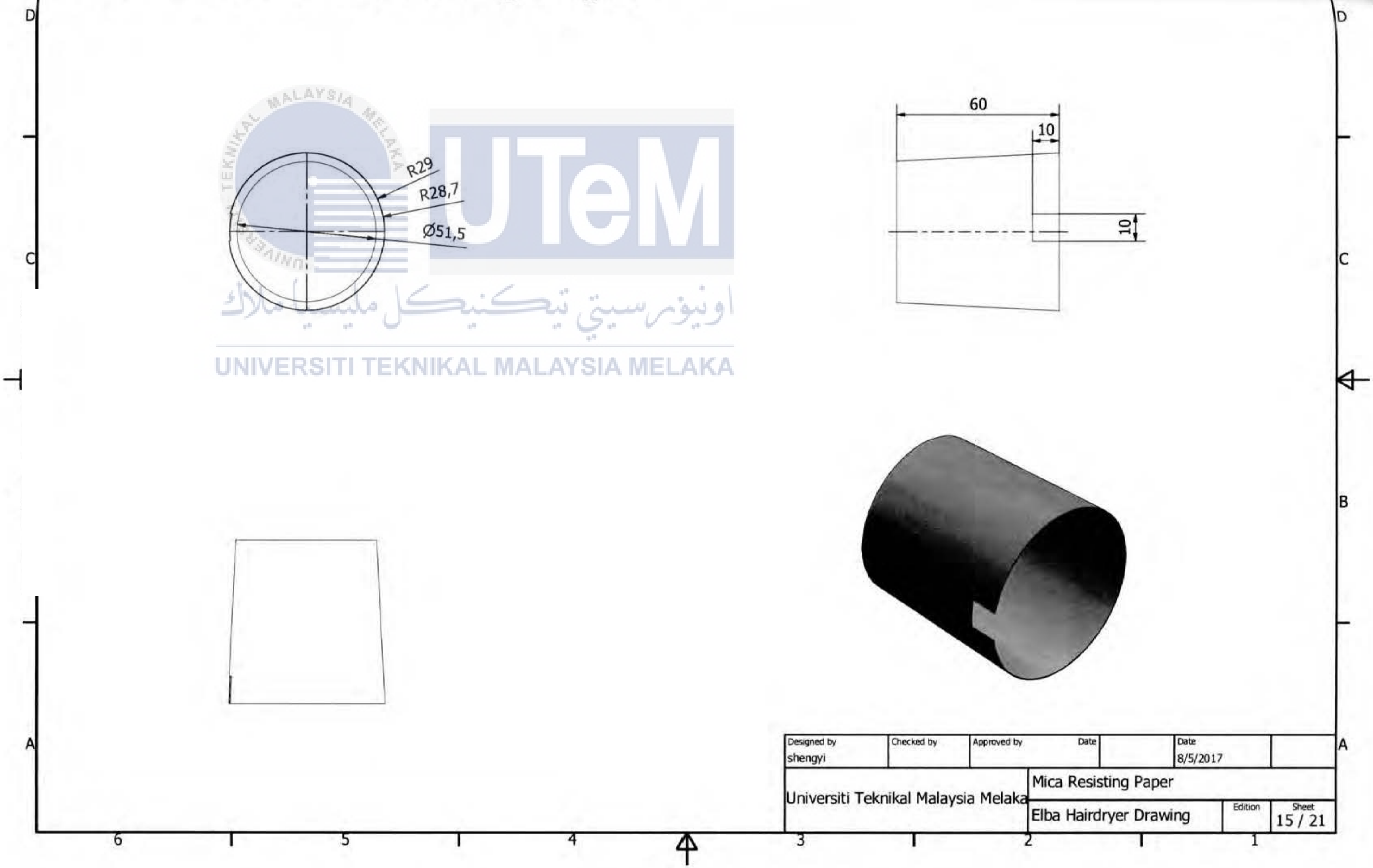
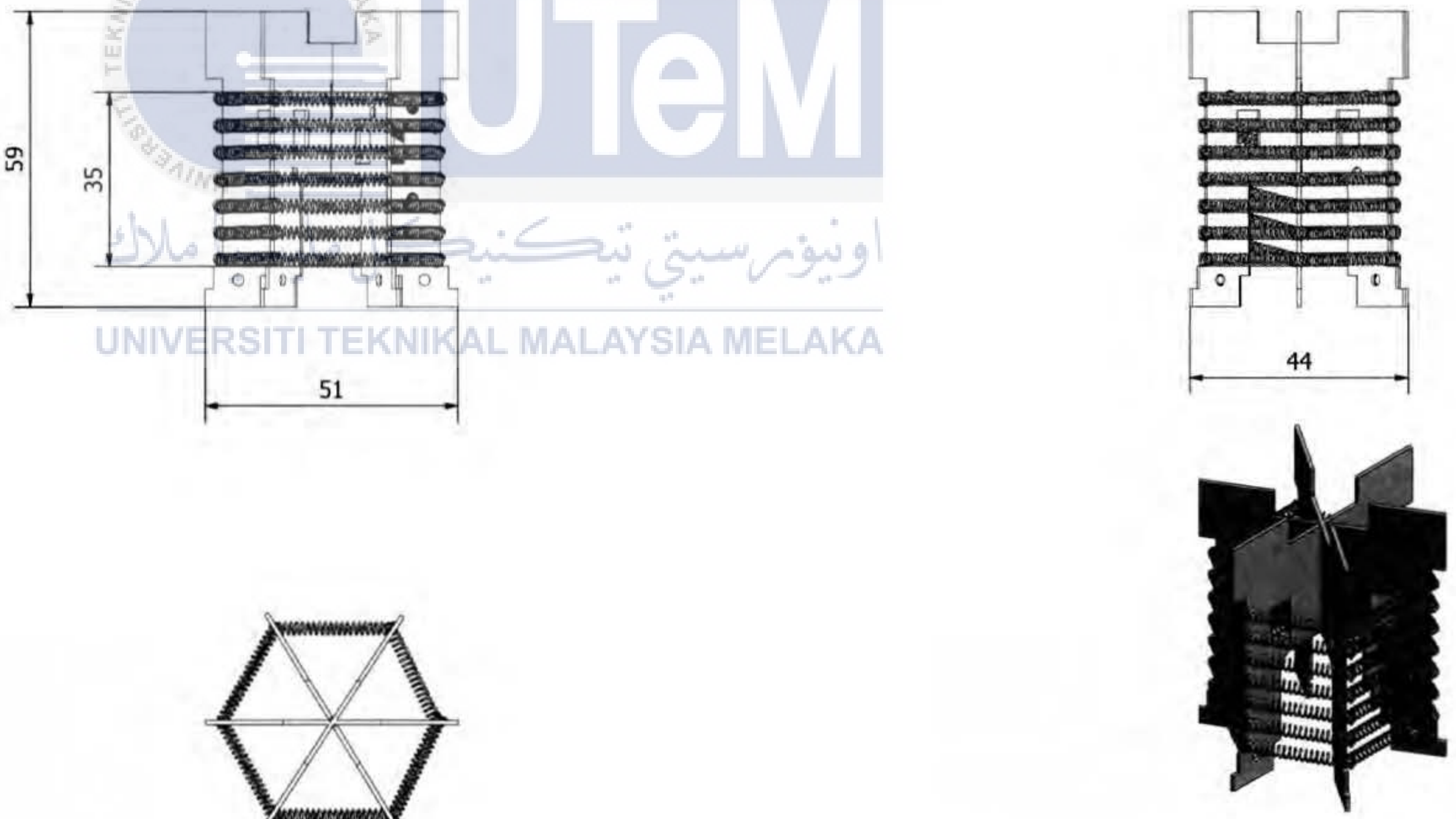
shengyi				8/5/2017	
Universiti Teknikal Malaysia Melaka	Joint				
	Elba Hairdryer Drawing			Edition	Sheet 14 / 21

