OPTIMIZATION OF KITCHEN SCALE DESIGN BY USING BOOTHROYD-DEWHURST DFA METHOD

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We certify that the project entitled " Optimization of Kitchen Scale Design By Using Boothroyd-Dewhurst DFA Method " is written by Muhammad Asyraf Bin Mohd Niza. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. We herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

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Examiner	Signature

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

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NOVEMBER 2009

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

....

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

....

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Date: 3 November 2009

DEDICATION

For my Father and Mother.

Mohd Niza Bin Abdul Aziz

Faridah Akmal Binti Ghazali

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ABSTRACT

This thesis deals with design optimization of existing produt (kitchen scale) for better improvement by using Boothroyd-Dewhurst Design for Assembly (DFA) Methodology. The objective of this thesis is to generate a new design of kitchen scale that consider the matter of parts elimination, cost estimation, and design efficiency (DE). The thesis describes the Boothroyd-Dewhurst DFA method in obtaining the suggestion for redesign of the parts evaluated. The strategy of evaluating the existing design is first to choose the available product in the market in order to solve a problem. The product choosen were then disassembled into several families or sub-assemblies. This is for understanding how the parts functioning during normal operating mode. After that, each parts been critics and study if there is a chances for redesign. Finally, referring to suggestion from Boothroyd-Dewhurst DFA method, the new parts design are generated. From the results, it is observed that the analysis using Boothroyd-Dewhurst DFA method is easier for determine the parts to be redesign. The acquired results utilizing the new design are much more efficient then the original design after the evaluation due to maximum reduction of components like screw and fasteners. However, reducing the parts not always meant that the design are being optimize. There are much more things to consider like the manufacturing process required to produce the new design. Therefore, the concept of concurrent engineering (CE) is important to have designers and production engineers way of thinking in redesigning the new parts or components.

ABSTRAK

Tesis ini membentangkan penyelidikan menggunakan kaedah Design for Assembly (DFA) Boothroyd-Dewhurst dalam mengoptimumkan rekabentuk produk sedia ada di pasaran. Objektif tesis ini ialah menghasilkan rekabentuk baru bagi produk penimbang dapur dengan mengambilkira isu bilangan komponen, anggaran kos, dan kejituan rekabentuk. Tesis ini melihat bagaimana kaedah DFA Bothrooyd-Dewhurst begitu berkesan dalam mencadangkan komponen yang berpotensi untuk diubah-suai. Strategi dalam menilai potensi rekabentuk sedia ada bermula dengan pemilihan produk yang sesuai dan berpotensi untuk dibangunkan. Kemudian, produk yang dipilih akan di leraikan mengikut kategori yang tertentu bagi memudahkan proses pemahaman cara produk berfungsi. Selepas itu, setiap komponen akan dikaji dan dikritik mengenai cara pemasangan dan pengendaliannya merujuk kepada kaedah DFA Boothroyd-Dewhurst tadi. Akhirnya, proses rekabentuk komponen baru dapat dilaksanakan hasil dari data dan cadangan daripada kaedah DFA Boothroyd-Dewhurst. Daripada kajian ini, dapat dikatakan bahawa kaedah DFA boothroyd-Dewhurst amat berkesan dan dapat memudahkan proses rekabentuk komponen dalam mengoptimumkan prestasi sesebuah produk. Keputusan akhir menunjukkan kos produk, bilangan komponen dan kejituan rekabentuk dapat dioptimumkan dengan cara pengurangan komponen penyambungan seperti skru dan pin. Namun, pengurangan bilangan komponen dalam proses rekabentuk baru tidak semestinya bermakna ianya dapat mengoptimumkan sesuatu produk itu. Hal ini kerana, banyak lagi faktor yang perlu diambil kira dalam menghasilkan produk baru seperti proses pembuatan komponen baru. Oleh itu, konsep '*Concurrent Engineering'* (CE) itu sendiri amat penting dimana pandangan dan pemikiran seperti seorang jurureka dan jurutera pengeluaran harus diberiperhatian selari dengan proses ubah-suai dan rekabentuk produk baru.

TABLE OF CONTENTS

CHAPTER 3 METHODOLOGY

CHAPTER 4 DESIGN EVALUATION AND MODELING

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

E_d	Functional efficiency
E_{ma}	Design efficiency
N_{min}	Theoretical minimum number of parts
T_a	Basic assembly time = 3 second
T_h	Handling time
T_{ma}	Estimated time to complete the assembly of the product
T_i	Insertion time

LIST OF ABBREVIATIONS

ABS	Acrylonitrile-Butadiene-Styrene
AEM	Assemblability Evaluation Method
ASF	Assembly Sequence Flowchart
CAD	Computer-aided design
CAE	Computer-aided engineering
CE	Concurrent Engineering
CFE	Candidate for Elimination
DFA	Design for Assembly
DFM	Design for Manufacture
DFMA	Design for Manufacture and Assembly
MPI	MoldFlow Plastics Insight
PC	Polycarbonate
PP	Polypropylene
PPO	Polyphenylene Oxide

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Developing successful product requires the ability to predict, early in the product development process, the life cycle impact of design decisions. Any misjudges can leads to poor product designs that may cause unforeseen problems and excessive costs. Cost to redesign at this late stage can be prohibitive. Sometimes companies must simply accept higher manufacturing costs and reduced product effectiveness resulting from early design errors.

Even for a product that has been already available in the market, product improvements are required for survival from every competition from other companies that are in the same business. Improvement can be done by optimizing a design itself, or production process for manufacturing and assembly.

This chapter provides an overview of the project of Product Design and Optimization of Kitchen Scale with using Design for Assembly (DFA) Method. Generally, problem statement briefly discuss about how the product improvement are important to highly demand product in market.

In this chapter, an overview of the background, objectives and scope of this project are reviewed. Basically, the objective of this study is to redesign a new selected product for a better design and lower production cost. Here, the DFA Method has been applied to analyze the original product (Kitchen Scale). Lastly, in this chapter, the overall thesis outlines are review and discussed in general.

1.2 PROJECT BACKGROUND

In recent years, research in the area of design for manufacturing and assembly has become very useful for industries that are considering improving their facilities and manufacturing methodology. In manufacturing industries, manufacturers focused on the quality and productivity of the product. To increase the productivity of the product, manufacturing companies and researchers have developed many design decision support tools referred to as Design for X (DFX) methodologies. The 'X' in DFX represents any one of a variety of design considerations occurring throughout the product life cycle, such as quality, manufacturing, production, or environment. A DFX decision support tool can take many forms. It could be procedure or a set of guidelines on paper, or it could be a computer program that performs various types of analyses resulting in cost, manufacturability, or performance estimates, which are then used by the designer in making decisions.

Design for Manufacturing (DFM) and Design for Assembly (DFA) are two of the most common and popular DFX tools. Traditionally, DFA methods evaluate the ease of assembly, and DFM methods evaluate the feasibility and cost of manufacturing the product at the operation level Bralla (1986), Anderson (1990), Corbett et al. (1991), and Boothroyd et al. (2002) provide detailed discussions on manufacturability and design.

1.3 PROBLEM STATEMENTS/ PURPOSE OF STUDIES

As kitchen scale is widely used by customer in the household appliance in the market nowadays, the product life volume of this product must be high due to high demand by the user. Thus, any cost reduction in kitchen scale production can be very significant to the manufacturer in term of profit and production cost.

This studies is to redesign a kitchen scale for improvement in term of product design and optimization in assembly process for a production, by using a one of many design decision support tools referred to as Design for Assembly (DFA) methodology.

For the original product (datum), kitchen scale consists of 24 components including screws and other type of fasteners. While to assemble the component of kitchen scale, there have problems that occur such as difficult to assemble the component because of having the different types and sizes of fasteners. The material of parts that been used and the process of making one part also affected the cost to manufacture the products.

Continuous development of kitchen scale can lead to improvement of manufacturing and assembly process, thus enhance rapid development of technology in manufacturing industry.

1.4 OBJECTIVE OF STUDIES

The main objective of this study is to analyze the selected product by using DFA method and propose potential alternative design for improvement in term of ease of assembly, cost estimates, and highly design efficiency. Besides that, the other objectives of the study are:

i. To design and improve existing design by using DFA method and observation upon information content optimization/ candidate for part elimination strategies.
ii. To suggest alternatives design and quantify the benefits of the redesign products/parts.

1.5 SCOPE OF STUDIES

In order to achieve the objectives the following scope of studies are performed:

i. Information contents gathering on kitchen scale with:
   a. Find out part function for each component.
   b. Dimensioning the current design using manual measured.
   c. Modeling the CAD drawing of current design by using Solidworks software.

ii. Improving areas on the kitchen scale parts by considering the new parts design for ease of assembly, cost & time estimation, and design efficiency.

1.6 REPORT ARRANGEMENT

This report is divided into six chapters. Chapter one gives the brief the content and background of the project. The problem statement, objectives and scope of study are also discussed in this chapter.

In chapter two, the literature review of the study is discussed. This chapter provided with introduction to product design strategies and methods. Here, the general design guidelines are to be discussed. Then, brief introduction to various methods of DFA, model-driven design, and product life cycle are disused. The discussions try to relate the equivalence of information content and cost estimation. The parts elimination strategy and snap fits design are also to be discussed before finally, the overview about previous related research are discussed.

For chapter three, the review of methodology is reviewed. The design of study and framework are studied at first. Then the introductions to manual calculation of Boothroyd Dewhurst DFA method, including the concept of the three question of DFA are to be discussed.

In chapter four, the design evaluation and CAD modeling are applied to the existing product assembly. In this chapter, the details of each disassemble parts of kitchen scale are critiqued and measured. Follow by the manual calculation to determine lead time for assembly, estimated cost, and more important is to determine design efficiency. The analysis also performed into suggested new part's design and the modifications are to be justified.

In chapter five, results of further analysis performed are to be discussed and the best alternative design are to be justify. Lastly in chapter six, the recommendation and conclusion are to be made. The next page shows the summary of the outline of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides a review of the concept of product design and methods of product developments. This chapter also relates how product design affects the cost, cycle time, and overall product quality. Besides that, this chapter also includes the information about advantages and disadvantages of DFA method, various methods of DFA, basic design concept and guidelines. At the end of this chapter, a review of the past research related to product design and cost optimization.

2.2 PRODUCT DESIGN ENVIRONMENT

Product design is generally conducted by a manufacturing enterprise whose primary purpose is to manufacture and sell products for profit. Design of products can generally categorize depending on the newness of the product and how free the design team to select new manufacturing method and processes. A new product is one that involves significant change from existing models of products in term of the working principle, styling, material, and technology applied.

An existing product, on the other hand, is current product that is redesign to reduce manufacturing cost and/or to correct and improve product performance and quality. New models or variants of existing products may also be designed to meet niche or new customer or market needs.

2.2.1 History of Product Development Process

In product development, design engineers are often the main decision makers from the time the idea is generated until the products are prototyped. Only after the design had finalized will the manufacturing team enter into development process to figure out way to minimize costs based on existing design.

This is what had happened in the past. The various stage of product development are broken down into series of sequential steps and carried out independently. This design structure separates the development process by functional groups and only promotes only one-way communication. (Figure 2.1) Specifically, only after completing conceptual sketches, detail drawings, and prototype of the product will the design engineers throw the design “over the wall” to the production engineers. The production engineers then independently alter the design and substitute materials to try reduce cost while imitating functionality. This sequential product development process is often help up or delayed while waiting for other groups to compete their task.