Part 12-Mica Resisting Paper



Part 13-Heating Element



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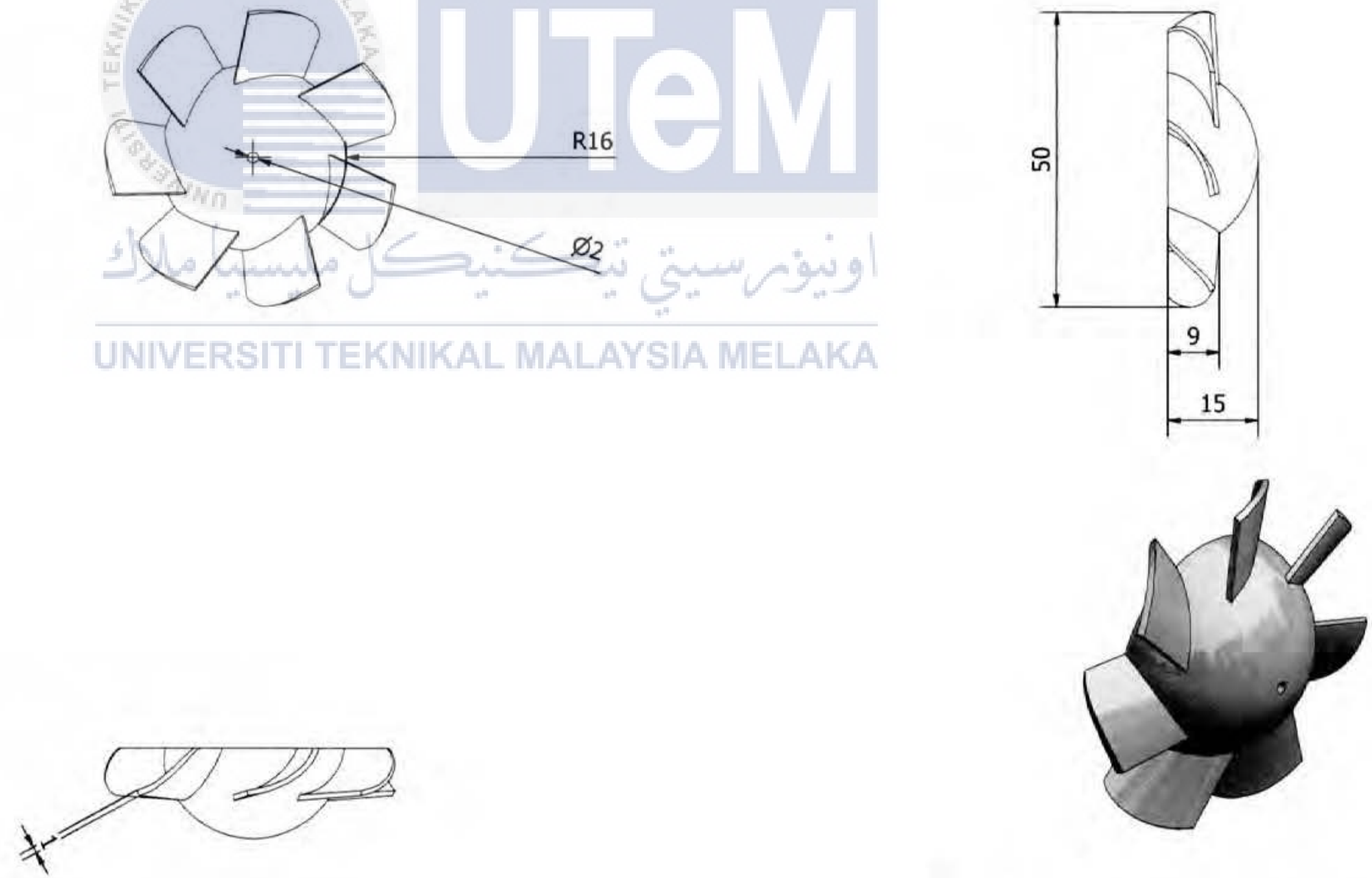
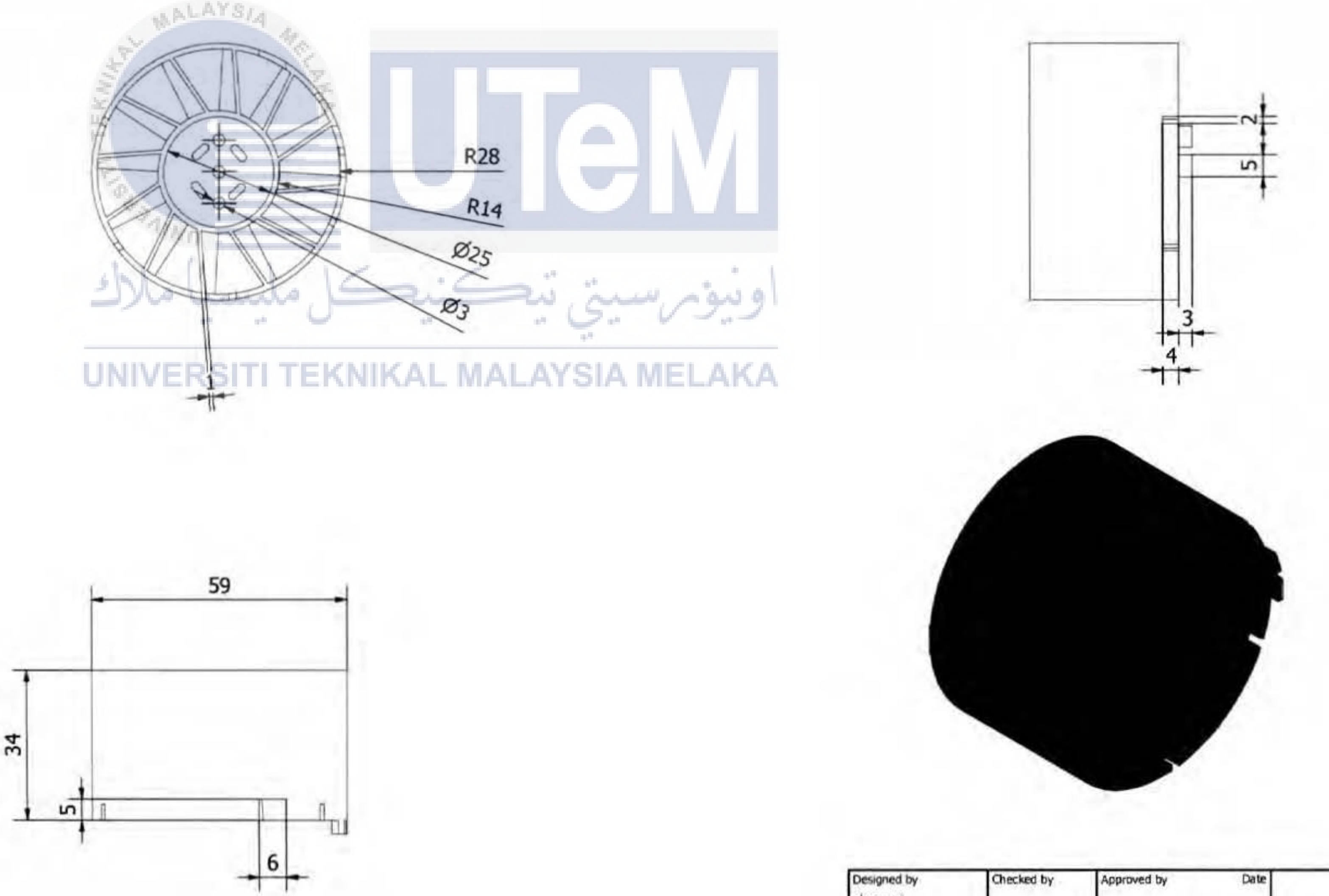
Universiti Teknikal Malaysia Melaka		Heating Element			
		Elba Hairdryer Drawing		Edition	Sheet 16 / 21

Part 14-Fan



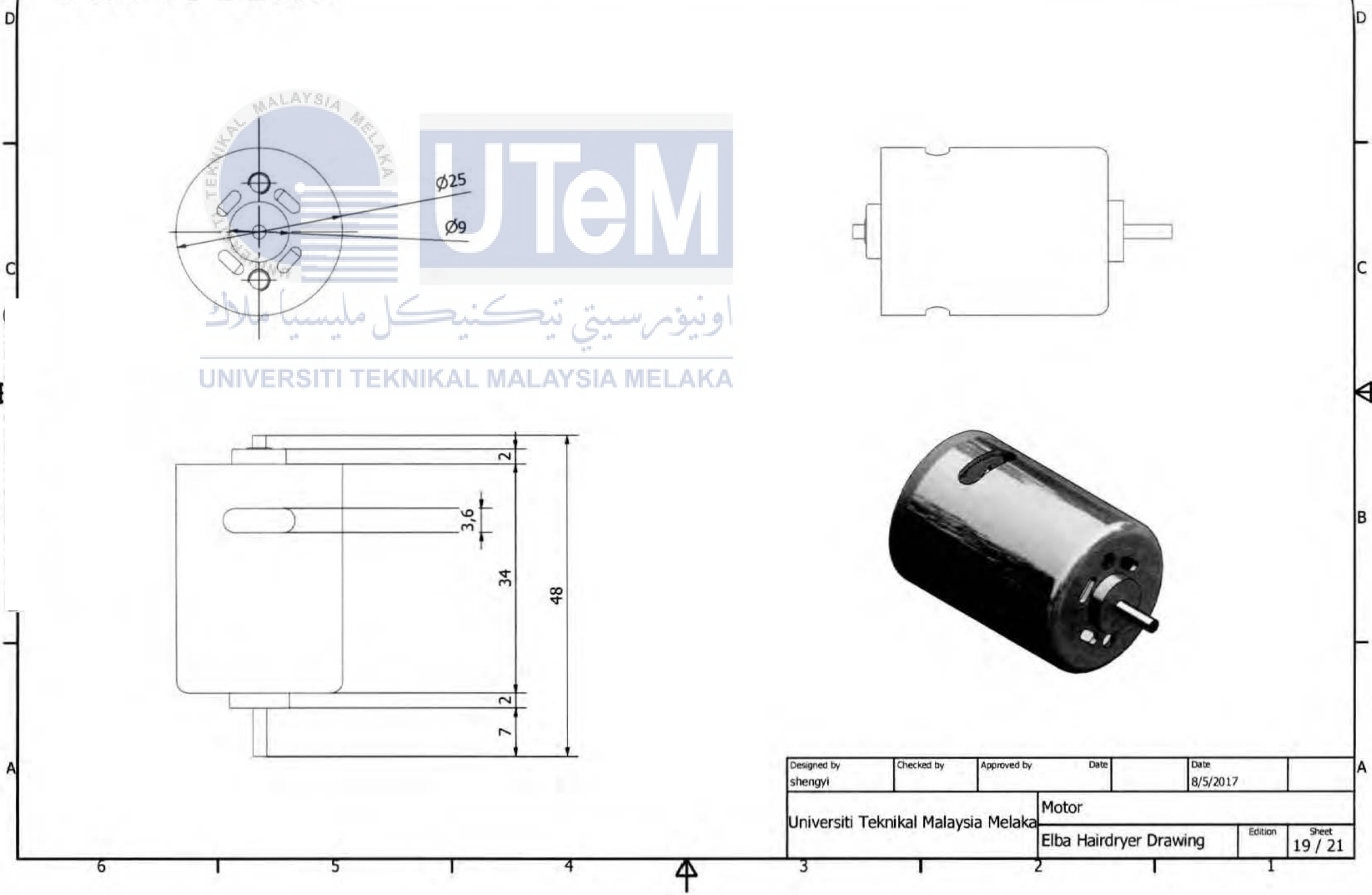
Designed by	Checked by	Approved by	Date	Date	
shengyi				8/5/2017	
Universiti Teknikal Malaysia Melaka		Fan			
		Elba Hairdryer Drawing		Edition	Sheet 17 / 21