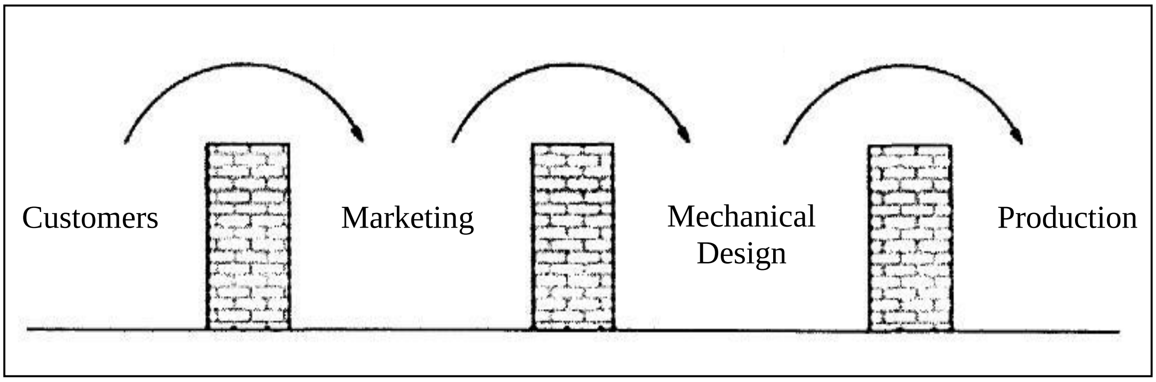


Figure 2.1: The “over the wall” design method.

Source: (Ada Yu, 2008)

In the 1970's, when companies realized the need to bring their products to market faster, the idea of concurrent engineering becomes popular. Ideally, teams of software, mechanical, electrical, and production engineers work together with marketing, sales, and management to ensure a timely and successful produce design.

2.2.2 Concurrent Engineering (CE)

Concurrent Engineering (CE) is a systematic approach to integrate product development that emphasizes the response to customer expectations. It embodies team values of cooperation, trust and sharing in such a manner that decision making involving all perspectives in parallel, from the beginning of the product life-cycle.

Under CE, design engineers generate ideas while production engineers focus on determining manufacture feasibility and finding economical alternatives. CE brings together multidisciplinary teams, where different functional groups work together in parallel from the beginning of the project to understand the limitations in mechanical engineering, electrical engineering, manufacturability, quality, reliability, testability, and program management. Implementation of CE enhances integration of product and process design with strategic objectives and provides a framework for effectively implementing design technology.

H.S Abdalla's study (1999) on concurrent engineering for global manufacturing found that CE enables companies to bring products to market at higher quality and less cost. Furthermore, with integrated teams and tools that work and support each other, designers and manufacturing engineers were able to cope with late changes in the product design. Additional benefits (Figure 2.2) include shorter time to market, better communication and management, fewer numbers of design changes, and reduced life-cycle cost in testing and reliability.

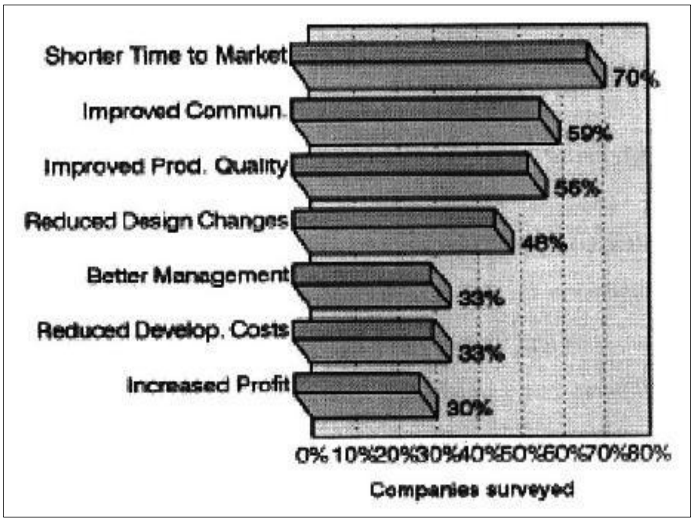


Figure 2.2: Benefits gained from implementing concurrent engineering in 150 surveyed companies.

Source: (Ada Yu, 2008)

2.3 TOTAL COST REDUCTION

Total cost is the sum of all costs, both direct and indirect, that result from the design, manufacture, distribution, sale, service, use, and disposal of the product over its life cycle. It is well known that a large percentage of total cost is determined by the product design, especially early design decisions that establish the particular physical concept and part decomposition to be employed. Unfortunately, it is often difficult or impossible to evaluate the impact of these early design decisions on total cost. This is because these decisions affect indirect cost much more than direct cost. Indirect cost is usually very difficult or impossible to estimate in the early stages of design, when most far-reaching design decisions are made.

So how can the manufacturing enterprise make quality early design decisions that reduce total cost when the effect of early design decisions on total cost can't be estimated? In this chapter, answer for this question will be studied by using information content as a surrogate for total cost. First is to discuss the shortcomings of current cost estimation methods. Then is to show that information content is equivalent to total cost.

This allows the inference that design decisions that reduce information content also reduce total cost. These results are then used to develop a total cost reduction strategy based on reduction of information content. These strategies are called "guided common sense.'

2.3.1 Cost Estimation

The ability to estimate cost as a function of design decisions is essential for reducing total cost by design. Unfortunately, estimating cost is an inexact science, especially in the early stages of design when design information is very tentative and incomplete. In addition, most of the cost estimation techniques available are based on historical data and often do not include indirect cost or consideration of cost consequences that may arise as a result of quality or manufacturing problems. Never the less, it is common practices to estimate cost and to use these cost as a basis for making many far-reaching design decisions.

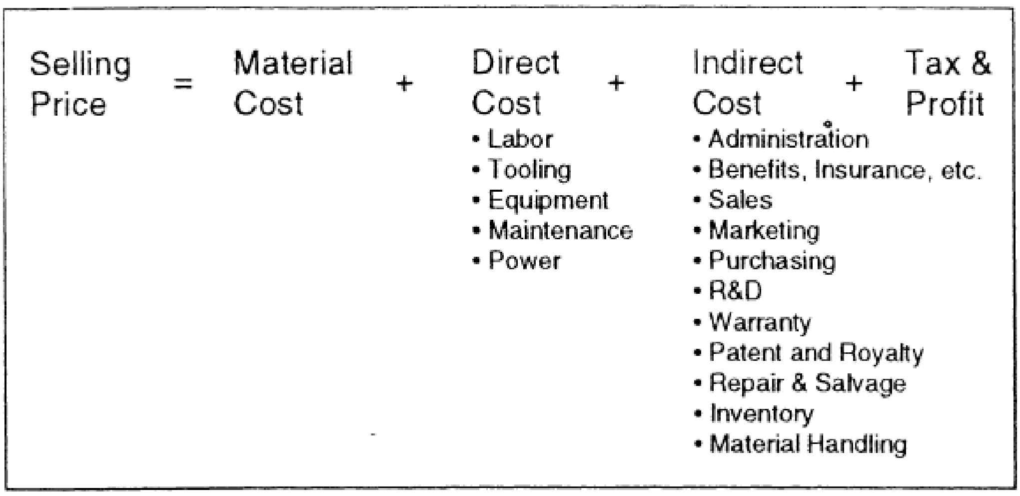


Figure 2.3: Price structure of a typical manufacturing enterprise. Commonly Used figures of merit include the processing overhead ratio (direct cost/material cost) and the operational overhead ratio (selling price/direct cost). For many firms, these ratios have numerical values of about 3. Hence, to make a reasonable profit, selling price needs to be approximately 9 times material cost.

Source: (Chow, 1978)

2.3.2 Information Content and Total Cost

A product designed using these principles will be inherently easier to design, manufacture, maintain service, and support over its life cycle. Such a product will naturally have the lowest possible cost. In other words, total cost is reduced by reducing the information content of the design, provided that all undesirable interactions are also avoided.

2.3.3 Strategies for Reducing Information Content

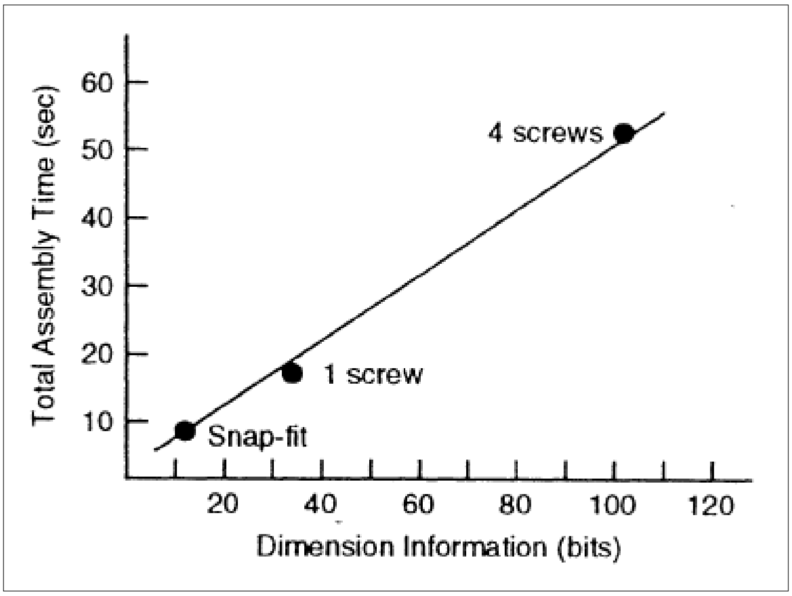


Figure 2.4: Plot of total assembly time verses dimensional information content

The amount of information content in a given part, or subassembly or product, or manufacturing system, is determined by design decisions. Eliminating dimensional, relax tolerance or both, dimensional information content will be reduced. And, because information content is equivalent to cost, these will in turn, decrease total cost. The concept of information content therefore provides the needed connection between designs decisions and total cost.

Source: (Stoll W.H, 1999)

Dimensions and tolerances are just one source or measure of information content. In most practical situations, there appears to be an almost limitless number of different sources. For products composed of discrete parts, for example, some of the more important sources of information content include:

i. The number of separate operations or activities, number of instructions per activity, and the number of repetitions of each activity required to manufacture and assemble a particular product, subassembly, or component.
ii. The number of different tools and processes utilized in a product or component manufacture.
iii. The number of unique features, facets, characteristics, functional surfaces, etc. contained in a component.
iv. The number of interfaces and interactions between assembled components.
v. The amount of part-to-part variability and product-to-product variability.
vi. The amount of randomness or variability associated with manufacturing processes, inspection processes, testing methods, material handling, order processing, shipping and warehousing, and all other activities associated with product manufacture.

The seemingly endless sources of information content make it appear that calculating information content is no easier or more straightforward than calculating total cost. In our view, however, the ability to calculate information content is not what is important. Rather, the key is to understand how information content is affected by design decisions and to know how to reduce information content by making the right design decisions.

2.4 PART ELIMINATION STRATEGIES

2.4.1 Candidate for Elimination

Elimination of separate parts is perhaps the single most effective way to eliminate information content. Parts account for the great majority of a product's cost, both direct and indirect. They are also the primary source of quality risk, unreliability, and customer dissatisfaction. Fewer parts mean less of everything involved in the design, manufacture, and support of a product.

A part is a candidate for elimination (CFE) if there is no need for- relative motion between it and parts already assembled, no need for subsequent adjustment between parts, no need for serviceability or reparability, and no fundamental reason requiring that materials be different. "Theoretical parts" are parts that cannot be eliminated. For a part to be a theoretical part, it must receive a "yes" answer to at least one of the following critical questions. (Boothroyd, *et. al,* 2002):

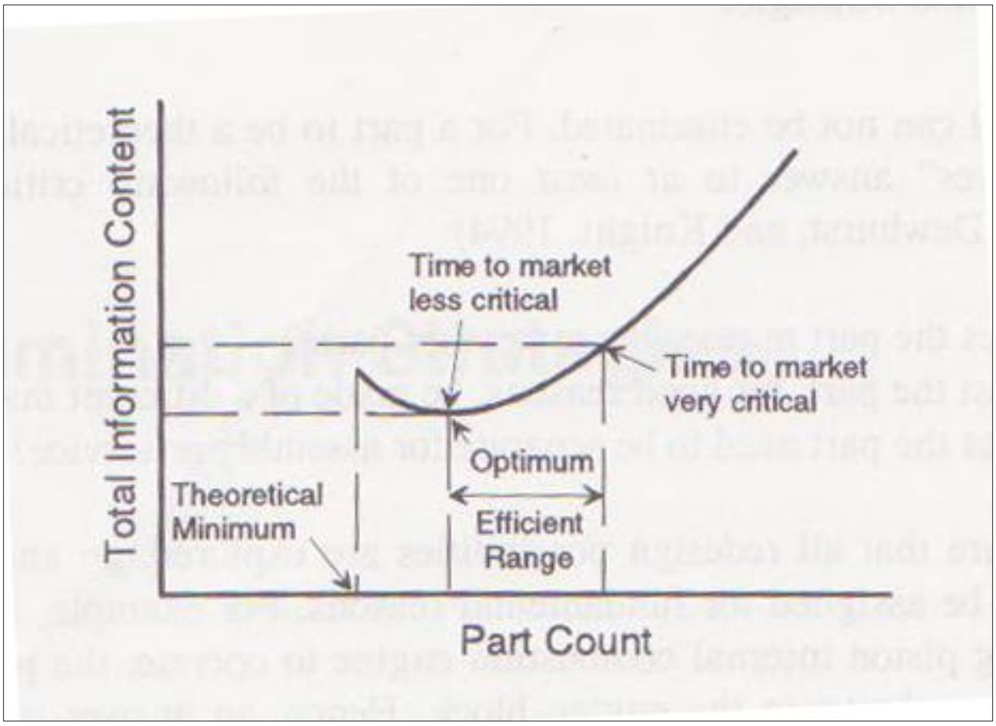


Figure 2.5 Achieving an efficient part count depends on a variety of factors. If development time is critical, it may be better to have more parts that are easier to tool and have shorter lead times. If development time is less important, fewer parts, even if they are more complex, will usually result in less total information content. The optimum part count may not correspond to the theoretical minimum, however, if part geometry becomes too complex.

Source: (Stoll W.H, 1999)

When applying the critical questions, it is also important to remember that the goal in eliminating parts is to minimize overall information content of the design. It is therefore possible that the optimum design might involve more than the theoretical minimum number of parts, especially when the minimum part design requires very complex part geometry (Figure. 2.5). Indications that the part reduction has gone too far include:

i. One or more parts are excessively heavy and/or hard to handle.
ii. Tooling is inordinately costly.
iii. Lead times are unacceptably long.
iv. Manufacturing processes are hard to control.
v. Manufacturing processes are exceeding best practice limits.
vi. Designed components are being used in place of standard components.

2.4.2 Consolidate Parts into an Integral Design

Integral design, which involves combining two or more parts into one, is possible whenever two or more adjacent parts have been identified as candidates for elimination based on the three Boothroyd-Dewhurst’s critical questions. Also, combining function into one part can often facilitate integral design.

Consolidating parts reduces information content by eliminating separate parts and reducing the amount of interfacing information required. Quality risk and stress concentration due to fasteners and joining processes are also eliminated. Because load paths are smoother and better defined, less material is required and the shape of the part can be adjusted to put material where it is needed. The result is lower weight, increased reliability, and reduced processing information, especially if near net-shape processes such as plastic injection molding, powder metallurgy, and precision casting can be used.

The use of plastic is often a key in integral design. Plastic materials are available for making nearly any part imaginable including springs, bearings, cams, gears, fasteners, hinges, optical elements, and so forth. When used in conjunction with plastic injection molding and other polymer processing methods, these materials can facilitate the consolidation of many parts into one as illustrated in Figure. 2.6.

There are many other materials and manufacturing processes that can be considered when plastic is unacceptable from a functional or cost point of view. For example, powder metallurgy is a good way to eliminate brazed, welded, or staked assemblies of stampings and/or machined parts. Compound gears, cams, links, "multifunction" parts, and other complex parts are also good powder metal candidates. Using extrusions is another highly viable alternative.

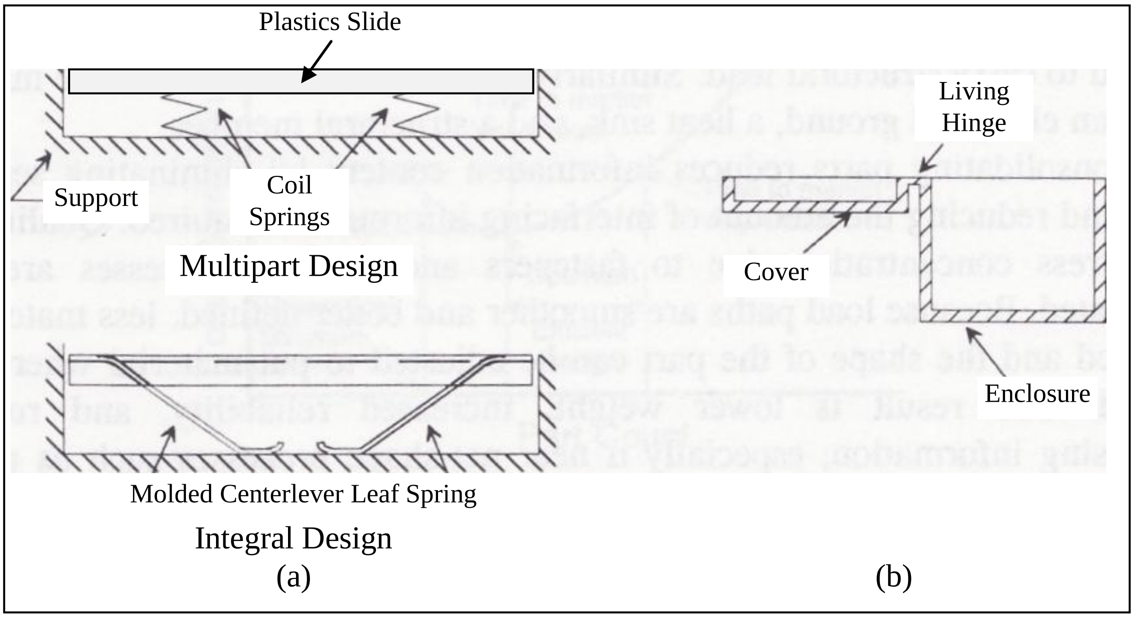


Figure 2.6 In integral design, many separate parts are consolidated into one. (a) Two metal coil springs together with nesting, handling, and other assembly problems are eliminated by the molded plastic cantilever leaf springs. (b) Molding the cover and enclosure as one part using a "living" hinge eliminates core pulls, hinge hardware, and alignment problems.

Source: (Stoll W.H, 1999)

2.4.3 Eliminate Separate Fasteners

Fasteners are always candidates for elimination since they will never receive an answer of "yes" to any of the critical questions. Therefore, integrating fastening functions into higher level parts using the principles of integral design can be an extremely effective way to reduce part counts (Figure. 2.5). In addition, separate fasteners have many undesirable characteristics. In automated operations, fasteners can be very difficult to feed reliably resulting in frequent jams and shutdowns, and they require monitoring for presence and preload. They must be purchased, received, inspected, stored, moved to the point of use, and kept separate to insure that the right fastener goes in the right place. If not properly installed or left lying loose in the assembly, they can present serious quality risk. The information content associated with fasteners is very large. Eliminating fasteners eliminates indirect cost that can be six to ten times the cost of the fastener itself.

The following recommendations provide an effective strategy for eliminating fasteners. Note that these recommendations are ordered according to the amount of information content. When possible, the first recommendation should be followed since it results in the lowest fastening system information content. When this is not possible, then the next possible recommendation should be followed. We refer to a set of design recommendations ordered in this way as *optimal recommendations* since the most optimal design is achieved by implementing the first feasible recommendation for a given design situation.

i. Use "snap together" designs whenever possible.
ii. Consider alternative joining processes.
iii. Use a minimum number of identical, standard fasteners.

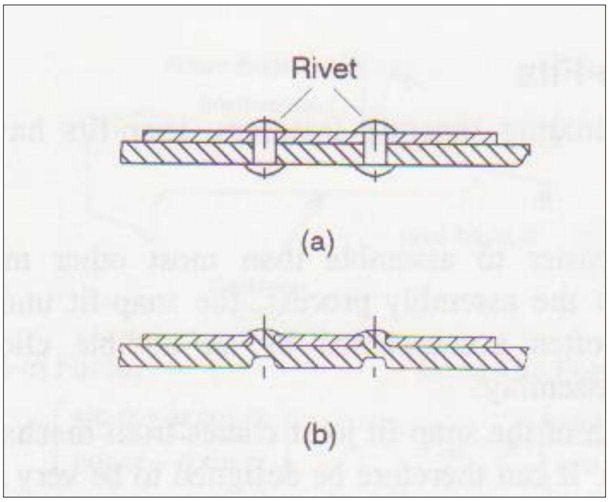


Figure 2.7 Four-piece riveted assembly redesigned as a two-piece assembly by integrating the fastening function into higher level parts. (a) Original riveted design. (b) Redesign using formed features.

Source: (Stoll W.H, 1999)

2.4.4 Reduce the Number of Theoretical Parts

When parts need to be separate because they move relative to each other, finding a design concept that requires the fewest theoretical parts is often the best strategy for eliminating parts.

2.4.5 Create Hybrid Parts

Hybrid parts are components that combine fabrication and assembly operations (Figure. 2.8). Common examples include insert molding of threaded metal bushings into plastic injection molded parts and joining of components such as shafts and gears using die-casting (Jay, 1971). Such parts are low information alternatives to integral design when materials must be different for reasons of electrical conduction, strength, wear, and so forth. They are also often the least costly alternative for achieving geometry that is too complex or intricate to be incorporated into the mold. Another desirable characteristic of hybrid parts is the very intimate fit that occurs because the cast-on or molded-on material shrink-fits around the insert.

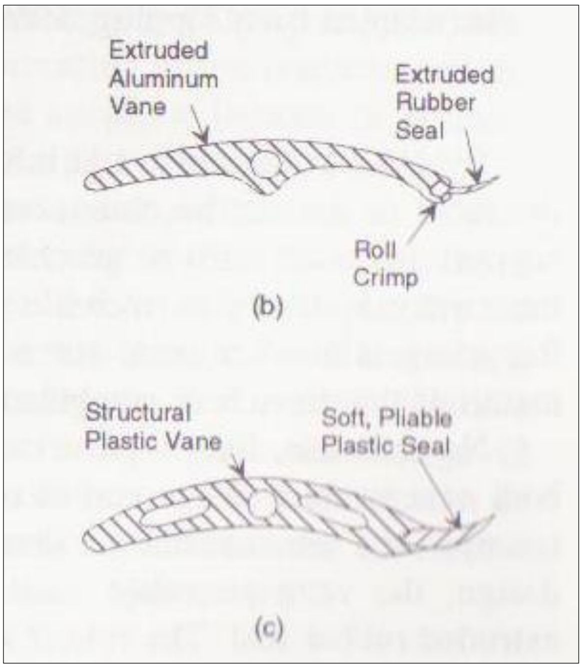


Figure 2.8 Replacing an assembly with the hybrid part: (b) cross-sectional view of the original two-piece extruded aluminum vane and extruded rubber seal assembly; (c) cross-sectional view of co-extruded hybrid plastic vane.

Source: (Stoll W.H, 1999)

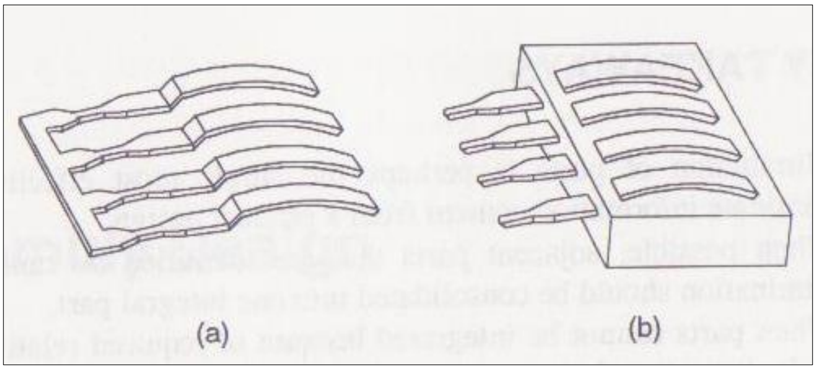


Figure 2.9 Reduce information content by postponing descretization. (a) The terminals are fabricated as a sheet metal stamping and assembled as a unit. (b) After insert molding, the connecting piece is cut away.