Part 15-Bracket

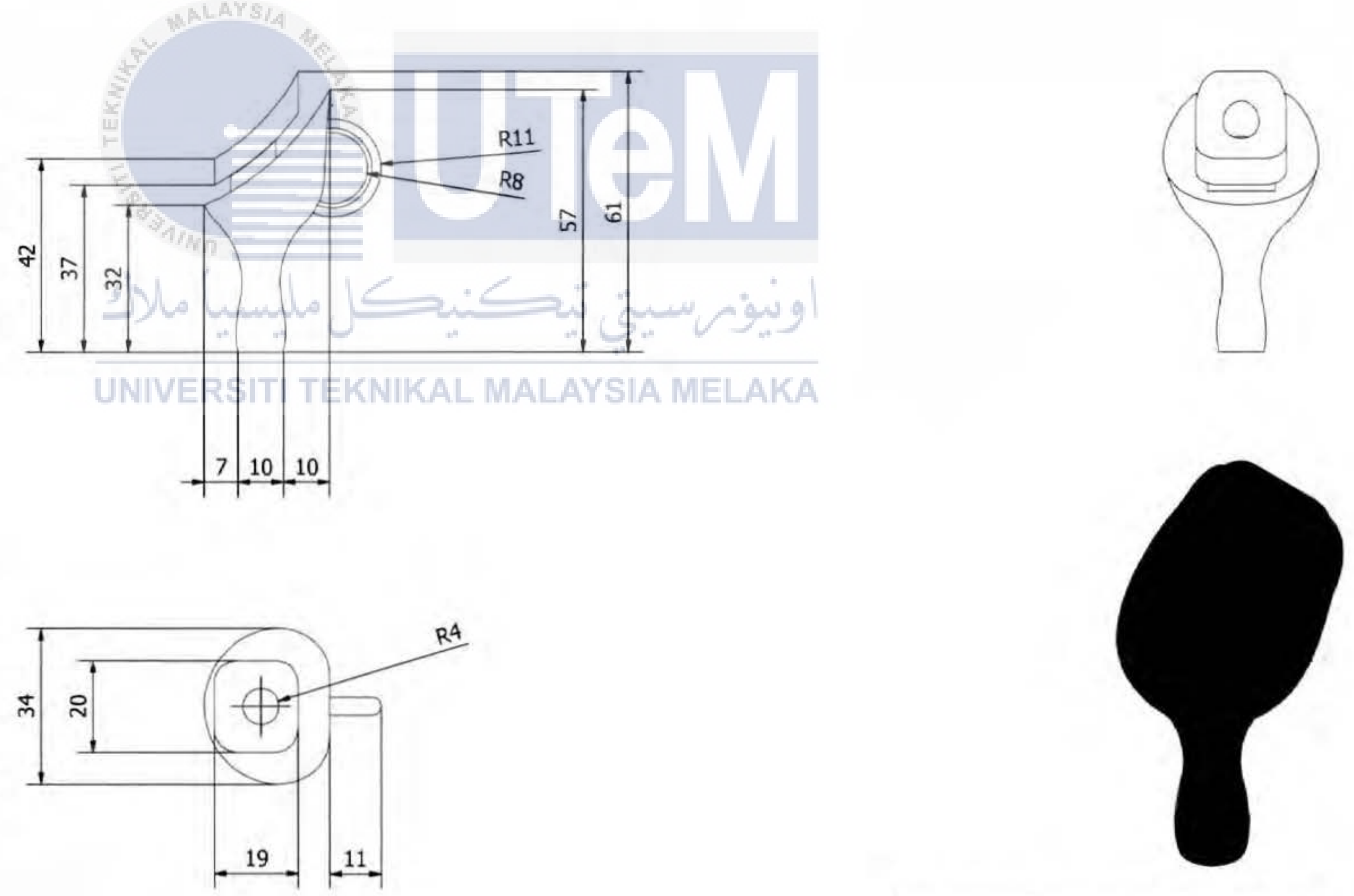


Designed by	Checked by	Approved by	Date	Date	
shengyi				8/5/2017	
Universiti Teknikal Malaysia Melaka			Bracket		
			Elba Hairdryer Drawing	Edition	Sheet 18 / 21

Part 16-Motor



Part 17- Wire Cord



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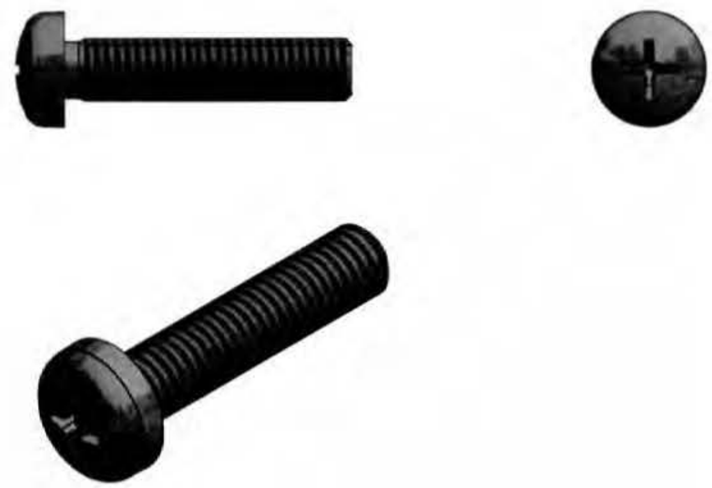
shengyi				8/5/2017	
Universiti Teknikal Malaysia Melaka			Wire Cord		
			Elba Hairdryer Drawing	Edition	Sheet 20 / 21

Part 18-Screw M3x10

Part 19-Screw M3x14



Part 20-Screw M3x8

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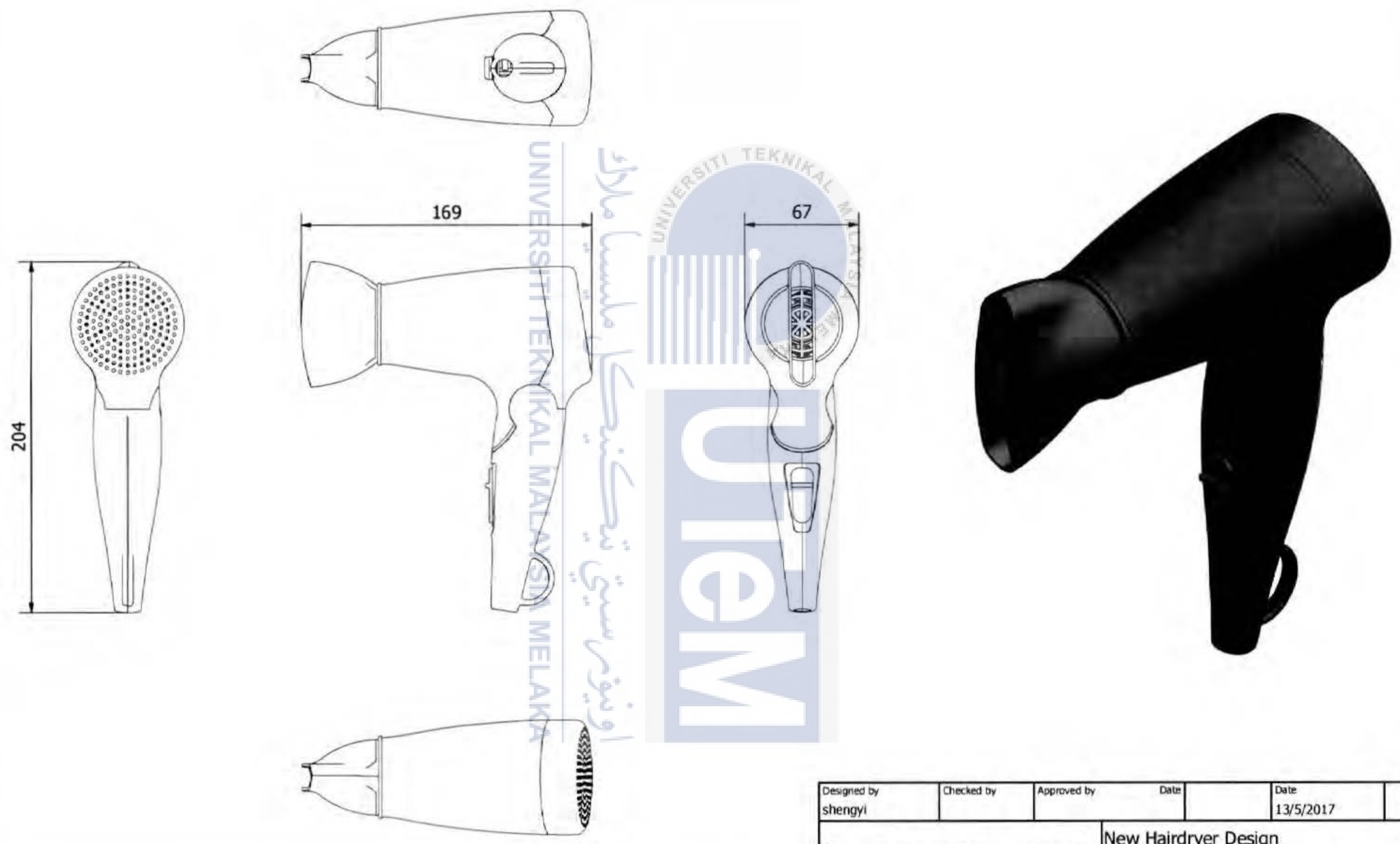
shengyi				8/5/2017	
Universiti Teknikal Malaysia Melaka			Fasteners		
			Elba Hairdryer Drawing	Edition	Sheet 21 / 21

New Hairdryer Design



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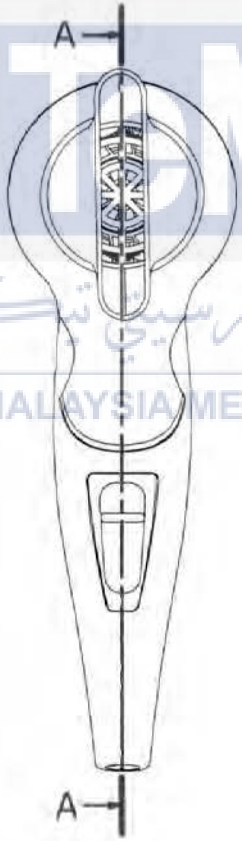
shengyi				13/5/2017	
Universiti Teknikal Malaysia Melaka			New Hairdryer Design		
			New Design Drawing	Edition	Sheet 1 / 15