Source: (Stoll W.H, 1999)

2.4.6 Standardize

One of the most effective ways to eliminate parts is to standardize part designs. In general, there are three strategies for using standardization to eliminate parts.

i. Design so that the same part or component can be used interchangeably in different subassemblies, products, and applications. Parts and components that are designed in this way are sometimes referred to as repeat parts or building block parts.

ii. Create standardized design systems that enable unique new part designs to be easily created, tooled, and introduced into production. Do this by using combinations of standard features, flexible manufacturing systems, special design rules, and so forth.

Design new products so that a short list of proven, "off-the-shelf' purchased components can he used everywhere.

Standardization works by eliminating options and reducing the information content of the options that remain. As a result, in addition to information producing significant benefits in the form of reduced information content and total cost, standardization can also add cost due to over-design, capital investment, and lost sales opportunities.

2.5 ASSEMBLY DESIGN

Assembly design focuses on the development of a coordinated overall part. Decomposition and detail component geometry that reduces assembly cost by facilitating and easing product assembly. Considering assembly design in the early conceptual stages of design has proven to be extremely effective because, in addition to reducing manufacturing cost, it often generates significant productivity and quality improvements. Assembly design is therefore an exceedingly important consideration, both for redesign of existing products and in new product development. Proper consideration of assembly is even more critical when automated assembly is considered, since cost, cycle time, and complexity of the automation is also directly determined by the product design.

The best way to avoid cost and problems associated with assembly is to avoid the need for assembly. Unfortunately, this is seldom an option because of many inherent reasons for assembly. For instance, providing for relative movement between parts almost always requires separate parts and therefore assembly. Different materials such as an electrical conductor isolated by an electrical insulator require assembly. Use of purchased components such as a light bulb or hydraulic valve requires assembly. Service modules and replaceable wear parts require assembly.

2.5.1 Assembly Cost Drivers

Assembly cost drivers are those features of the part decomposition and detail component geometry that determine or establish assembly needs and cost. Analysis of the assembly process shows that, in general, adding a component to the assembly will involve some or all of the following basic functions:

Handling: The process of grasping, transporting, and orienting components.
Insertion: The process of adding components partially built-up assembly.
Securing: The process of securing components partially built-up assembly,

Adjustment: The process of using judgment or other decision-making processes to establish he correct relationship between components.

Separate Operation: Mechanical and non-mechanical fastening processes involving parts already in place but not secured immediately after insertion (e.g., bending, upsetting, screw tightening, resisting, welding, soldering, adhesive bonding, etc.). Also other assembly operations such as manipulating of parts or subassemblies, adding liquids, etc.

2.5.2 Component Handling

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

i. Component size
ii. Need for orientation
iii. Handling impediments and difficulties

Guidelines for Part Handling

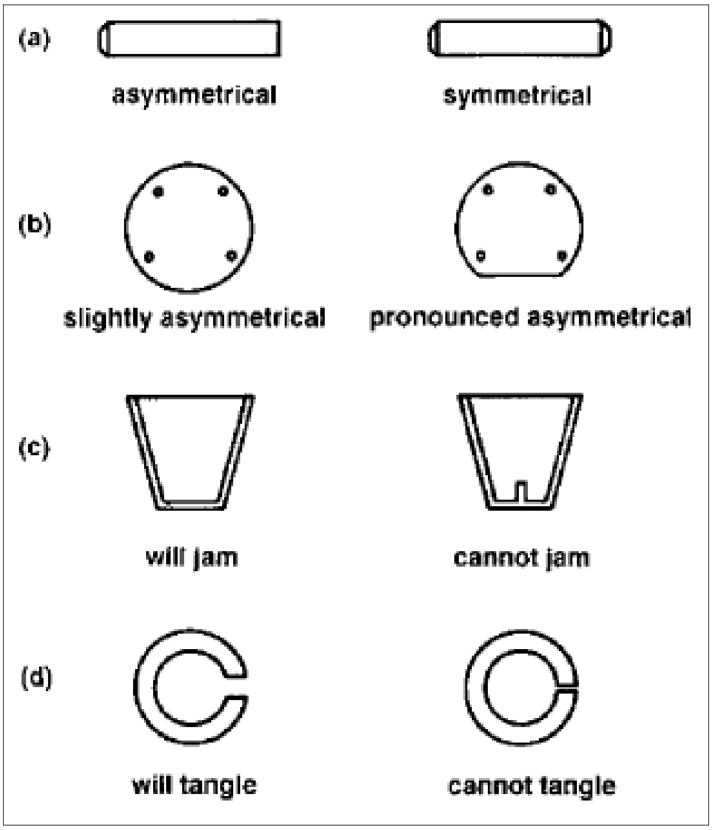


Figure 2.10

Source: (Boothroyd et al., 2002)

In general, for ease of part handling, a designer should attempt to:

i. Design parts that have end-to-end symmetry and rotational symmetry about the axis of insertion. If cannot be achieved, try to design parts having the maximum possible symmetry
ii. Design parts that, in those instances where the part cannot be made symmetric, are obviously asymmetric (Figure 2.10 b)
iii. Provide features that will prevent jamming of parts that tend to nest or stack when stored in bulk (Figure 2.10 c)
iv. Avoid features that will allow tangling of parts when stored in bulk (Figure 2.10 d)
v. Avoid parts that stick together or are slippery, delicate, flexible, very small, or very large or that are hazardous to the handler (Figure 2.11)

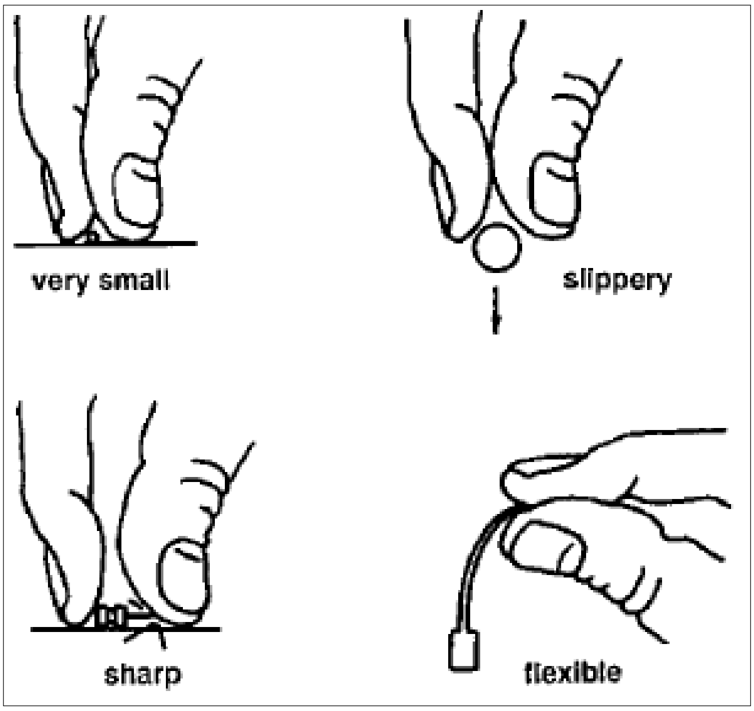


Figure 2.11

Source: (Boothroyd et al., 2002)

2.5.3 Component Insertion

Guidelines for Insertions and Fastening

For ease of insertion, a designer should attempt to:

i. Design so that there is little or no resistance to insertion and provide chamfers to guide insertion of two mating parts. Generous clearance should be provided, but care must be taken to avoid clearances that will result in a tendency for parts to jam or hang-up during insertion.

ii. Standardize by using common parts, processes, and methods across all models and even across product lines to permit the use of higher volume processes that normally result in lower product cost

iii. Use pyramid assembly- provides for progressive assembly about one axis of reference. In general, it is best to assemble from above.

iv. Avoid where possible, the necessity for holding parts down to maintain their orientation during manipulation of the subassembly or during the placement of another part. If holding down is required, then try to design so that the part is secured as soon as possible after it has been inserted.

v. Design so that a part is located before it is released. A potential source of problems arises from a part being placed where, due to design constrains, it must be released before it is positively located in the assembly. Under this circumstance, reliance is placed on the trajectory of the part being sufficiently repeatable to locate it consistently.

vi. When common mechanical fasteners are used the following sequences indicate the relative cost of different fastening process, listed in order of increasing manual assembly cost.

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

Avoid the need to reposition the partially complete assembly in the fixture.

2.5.4 Component Securing

Component securing is the process of physically attaching components to the partially built-up assembly using permanent or non-permanent joining processes securing may occur as part of the insertion process (e.g., installation of a threaded fastener) or it may be performed as a separate operation (e.g., adhesive bonding of joint). A component is designed for easy securing when it is located and retained upon insertion and requires no screwing or plastic deformation as part of the securing operation. Snap-fits, press-fits, circlips, spire nuts, and so forth are examples of components that are easy to secure.

2.5.5 Separate Operations

Separate operations include all assembly operations other than those directly associated with adding a part moving to another assembly surface, or performing an adjustment. Examples include mechanical joining processes such as riveting, welding, adhesive bonding, bolt tightening, and so forth. Separate operations should be avoided whenever possible since they add information content in the form of instructions, material handling, floor space, quality risk, to name just a few.

2.6 COMPONENT DESIGN

The goal of component design is to ensure that designed components are functionally acceptable and also easy to fabricate using the selected material and manufacturing processes. Component design is implemented by creating detail component configurations that minimize information content of the tooling and the process. Tooling information content is minimized when standardized tooling is used and/or the tooling is easily designed and fabricates and has minimal operational complexity. Process information content is minimized when the number of individual processing steps is a minimum, the design specification is well within the process capability, and parameter values are selected to minimize cycle time and cost while also avoiding potential flaws such as porosity, warping, tears, cold solder, and so forth.

2.6.1 Process-Specific Design

Process-specific component design has to do with the design of parts to be manufactured using particular manufacturing methods or processes such as casting, forging, injection molding, and sheet metal stamping. A large variety of different manufacturing processes are widely used to produce individual piece parts (Figure. 2.12). It is interesting to note that most of these manufacturing processes as well as many others can be synthesized using the rational building block method by employing different combinations of material flow, energy flow, and information flow building blocks.

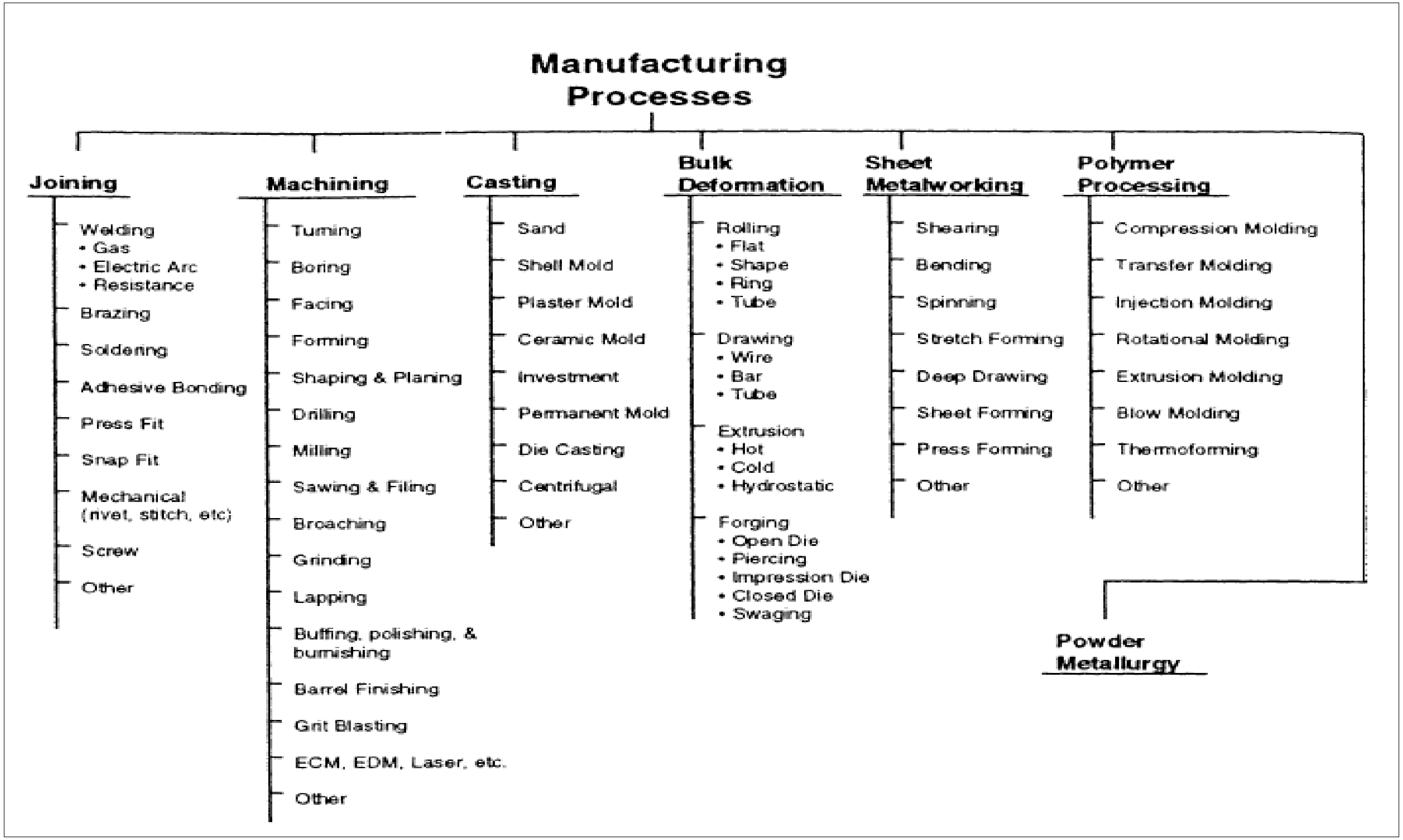


Figure 2.12: Classification of commonly employed manufacturing processes.

Source: (Boothroyd et al., 2002)

2.6.2 Design for Plastic Injection Molding

To illustrate the approach, consider plastic injection molding, which is a near net-shape manufacturing process that is widely used to produce large quantities of production parts. In plastic injection molding, plastic material is heated to form a "melt" which is then forced under pressure into the mold cavity to front the part. Because the material is molten when injected into the mold, complex shapes and good dimensional accuracy can be achieved. Molds with moving cores and unscrewing mandrels allow the molding of parts with undercuts and internal and external threads. The molds may have multiple cavities so that more than one part can be made in one cycle. Proper mold design and control of material flow in the mold cavities are important factors in the quality of the product. Other factors affecting quality are injection pressure, temperature, and condition of the resin.

Process Limitations and Requirements

There are three major product/processing interactions that must be considered in the design of a plastic injection molded part: material shrinkage, gating location, and parting line selection.

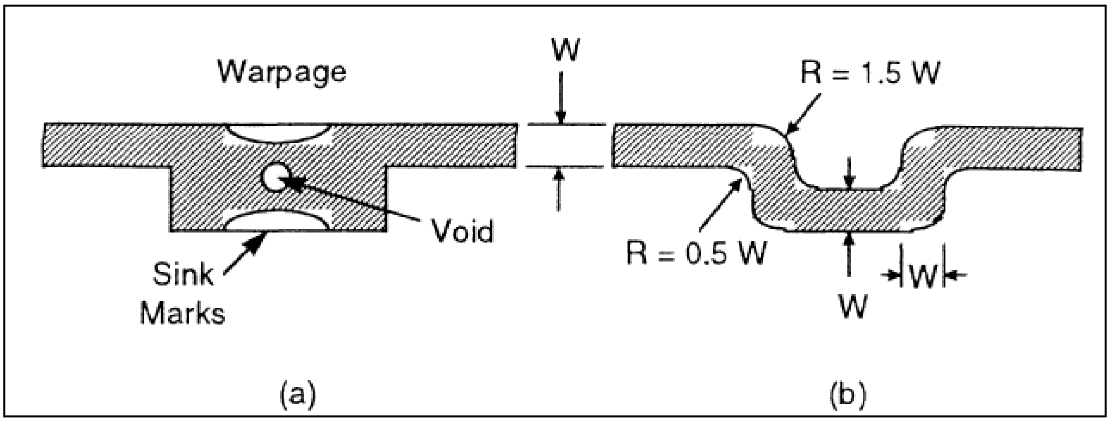


Figure 2.13: (a) Shrinkage defects occur due to variations in thermal mass in different regions of a plastic injection molded part. (b) A uniform wall thickness (nominal wall) combined with generous fillets and radii help avoid shrinkage problems.

Source: (Stoll W.H, 1999)

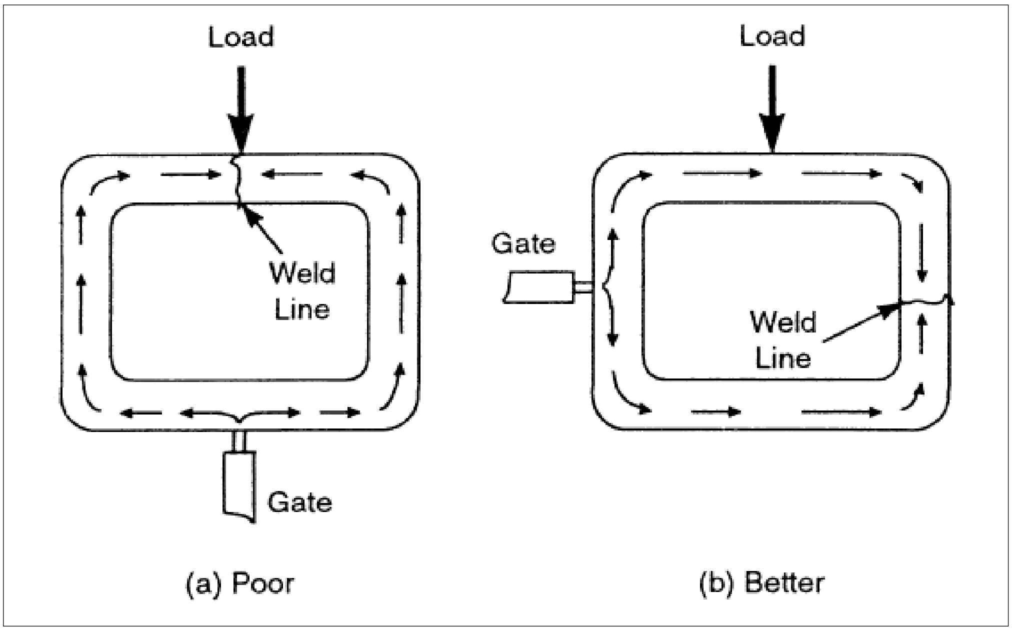


Figure 2.14: Weld lines form when the plastic flow divides into two or more paths. (a) This gate location causes a weld line to form in a critical region of the part. (b) This gate location causes the weld line to form in a less critical region.

Source: (Stoll W.H, 1999)

2.6.3 Design for Machining

Machining is a material removal process in which the part is generated by moving the work piece and the tool relative to each other using a variety of machine and tool combinations (see Figure. 2.12). Because the shape information is impressed by tool motion rather than tool geometry, the machining process, has the great advantage of being flexible and easily adapted to a variety of par: sizes, shapes, and detail geometry. Machining is therefore often the process of choice for low volume production. In addition, the machining process is capable of generating very complex and highly precise geometry. For this, reason, it is often used as a secondary process to complete parts that are initially formed using a primary process such as casting or welding.

Process Limitations and Requirements

There are three major process characteristics that must be considered in the design of parts that are to be machined. First, the process must be setup. This involves mounting the workpiece in the appropriate work holding fixture and adjusting the machine to perform the desired machining operations. Setup takes time so whatever can be done to simplify or avoid setup is a plus. Another limitation is the relationship that exists between surface finish, cutting conditions (i.e., depth of cut, cutting speed, and feed rate), and tool life. From cycle time standpoint, it is desirable to machine as fast as possible. However this can result in unacceptable surface finish and excessive tool cost and tool change time. Hence it is usually necessary to use cutting conditions the effectively balance these factors. Finally, machining processes often involve considerable handling and manipulation of the workpiece as well as moving the workpiece from machine to machine. As in setups, anything that can be done "by design" to eliminate and minimize non-value added material handlings is a plus with respect to cost.

2.7 VARIOUS METHOD OF DFA

There are various methods that have been using in Design for Assembly in industry nowadays such as:

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

Designs for assembly procedures are guidelines that guide the designer to implement DFA in real practice. Three of the better-known quantitative evaluation techniques has been used in industry are Boothroyd-Dewhurst (USA), Lucas (UK) and Hitachi (Japan). The recommendations suggested by the DFA methodologies can be summarized into the following below:

i. Eliminate the part. Parts such as screw, nut and spring are usually considered to be eliminated as much as possible.
ii. Combine the part with it mating part. This is due to recommendation of the Boothroyd's three criteria.
iii. Simplify the assembly operations. This includes consideration of the structure of product and designs each component.

2.7.1 Boothroyd-Dewhurst DFA Method

Design for assembly (DFA) that formulated by Boothroyd and Dewhurst are one of the most widely DFA methodologies which is used on productivity improvement through product design in term of assembly ease and reduce assembly time. Boothroyd and Dewhurst DFA methodology has been recognized as a very useful tool in increasing competitiveness by reducing the part number of components, simplifying the product design structure and improving product design reliability. The procedure for analyzing product for manual assembly Boothroyd and Dewhurst method is summarized as following below (Stoll W.H, 1999).

i. Obtain the best information about the product or assembly. Useful items include engineering drawing, exploded three-dimensional views, an existing version of the product, or prototype.

ii. Take the assembly apart. Assign an identification number to each item as it is removed. Initially, treat subassemblies as parts and then analyze them as assemblies later.

iii. Reassemble the product starting with the part having the highest identification number. As each part is added to the assembly, analyze its ease of handling and insertion and use the three questions to decide if it is a candidate for elimination or combination with other parts

iv. Redesign the assembly using the insights gained from the analysis. Analyze the new design by repeating step 1 through 4 and gage improvements by comparing design efficiencies between current and modified design. Iterate until satisfied.