New Handryer Design Sectional View



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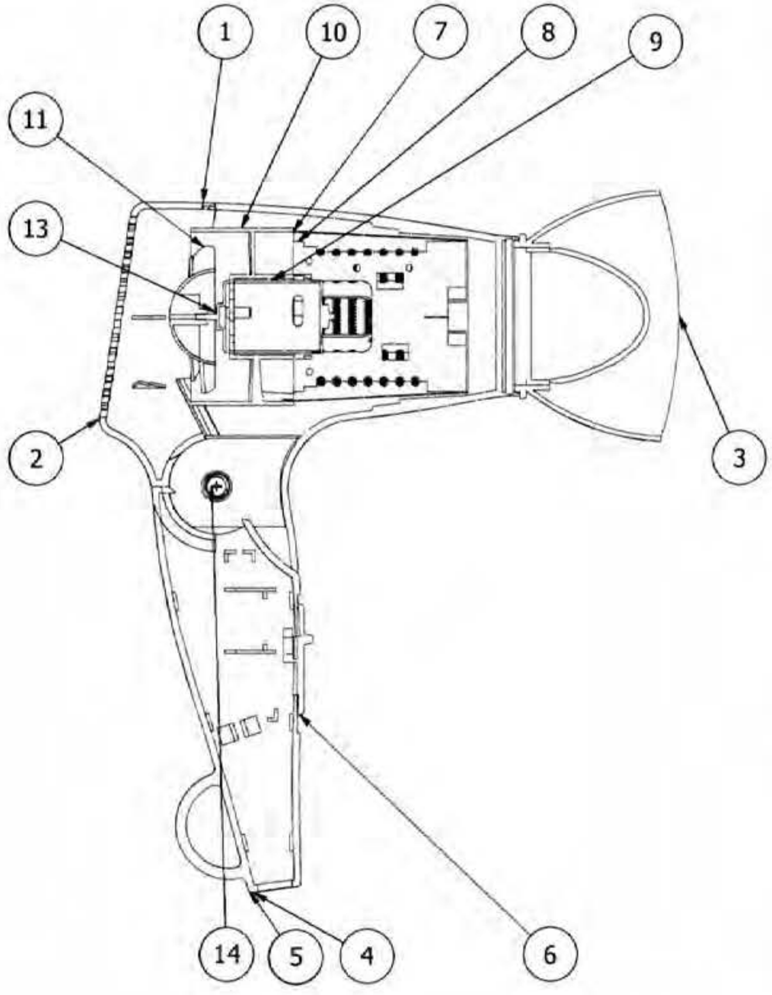

PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Front Body
2	1	Back Body
3	1	Concentrator
4	1	Handle1
5	1	Handle2
6	1	Button
7	1	Mica Resisting Paper
8	1	Heating Element
9	1	Motor
10	1	Bracket
11	1	Fan
13	2	Screw M3 x 8 - 4.8 - H
14	1	Screw M3 x 14 - 4.8 - H

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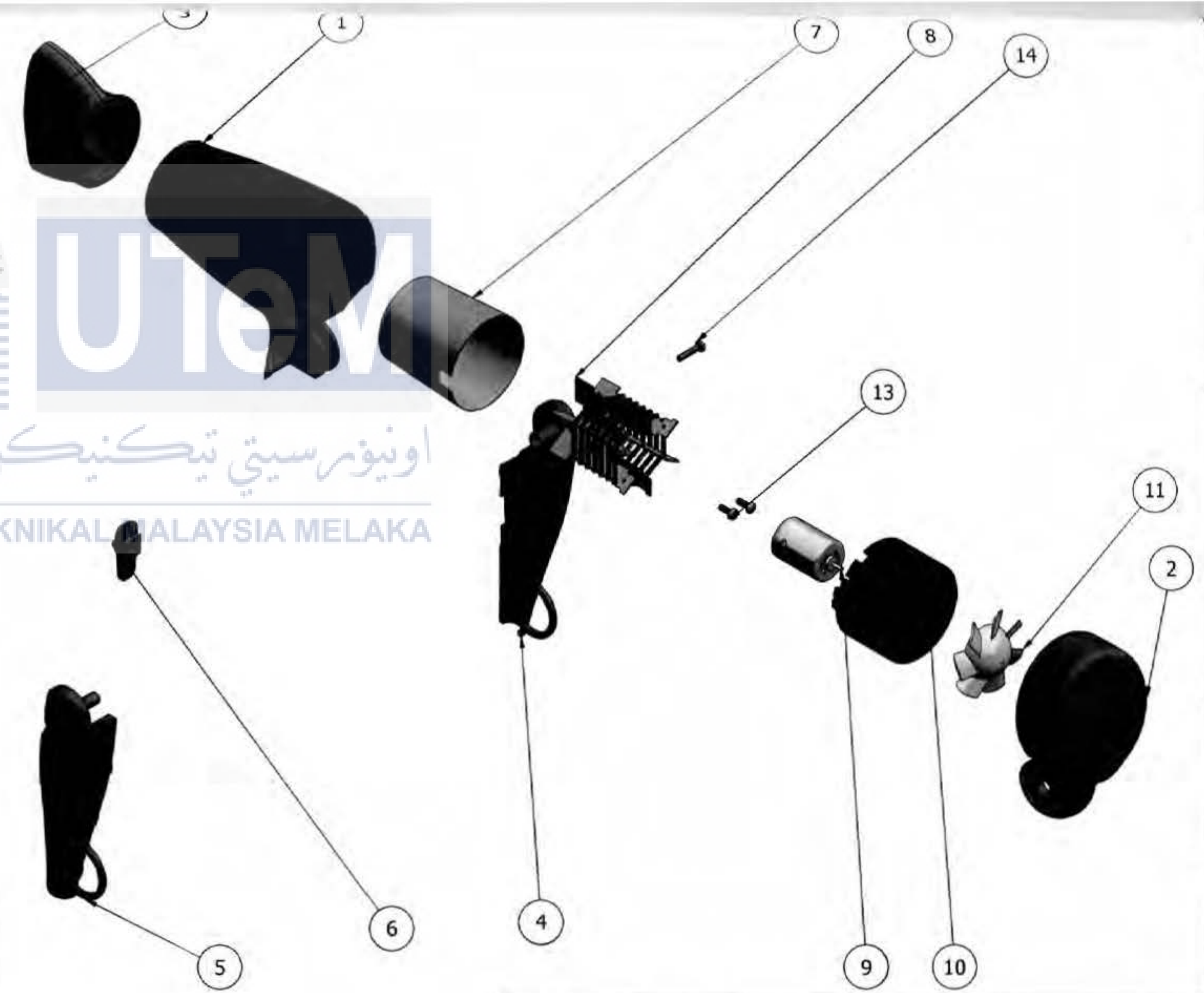
shengyi				13/5/2017	
Universiti Teknikal Malaysia Melaka			Sectional View		
			New Design Drawing	Edition	Sheet 2 / 15



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Front Body
2	1	Back Body
3	1	Concentrator
4	1	Handle1
5	1	Handle2
6	1	Button
7	1	Mica Resisting Paper
8	1	Heating Element
9	1	Motor
10	1	Bracket
11	1	Fan
13	2	Screw M3 x 8 - 4.8 - H
14	1	Screw M3 x 14 - 4.8 - H

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Exploded View

New Design Drawing

Edition

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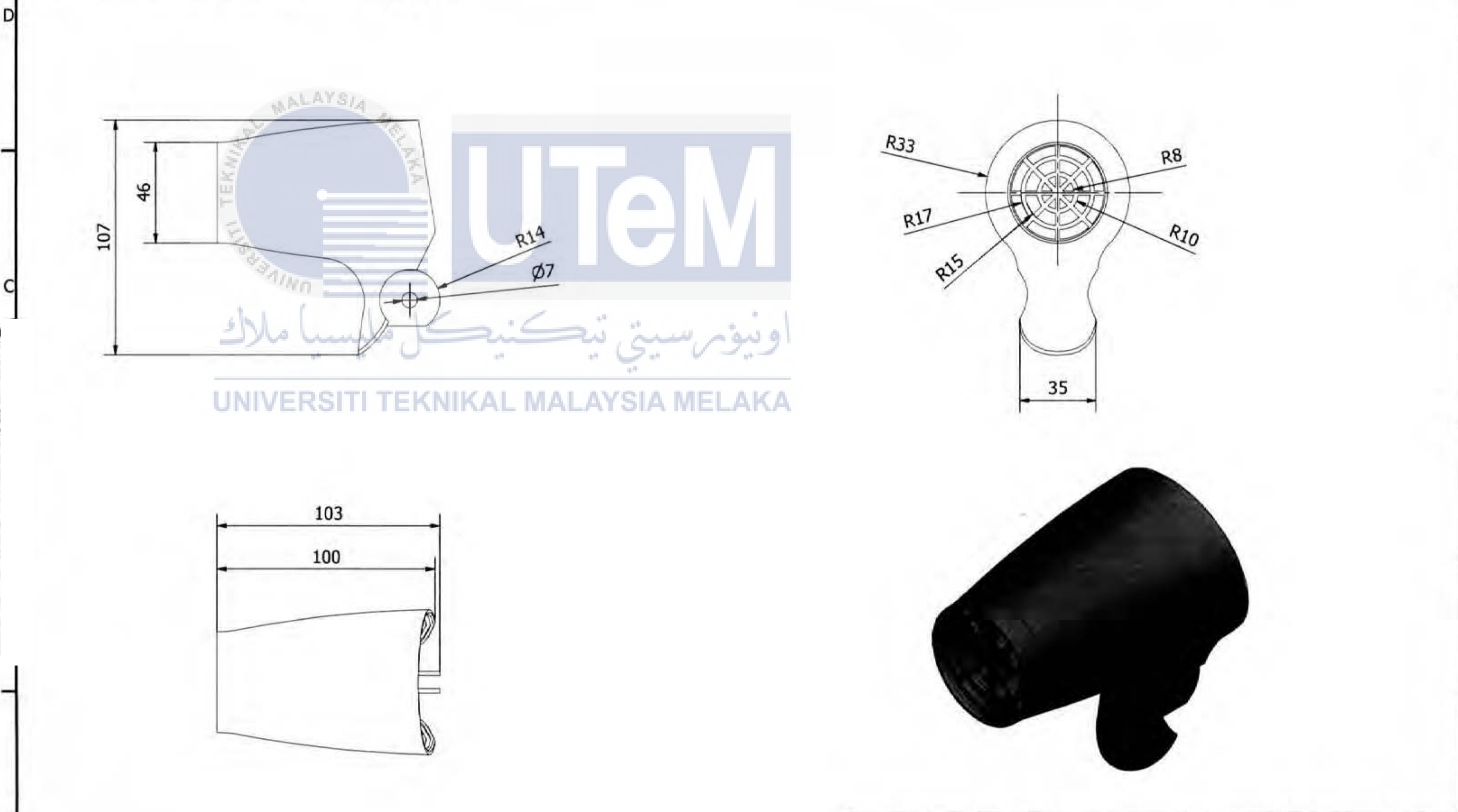
Part 1-Front Body