The Boothroyd and Dewhurst DFA analysis is basically completed in 6 steps. The flow chart of Boothroyd and Dewhurst DFA analysis is shows in Figure 2.15:

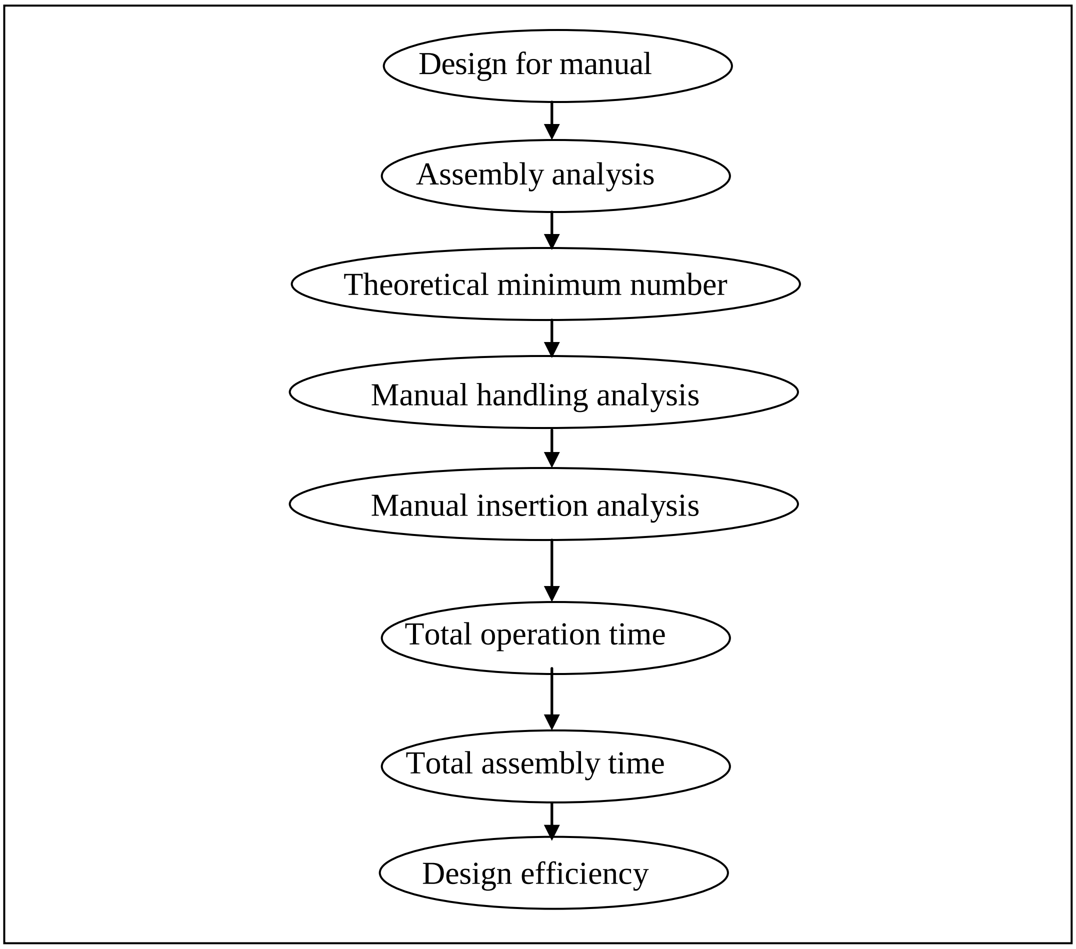


Figure 2.15: Boothroyd and Dewhurst DFA analysis.

Source: (Boothroyd et al., 2002)

As an illustration Figure 2.15 the analysis is starting with defined the theoretical minimum number. The purpose is to define each part in assembly as a necessary part or candidate to be eliminated or to be combined with other part. Each part in assembly must answer the three following question below (Boothroyd *et al.*, 2002):

i. Does the part move relative to other parts?
ii. Must the part, for good reasons, be made of a different material?
iii. Does the part need to be separate for assembly or service?

If the answer "yes" to at least one of the following three questions above for a part, the part are the theoretical minimum number. Otherwise if the answer "no", the part are the candidate to eliminate or combine with other part.

The second step is manual handling analysis on each part. This analysis is used to define the estimated time for handling the part according the weight, thickness, end-to-end part symmetry and rotational part about the axis. The third step is manual insertion analysis that used to estimate the insertion time for each part according the resistance and alignment during insertion and how the part is secured such as the part secured using snap fit or mechanical tools. Then fourth and fifth step is calculated the total operation time and the total assembly time. The formulated is following below:

$$Total\ operation\ time\ in\ second\ = T_h + Ti \tag{2.1}$$

where;

T_h = handling time

T_i = insertion time

$$Total\ assembly\ time\ (sec) = E\ total\ operation\ time\ of\ each\ part \tag{2.2}$$

The last step is calculated the design efficiency. The design efficiency is obtained by using the formula below (Boothroyd et al, 1994)

$$Design\ efficiency, Ema\ = \frac{Nmin\ xTa}{Tma} \tag{2.3}$$

where;

N_{min} = theoretical minimum number of parts

T_a = basic assembly time = 3 second

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

Hitachi Assemblability Evaluation Method

This method developed by Miyakawa and Ohashi in the late 1970 as part Hitachi desire for products, which could be efficiently assembled by automation. The main objective is to facilitate design improvements by identifying 'weaknesses' in the design at the earliest possible stage in the design process, by the use of two indices:

i. Assemblability evaluation score ratio (E), used to assess design quality by determining the difficulty of operations
ii. Assembly cost ratio (K) used to project elements of assembly cost

The assembly process is analyzed using 20 AEM elements. The total assemblability evaluation score for the product is defined as the sum of the assemblability scores for the individual tasks, divided by the number of tasks. This may be considered to be a measure of design efficiency where a score of 100 would represent a perfect design. Hitachi consider that an overall score E of 80 is acceptable and overall assembly cost ratio K less than 0.7 is acceptable.

The Assemblability Evaluation Method (AEM) is an effective tool developed by Hitachi Ltd. to improved design quality for better assembly producibility. The AEM has been widely used by the Hitachi Group as well as by more than 20 other well known companies around the world. Using this method, in the early design stage, product design quality is analyzed quantitatively and weakness in the design’s assembly producibility are highlighted. In addition, the effects of design improvement are confirmed with respect to assembly cost.

2.7.2 Lucas Hull DFA Method

Although the Boothroyd Dewhurst method is widely used, it is based on timing each of the handling and insertion method. Although tables of data are available, the most accurate numbers are compiled through times studies in particular factories.

Lucas Corporation in the United Kingdom was developed the Lucas DFA method early year of 1980's. The Lucas Method is differing from Boothroyd method, where the Lucas Hull method is based on "point scale" which gives a relative measure of assembly difficulty. The method is based on three separate and sequential analyses.

These are best described as part of the assembly sequence flowchart (ASF):

i. Specification
ii. Design
iii. Functional analysis (this is the first Lucas analysis)

Possibly loop back to step 2 if the analysis yields problems

iv. Feeding analysis (this is the second Lucas analysis)
v. Fitting analysis (this is the third Lucas analysis)
vi. Assessment
vii. Possibly return to step 2 if the analyses identify problems

In this analysis, the components of the product are reviewed only for their function. The components are divided into two groups. Parts that belong to Group A are those that are deemed to be essential to the product's function; Group B parts are those that are not essential to the product's function. Group B functions include fastening, locating and etc.

The functional efficiency of the design can be calculated as:

$$E_d = \frac{A}{(A+B)} \text{ x } 100\% \tag{2.4}$$

Where:

A: the number of essential components

B: the number of non-essential components.

Note that the design efficiency is used to pre-screen a design alternative before more time is spent on it. This is different than the Boothroyd-Dewhurst method (which assumes a design is already available). This analysis is intended to reduce the part count in the product. Typically, a design efficiency of 60% is targeted for initial designs.

Similar to the Boothroyd–Dewhurst analysis, both the part handling and insertion times are examined here. In the feeding analysis, the problems associated with the handling of the part are score using an appropriate table. For each part, the individual feeding index is scored. Generally, the target index for a part is 1.5. If the index is greater than 1.5, the part should be considered for redesign. An ideal feeding ratio is generally taken to be 2.5. Overall, all of the product's components should meet a "feeding ratio" defined as:

$$Feeding\ Ratio\ = \frac{Total\ Feeding\ Index}{no.of\ essential\ components} \tag{2.5}$$

Where:

Total feeding index = sum of all the indices of all the parts

No. of essential = the value A from the functional analysis

The fitting Analysis is calculated similarly to the feeding analysis. A fitting index of 1.5 is a goal value for each assembly. However, it should be noted that there is usually greater variance in the fitting indices than in the feeding indices. In fitting, an overall fitting ratio also 2.5.

2.7.3 Comparing Various Method of DFA

The comparison between three DFA methods:

i. Boothroyd and Dewhurst DFA

Advantages

It is very suitable for the redesign product based on design efficiency and the part that required high assembly time to assembly and unnecessary should be redesign or eliminate.

Disadvantages

Does not show the evaluation of the whole assembly sequence and also no support on how to redesign the evolution shows the poor results.

ii. Lucas / Hull DFA

Advantages

It is very suitable in develop new product design based on design efficiency and also evaluated the part based on functional, handling and fitting analysis.

Disadvantages

The function analysis does not show the reason why the part should exist and it is also no support on how to redesign the evolution shows the poor results.

iii. Hitachi Assemblability Evaluation Method (AEM)

Advantages

It is analyzes the assembly operations of each component of the product.

Disadvantages

Only focuses on the insertion and fastening process and neglected the handling process. It is also no support on how to redesign the evolution shows the poor results.

2.8 DFA TOOLS AND SOFTWARE

2.8.1 Boothroyd-Dewhurst DFA Software

Boothroyd-Dewhurst DFA Software version 9.3.0.41 are commonly used in this analysis. Design for Assembly is a methodology for evaluating part designs and the overall design of an assembly. It is a quantifiable way to identify unnecessary parts in an assembly and to determine assembly times and costs. Using DFA software, users assess the cost contribution of each part and then simplify the product concept through part reduction strategies. (Boothroyd Dewhurst, Inc., 2005)

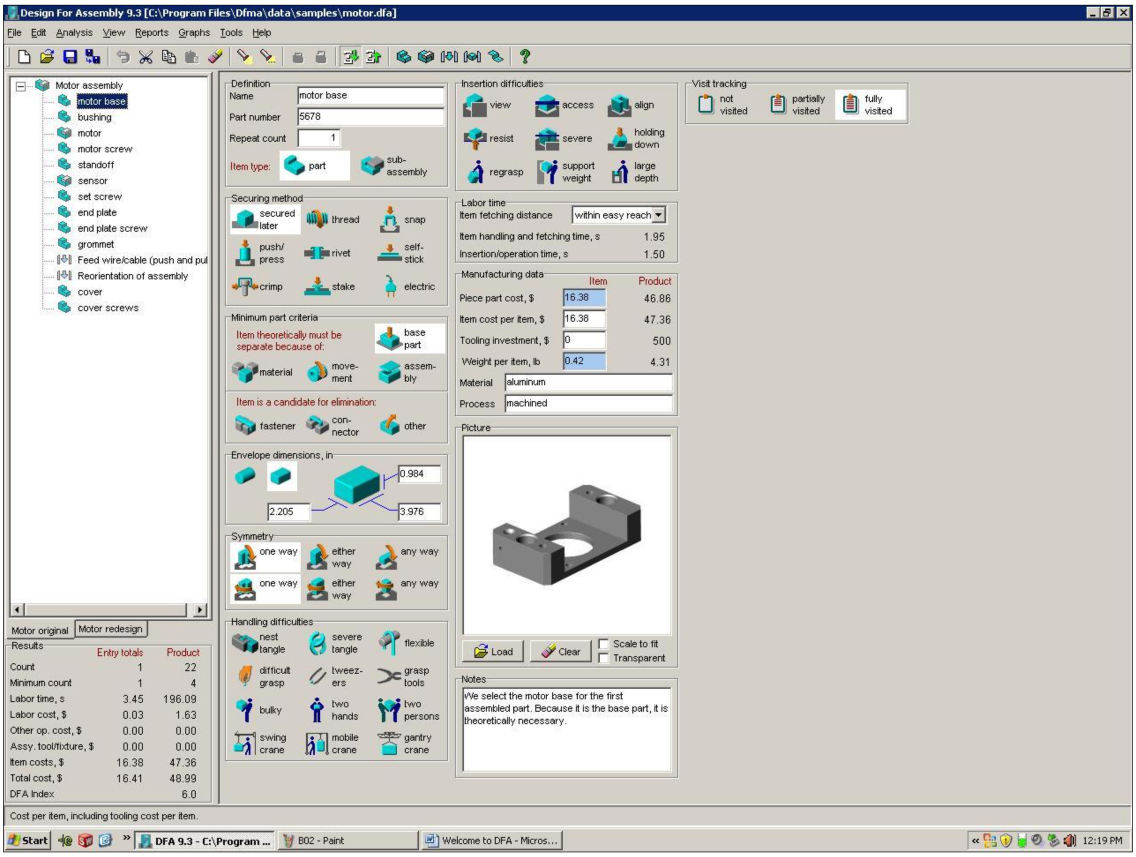


Figure 2.16: Screenshot of Boothroyd-Dewhurst DFA Software interface.

Source: Boothroyd-Dewhurst DFA Software version 9.3.0.41

These strategies involve incorporating as many features into one part as is economically feasible. The outcome of a DFA-based design is a more elegant product with fewer parts that is both functionally efficient and easy to assemble. The larger benefits of a DFA-based design are reduced part costs, improved quality and reliability, and shorter development cycles.