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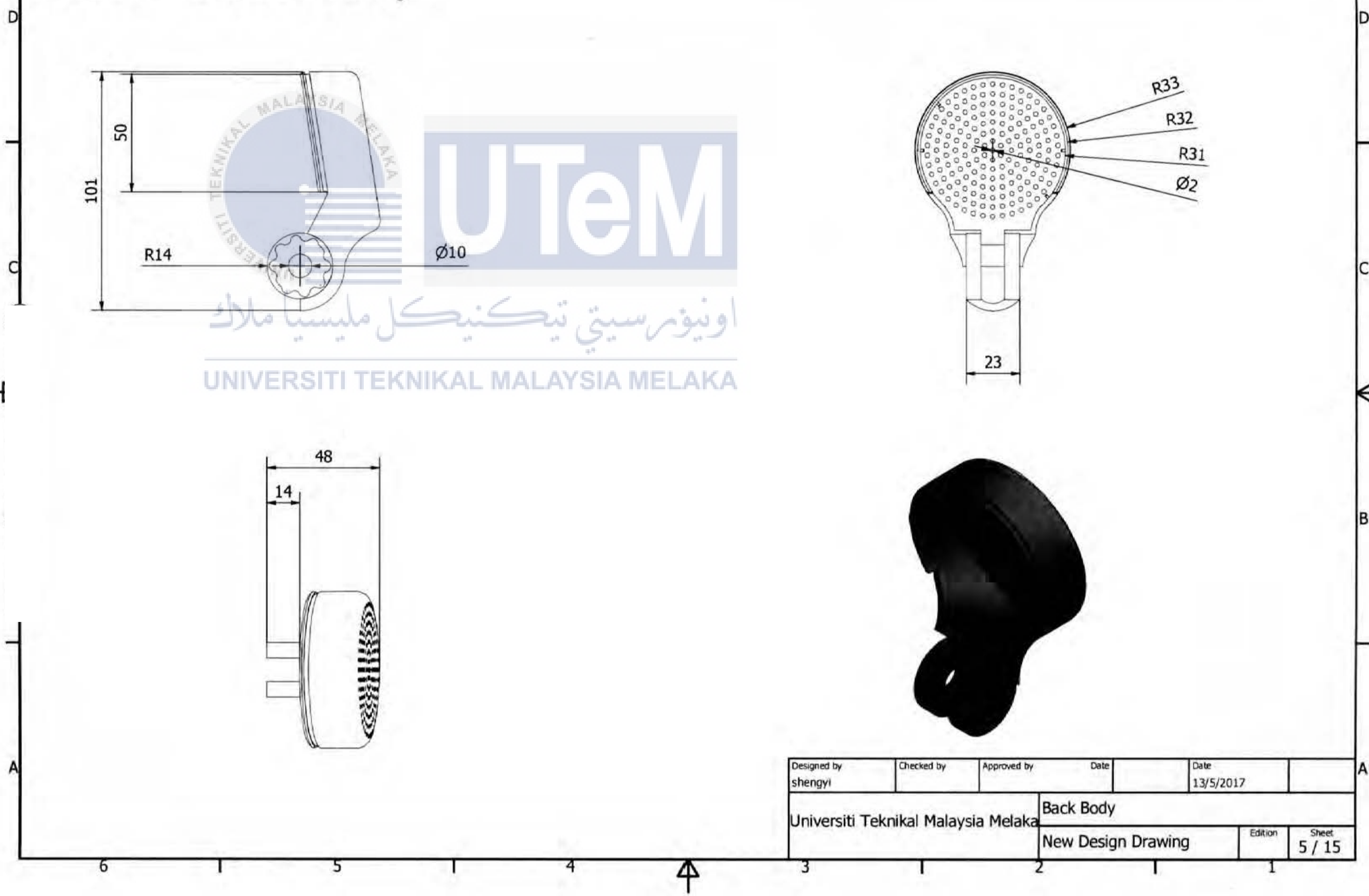
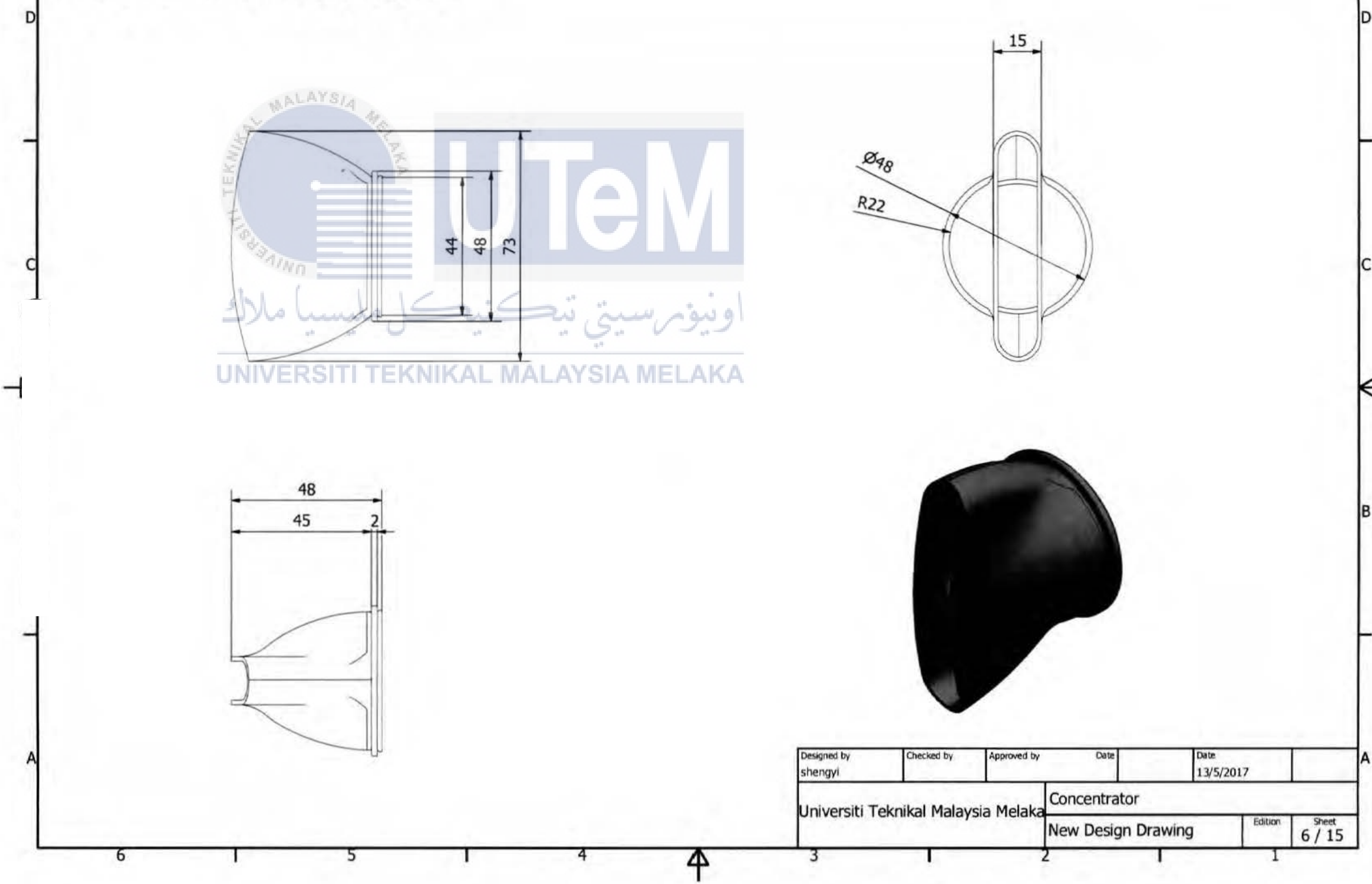
shengyi				13/5/2017	
Universiti Teknikal Malaysia Melaka		Front Body			
		New Design Drawing		Edition	Sheet 4 / 15

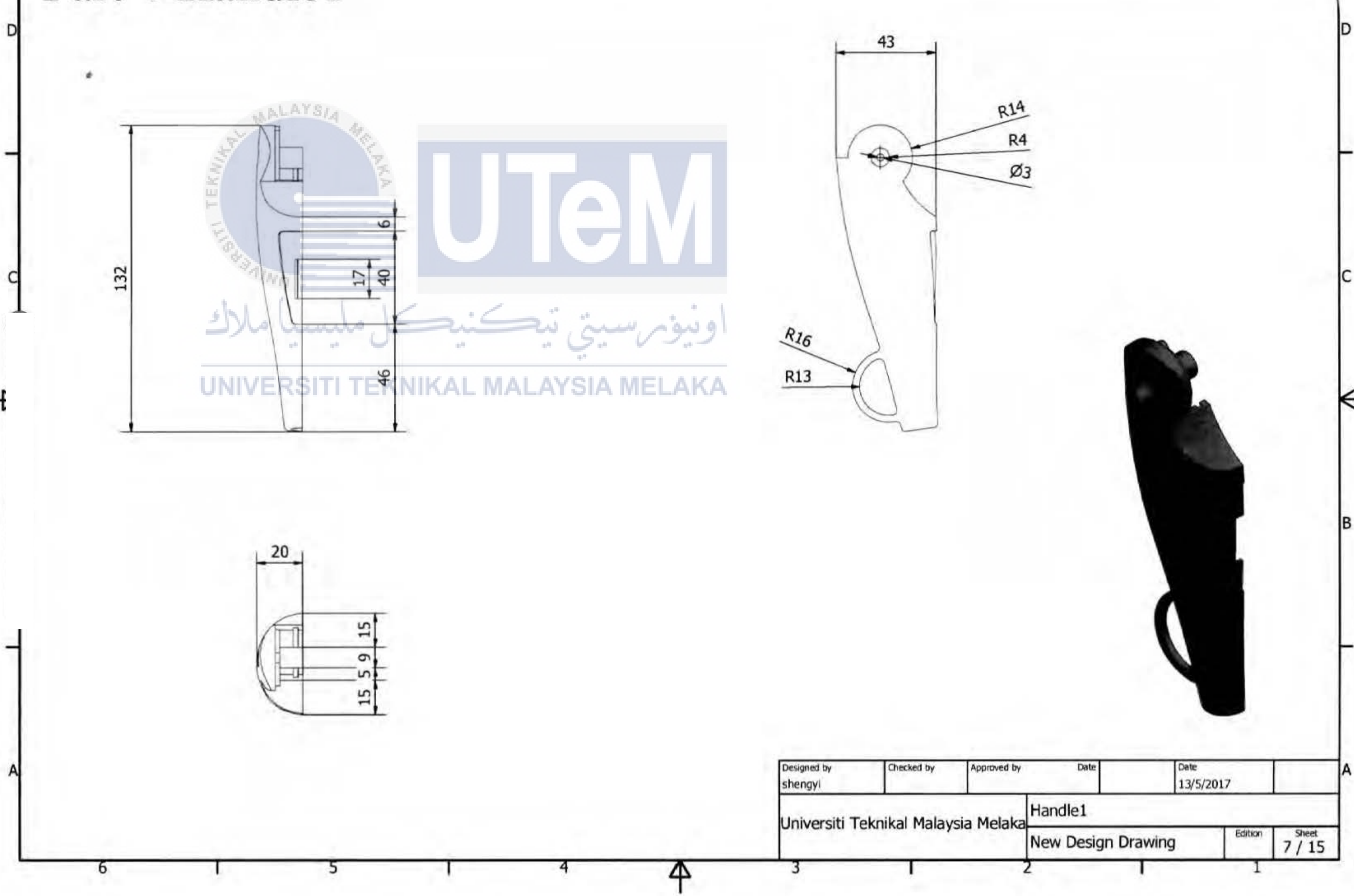
Part 2- Back Body



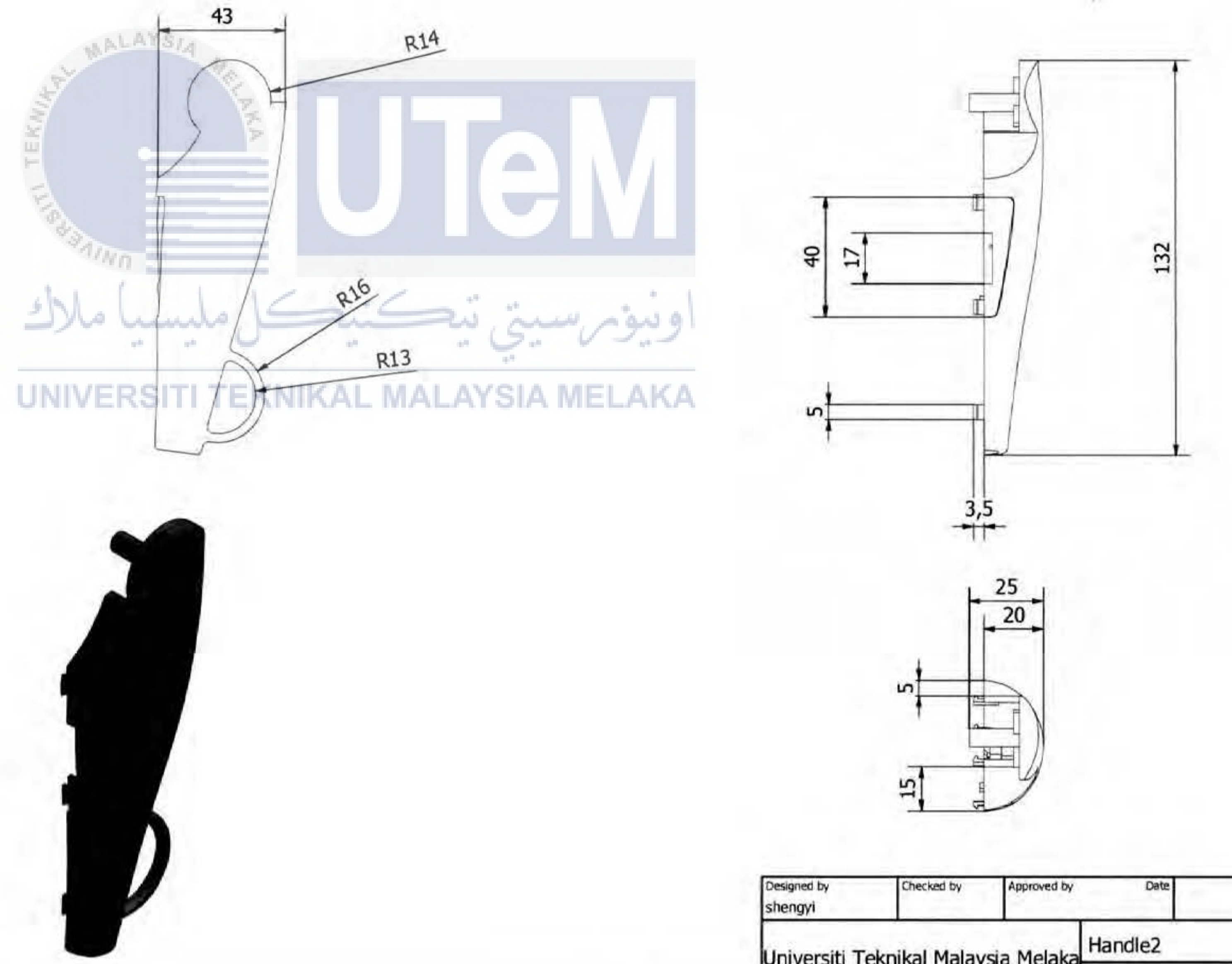
Part 3-Concentrator



Part 4-Handle1

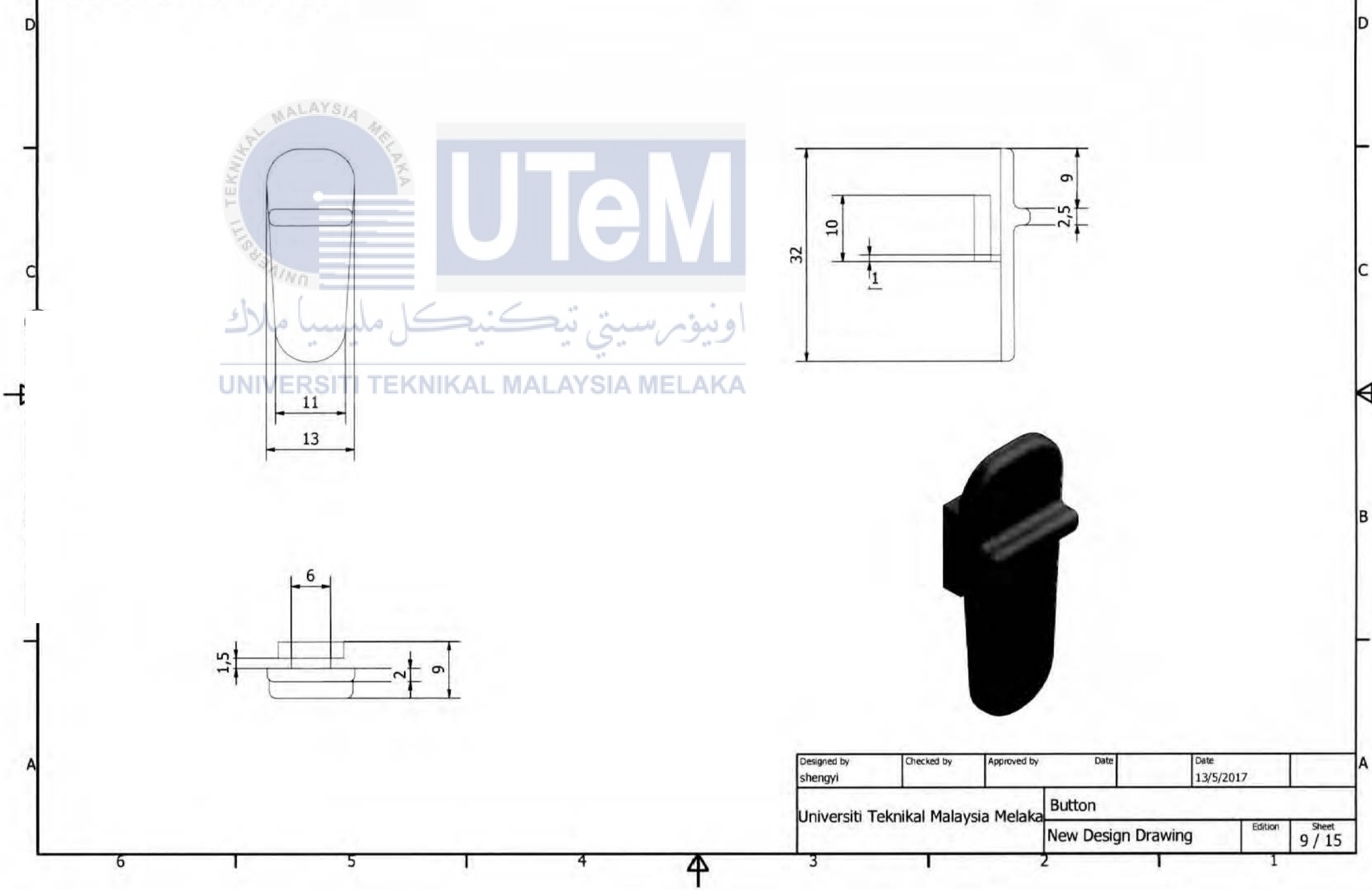


Part 5-Handle2

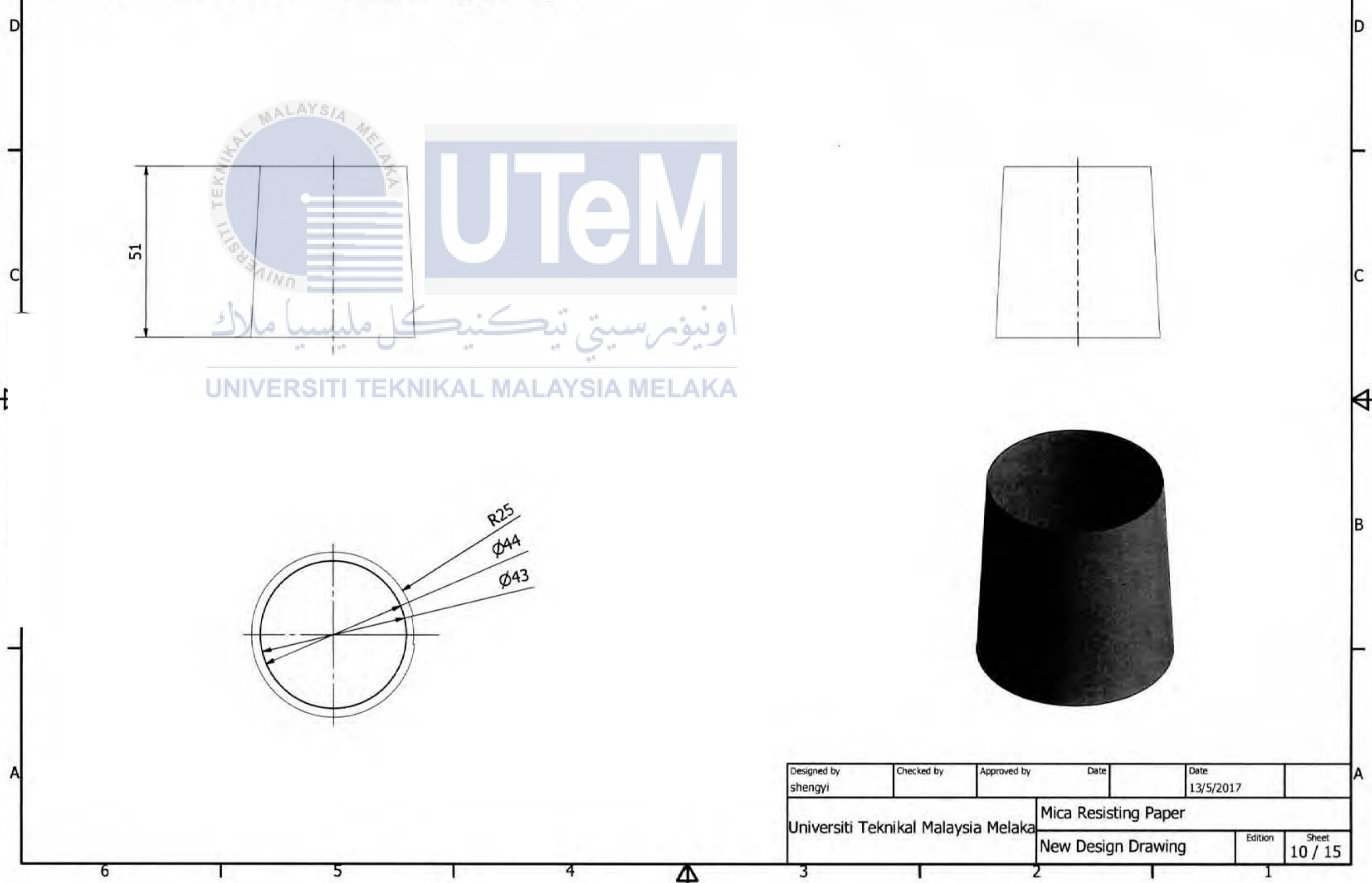


Designed by	Checked by	Approved by	Date	Date	
shengyi				13/5/2017	
Universiti Teknikal Malaysia Melaka		Handle2			