The software is divided into three important main sections that are Structural Chart, Question Panel, and Result Box. To answer all question accordingly in the Question Panel are very important to get an accurate analysis result that will appear in Result Box (Figure 2.17)

Results	Entry totals	Product
Count	1	22
Minimum count	1	4
Labor time, s	3.45	196.09
Labor cost, $	0.03	1.63
Other op. cost, $	0.00	0.00
Assy. tool/fixture, $	0.00	0.00
Item costs, $	16.38	47.36
Total cost, $	16.41	48.99
DFA Index		6.0

Figure 2.17: Result Box.

Source: Boothroyd-Dewhurst DFA Software version 9.3.0.41

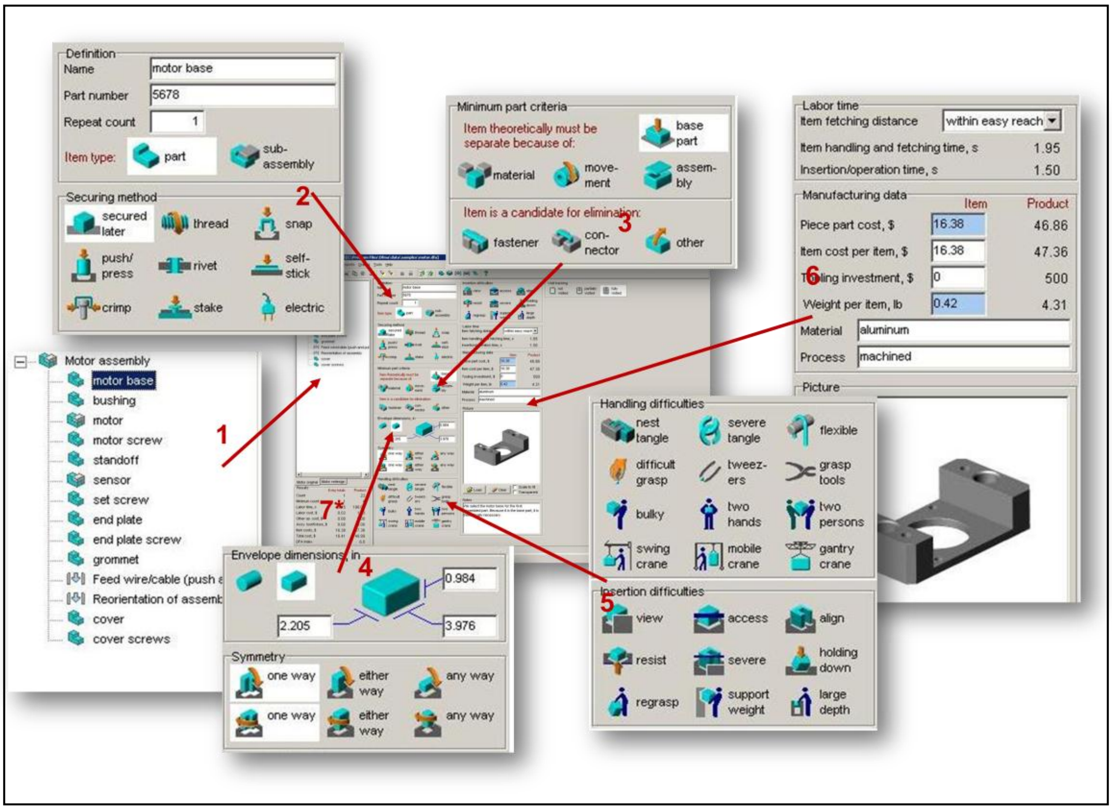


Figure 2.18: Important tools and box in the Boothroyd-Dewhurst DFA Software [Structural Chart (1), Question Panels (2)-(6) and Result Box (7)].

Source: Boothroyd-Dewhurst DFA Software version 9.3.0.41

The most important above all is the Question Panel in figure 2.18, which is the input that user need to enter correctly. Good understanding in DFMA guidelines and rules are required to deal with question related to parts securing method, minimum part criteria, and envelope dimension for packaging, handling difficulties, insertion difficulties, and manufacturing data.

Type of item like part or subassembly also can be manage in the structural chart in figure 2.18,(1) to organize the parts or subassemblies in one product. Besides, these two item type, parts from DFM Concurrent Costing® for certain parts which contains process and material information for quickly estimating the cost of manufacturing and finishing parts.

2.8.2 DFM Concurrent Costing® Software

DFM Concurrent Costing® contains process and material information and calculations for quickly estimating the cost of manufacturing and finishing a part. It is designed to isolate the principal cost components, to allow you to investigate design changes to reduce costs and to compare alternative processes and materials for the part. (Boothroyd Dewhurst, Inc., 2006)

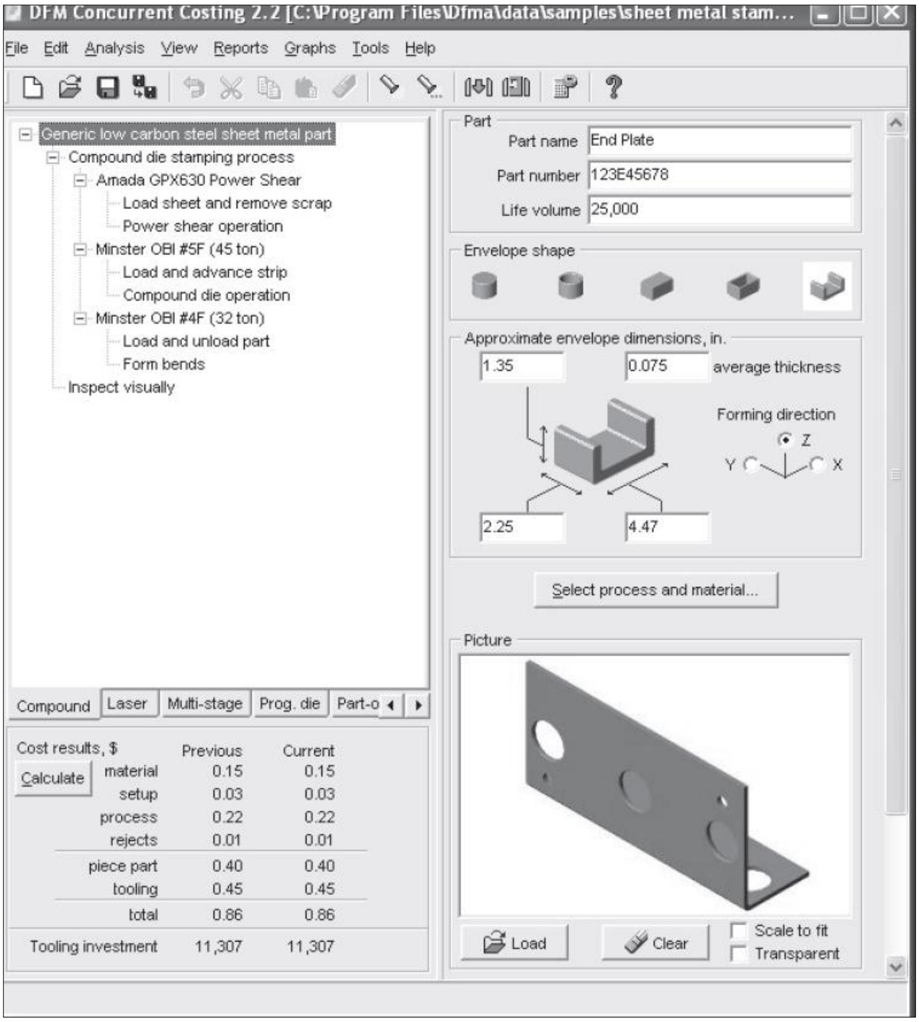


Figure 2.19: Print screen of BDI-DFM Concurrent Costing® Software.

Source: DFM Concurrent Costing® Software

The cost of one part can be estimate as it being design. Besides that the tooling cost with appropriate manufacturing process can be generate. In this project, the DFM Injection Molding Module is expected to be used. This module can provide the component cost of an injection molded part with mold cost, processing cost, and material costing estimation.

Process parameters such as optimum number of cavities, set up time, set up cost, and mold time are also estimated by the software. This allow designer to see the cost impact of tolerance and finish specifications which can be optimize by “what if” analysis.

2.9 PREVIOUS RESEARCH ON DFA

One example of the general benefits to be gained from DFA has been documented by Motorola. Motorola discovered that DFMA helped them towards their goal of achieving and maintaining a 'six-sigma design' philosophy. That means achieving no more than 3.4 defects per million parts - predicted during design. Motorola discovered that there was an 80% reduction in assembly defects on DFA-designs compared to non-DFA designs. Encouraged by the result, Motorola surveyed eleven other DFA-analyzed products and found a strong correlation between assembly efficiency arid defect yields. Simply stated, Motorola finds that the higher the ease-of-assembly, the lower the defect rate. (Brannan, B., 1991)

A design & manufacturer of Missile Systems, Fire Control Systems, and Electro-Optics, Lockheed-Martin (LM) cites itself as a world leader in Advanced Combat Systems. With shrinking defense spending, the 'battle' of cost and performance was upon them. Application of DFMA began in earnest in 1993 on a project where competition was fierce and the most-affordable solution was needed. External consultants facilitated in-house workshops for teams that included key suppliers. Proposed redesigns showed a path to Part count reductions, ranging from 20 to 74 per cent, on just six key assemblies. Similar improvements were discovered in assembly time. To date, LM have trained over 500 personnel in DFMA with I75 being suppliers. They have analyzed more than 60 products, in I7 programs and achieved savings averaging 20 to 30%. DFMA' is deemed by LM to be a 'principal design requirement'. (Davidoff, A., 1996)

Another research are done for Small Unmanned Ground Vehicle (SMGV) or ‘iRobot‘ as part of U.U Army’s future combat system. Since 100% iRobot’s manufacturing is outsourced, the team were optimizing the mechanical design by using Design for Manufacturing and Assembly (DFMA) method. After the optimization, the project break even in less than two years, and the expected net present value for this project comes to more than $22.3 million. (Ada Yu, 2008)

Ford Motor Company leads the field in terms of aggressive use and support of DFMA. They are reputed to have trained more than 10,000 engineers in BDI DFA, and contribute substantially to DFMA research programs. Ford (along with GM and Chrysler) is now requiring it‘s ‘design-responsible’ suppliers conduct DFMA analysis prior to submitting bids on subcontract products. DFMA has now become “part of the very fabric of Ford” according to James Cnossen, Ford’s Manager of Manufacturing Systems & Operations Research. This is not surprising when Ford attributes a saving of $ 1,000 million to DFA in I987 alone. In 414 the Transmission & Chassis Division, the average of all improvements made on analyzed products stands at 29% saving in assembly time, 20% fewer parts and 23% fewer operations. (Burke, G., 1989)

McDonnell Douglas (MCD) set out to develop the F- I8 Super Hornet Fighter Aircraft in 1990. The fighter aircraft had to fly 40 per cent further and carry 20 per cent more payload. Tight cost constraints were also imparted yet MCD knew production volumes would not exceed six aircraft per year. The DFMA process was implemented in 1992 via an aggressive training program - before projects commenced. The Super Hornet E/F model rolled out on time, within budget and although 25 per cent larger than the C/D version, the E/F had 42 per cent fewer parts. It was also 500 kg under the Navy’s weight limit. This produced another benefit, as each kilogram of aircraft weight costs $100,000 in fuel to move around over the life of a fighter aircraft. (Buchholz, K., 1996)

Previous research on similar method of DFA has been done in one or two year by Mohd Faizal Bin Alias, in Universiti Malaysia Pahang. The research objective is to improve product of rice cooker by using integrate method of Axiomatic Design analysis and DFA method. (Muhammad Faizal Bin Alias, 2007)

Another similar research titled ‘Design and Analysis for the Improvement of Electric Kettle Performance’ also has been done by Mas Ayu Hassan in 2008. (Mas Ayu Hassan, 2008)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter presents the review of the methodology that has been suggested in conducting this study for two semesters. Starting with design of study, where the methodology in performing this study has been reviewed. Framework of the study however, are reviewed the planning that has been suggested in conducting this study referring to DFA design-analyzed-redesign strategies, which this systematic approach used for analyze an existing or proposed product design to identify opportunities for simplifying and improving efficiency of manufacture and assembly. This method seeks to minimize information content by eliminating parts and processes, simplifying the parts and processes that remain, and standardizing where possible.