		New Design Drawing		Edition	Sheet 8 / 15

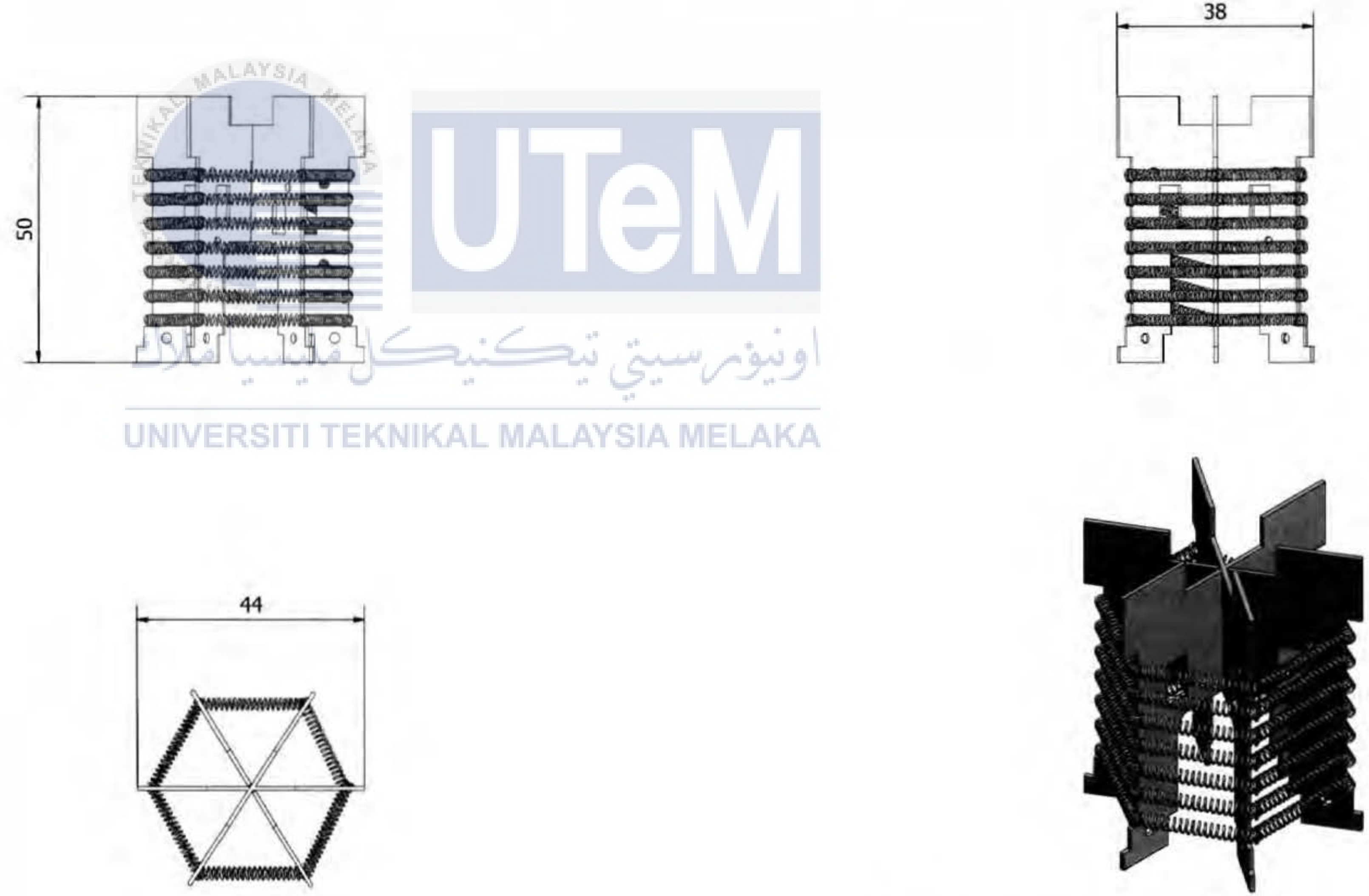
Part 6-Button



Part 7-Mica Resisting Paper



Part 8-Heating Element



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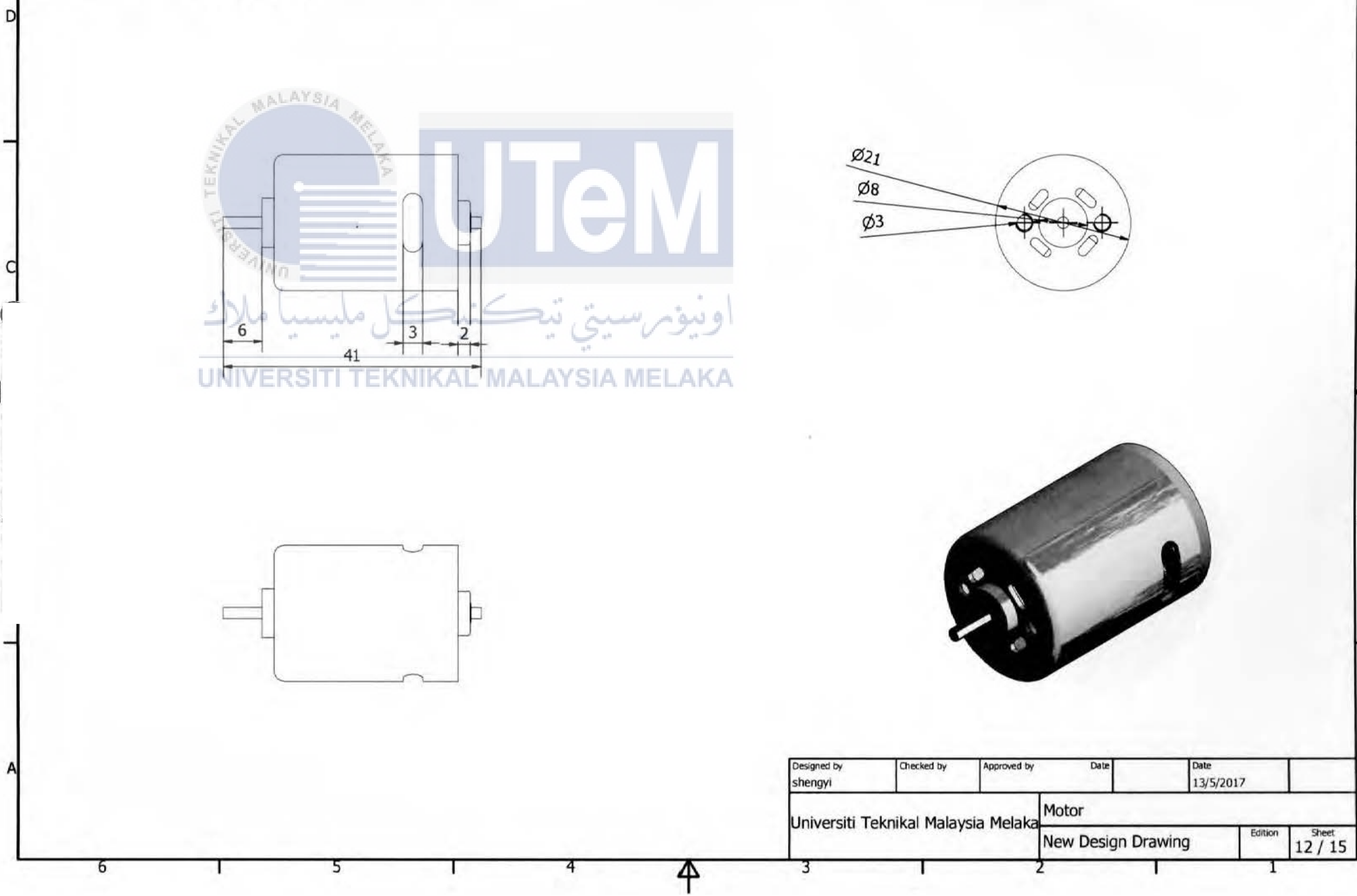
shengyi				13/5/2017	
Universiti Teknikal Malaysia Melaka			Heating Element		
			New Design Drawing	Edition	Sheet 11 / 15

Part 9-Motor


Ø21
Ø8
Ø3
6
3
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41
Designed by
shengyi
Checked by
Approved by
Date
Date
13/5/2017
Universiti Teknikal Malaysia Melaka
Motor
New Design Drawing
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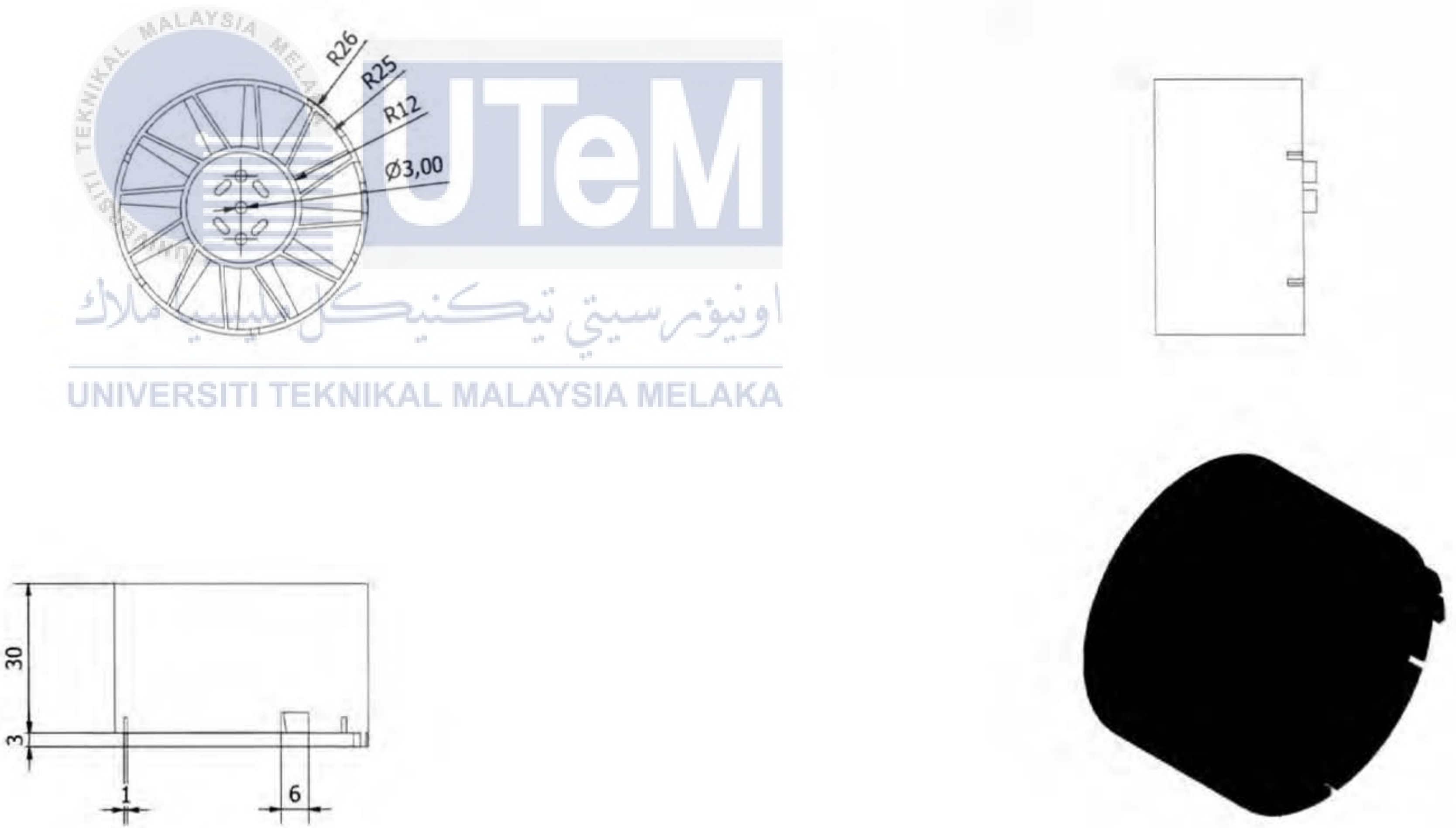
Part 10-Bracket



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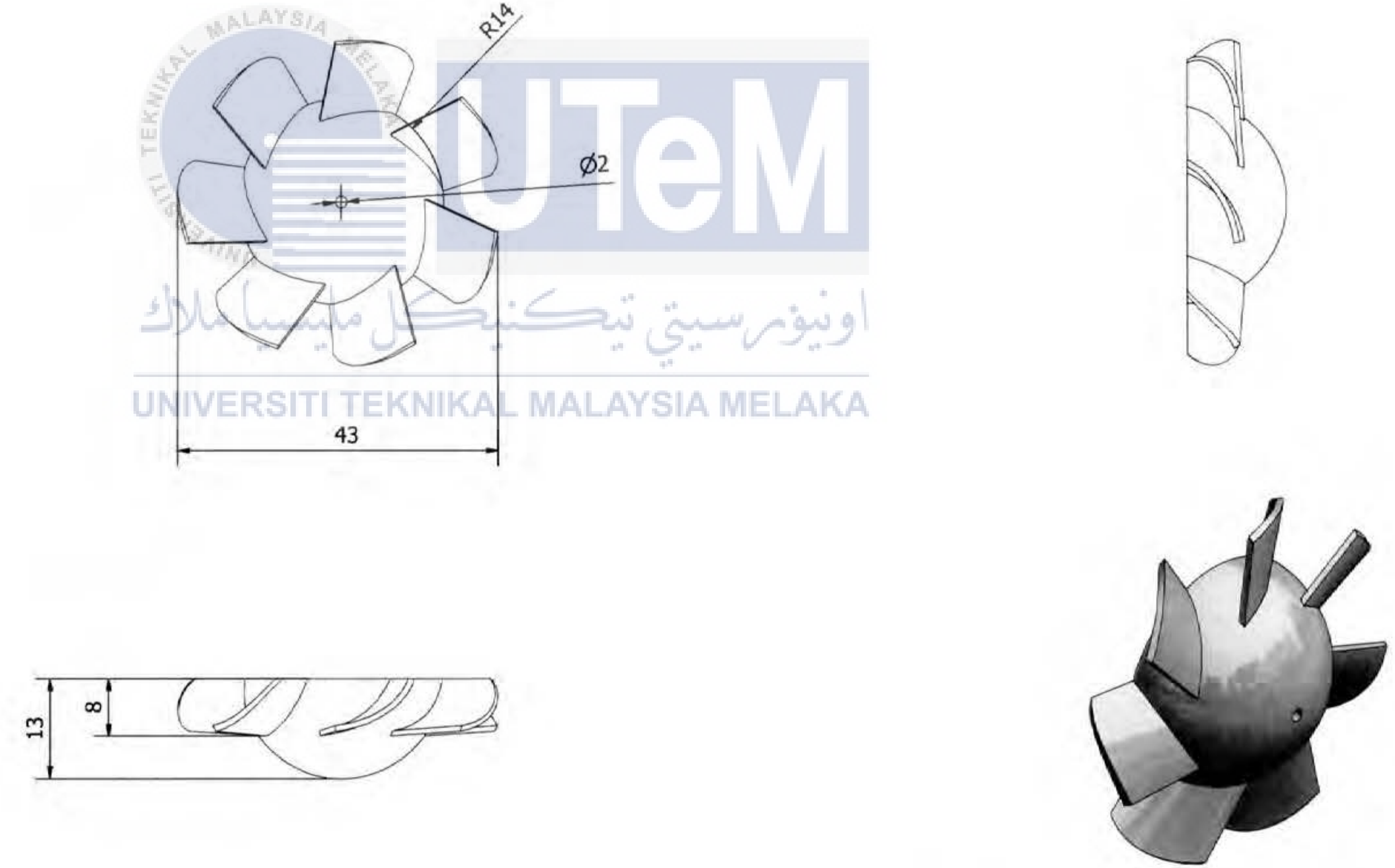
shengyi				13/5/2017	
Universiti Teknikal Malaysia Melaka	Bracket				
	New Design Drawing			Edition	Sheet 13 / 15

Part 11-Fan



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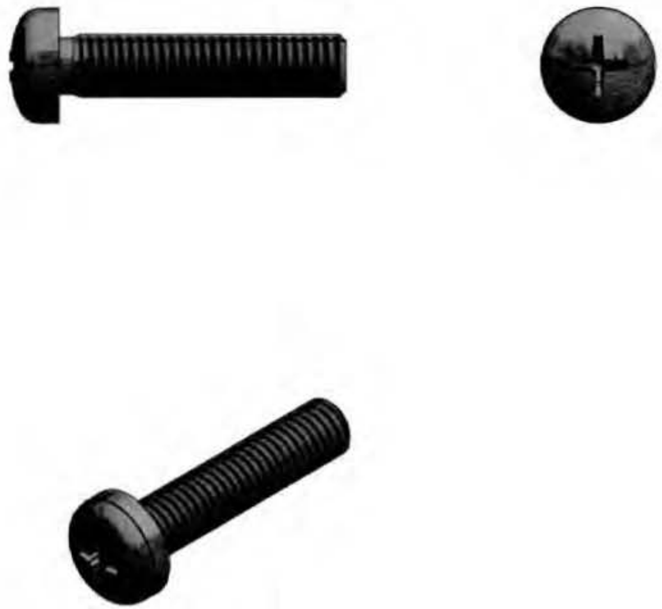
shengyi				13/5/2017	
Universiti Teknikal Malaysia Melaka			Fan		
			New Design Drawing	Edition	Sheet 14 / 15

Part 12-Screw M3x8

Part 13-Screw M3x14



Designed by shengyi	Checked by	Approved by	Date	Date 13/5/2017	
Universiti Teknikal Malaysia Melaka			Fasteners		
			New Design Drawing	Edition	Sheet 15 / 15