3.2 DESIGN OF THE STUDY

The methodology that have been used in this study is basically similar to the others studies done before. The first steps that are considerably important are conformation of thesis title. After the conformation, discussions with supervisor have been conduct to arrange the weekly appointment time.

The study is proceeding with identifying the problem statement of the study before the objectives are stated. In order to perform this study, the next steps that have been taken are to identify the scopes of study. This is really important step as this scopes are making the objective of the study are clearer. Then the outline of the study has been review. In the same time the products searching to perform this study are done.

The next steps that have been taken are searching for available journals and references from internet and library. The common keywords that had been used in searching and browsing the journals are like ‘Parts Elimination’, ‘Information Content’, ‘Boothroyd-Dewhurst’, ‘DFA’, ‘DFMA’, ‘Design Efficiency’, ‘Concurrent Engineering’, ‘Insertion/Handling Code’, ‘Cost Estimation in Product Design’, ‘Snap-fits’, ‘Design Guidelines’, ‘Assembly time’ and ‘Product Design Improvement’. Basically, there are about five journals mentioned and discuss in previous chapter, are amongst the references that had been used during to this study. Reference and text book in other hand are used in understanding the concept and detail methods to evaluating the products. At the same time, meetings and lecture session from university’s DFMA curriculum syllabus are beneficial to this study.

Then, this study proceeds with design of the framework and project methodology. In this section, the overview of methods that had been used in completing the study is reviewed in general. Here, the manual calculating method to determine assemblies’ handling and insertion code are discussed. Besides that, the important ‘3 Questions’ of Boothroyd-Dewhurst DFA are reviewed before the method for selecting the best alternative design is being discussed.

The study progress is proceed with design evaluation and modeling. In this section the data measured form each parts that have been disassembled are present. In here, parts dimension and criticism has been included. Basically the evaluations of the design consist of two phases. Phase one is evaluation and CAD modeling of existing design in order to determine how the system works and function. Evaluation also suggested candidates for elimination in order to perform some modifications to the design. In the other hand, phase two is more concern about analysis and selection of new proposed designs. The justifications for each new design also discussed in this section.

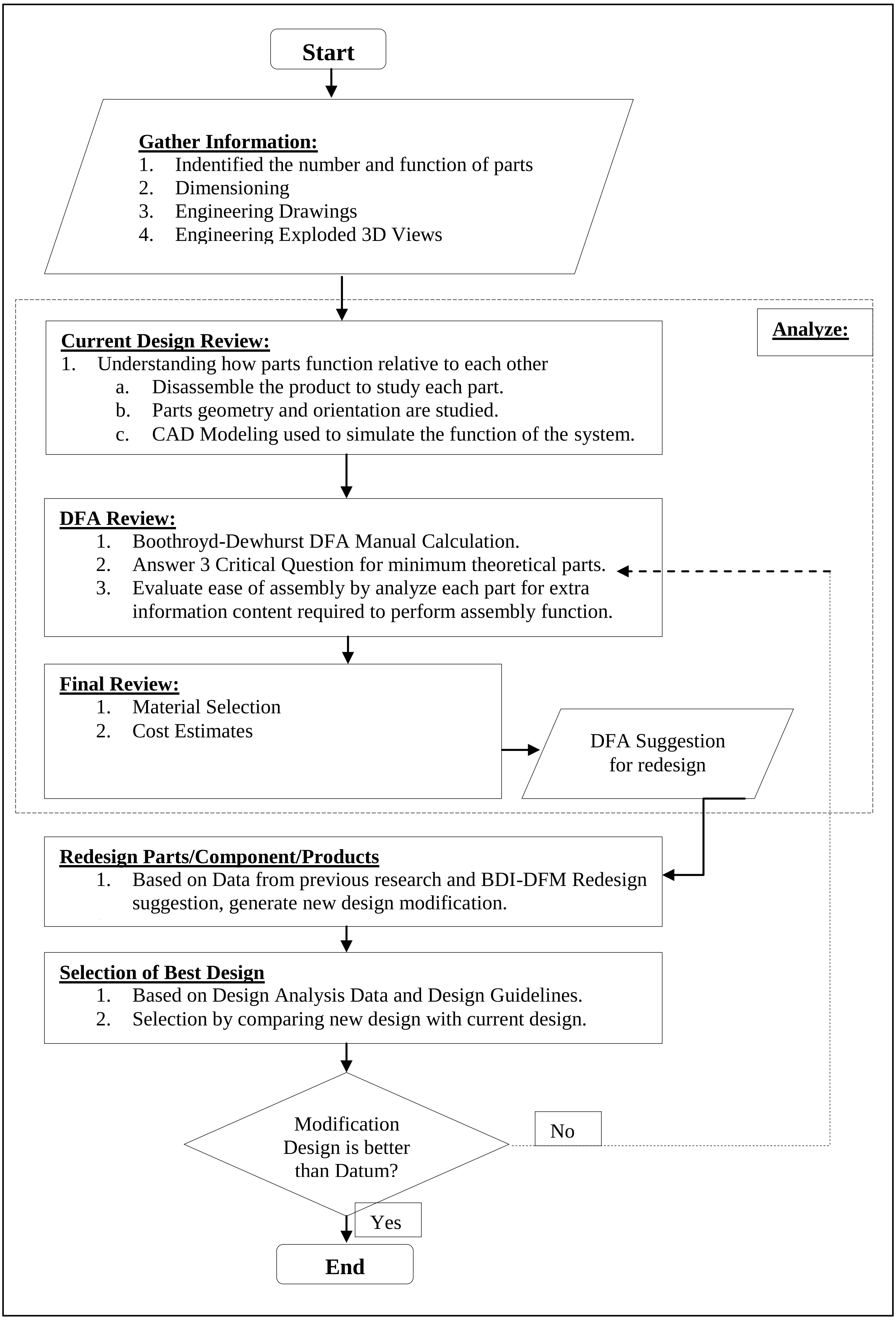


Figure 3.1: Framework of the study.

3.3 FRAMEWORK OF THE STUDY

The method utilizes an analyze-redesign approach to implement the design guidelines. First, an existing design is analyzed. The insights gained from the analysis are then used to develop and refine redesign alternatives aimed at eliminating parts and making the parts that remain easy to manufacture and assemble. The step-by-step procedure is as follows (Figure 3.1):

i. Gathering the Information of parts/product.
ii. Analyze the whole system as parts function relative to each other.
iii. Redesign the new improved parts according to DFA suggestion.
iv. Finalized the new design.
v. Comparing the design efficiency of existing and new design.

3.3.1 Identifying and selection of product

Kitchen scale is chosen in this study for determine the optimization of the cost and assembly efficiencies. Nowadays, the kitchen scale is being widely used especially for household use for measure cooking ingredients during cooking activities.

The kitchen scale was imported by Seng Huat Hang Sdn Bhd, 1473, Lorong Perusahaan Maju 8, Perai Industrial Estate 4, 13600 Prai, Penang. The kitchen scale product is considered as a medium cost mechanical appliance. For more detail of specification please refer to Table 4.1. It is absolutely beneficial to reconsider its design for assembly (DFA) features so that overall cost can be reduced.

3.3.2 Parts disassemblies

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

3.3.3 Measuring and CAD Modeling

Obtain the best information available about the product or assembly. Useful items include:

1. Engineering drawings
2. Engineering Exploded three-dimensional views
3. An existing version of the product
4. A prototype

The step of redesign the product is starting by gather information about the current product. In this project, the current product is electric kettle that must be disassembled part by part to get the detail number of component. Then measure each parts or component by using manual measuring tool like vernier caliper to get the dimension detail of each part. The next step is to generate 3D model of current design. It is very important to modeling the design in 3D view by using CAD software. The design need to show in explode three-dimensional drawing because it, explained virtually how the each part is assemble and also shows the total of part in the current design.

3.3.4 Boothroyd-Dewhurst DFA Manual Evaluation

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

1. Does the part move relative to all other parts already assembled in the normal operating mode?
2. Must the part be of a different material or be isolated from other parts already assembled?
3. Must the part be separate from all other parts already assembled because otherwise necessary assembly or disassembly of other parts would be impossible?

DFA Manual Worksheet

Table 3.1: Example of Design for Assembly Manual Worksheet.

Part ID no	**Part Name**	**Number of times the operation is carried out consecutively**	**Two digit Manual Handling Code**	**Manual Handlin g time per part**	**Two digit Manual insertio n code**	**Manual insertion time per part**	**Operatio n time**	**Theoretic al minimum number of parts**
				T_h		T_i	$T_h + T_i$	`1/0
						TOTAL:	T_{ma}	N_{min}

Source: (Boothroyd et al., 2002)

DFA Manual Worksheet as in table 3.1 has been filled with the coding and time for each part of the product. With the understanding of how part work and relate to each other in normal operating mode, the handling and insertion difficulties of the part are define by the code obtained from Boothroyd-Dewhurst DFA Manual Handling (Figure 3.2) and Insertion Table (Figure 3.3).

Assembly operations always involve at least two component parts: the part to be inserted and the part or assembly (receptacle) into which the part is inserted. Orientation involves the proper alignment of the part to be inserted relative to the corresponding receptacle and can always be divided into two distinct operations: (1) alignment of the axis of the part that corresponds to the axis of insertion, and (2) rotation of the part about this axis. It is therefore convenient to define two kinds of symmetry for a part:

i. Alpha symmetry: depends on the angle through which a part must be rotated about an axis perpendicular to the axis of insertion to repeat its orientation.
ii. Beta symmetry: depends on the angle through which a part must be rotated about the axis of insertion to repeat its orientation.

Boothroyd DFA Manual Handling Table

MANUAL HANDLING—ESTIMATED TIMES (seconds)

Key: ONE HAND

		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
parts can be grasped and manipulated by one hand without the aid of grasping tools	(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

Key: ONE HAND with GRASPING AIDS

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

Key: TWO HANDS for MANIPULATION

	parts present no additional handling difficulties					parts present additional handling difficulties (e.g. sticky, delicate, slippery, etc.) (1)				
	α ≤ 180°			α = 360°		α ≤ 180°			α = 360°	
	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
parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary) (2) — 8	4.1	4.5	5.1	5.6	6.75	5	5.25	5.85	6.35	7

Key: TWO HANDS required for LARGE SIZE

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

Figure 3.2: Boothroyd-Dewhurst DFA Manual Handling Table.

Boothroyd DFA Manual Insertion Table

MANUAL INSERTION—ESTIMATED TIMES (seconds)

Key: PART ADDED but NOT SECURED

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

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

Key: SEPARATE OPERATION

		mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-fastening processes	
		none or localized plastic deformation				metallurgical processes					
		bending or similar processes	rivetting or similar processes	screw tightening (6) or other processes	snap fit, snap clip, press fit, etc.	no additional material required (e.g. resistance, friction welding, etc.)	additional material required: soldering processes	additional material required: weld/braze processes	chemical processes (e.g. adhesive bonding, etc.)	manipulation of parts or sub-assembly (e.g. orienting, fitting or adjustment of part(s), etc.)	other processes (e.g. liquid insertion, etc.)
		0	1	2	3	4	5	6	7	8	9
assembly processes where all solid parts are in place	9	4	7	3	3.5	7	8	12	12	9	12

Figure 3.3: Boothroyd-Dewhurst DFA Manual Insertion Table.

for parts that can be grasped and manipulated with one hand without the aid of grasping tools

sym (deg) = (alpha+ beta)		no handling difficulties			part nests or tangles		
		thickness > 2mm		< 2mm	thickness > 2mm		< 2mm
		size > 15mm	6mm < size < 15mm	size > 6mm	size > 15mm	6mm < size < 15mm	size > 6mm
		0	1	2	3	4	5
sym < 360	0	1.13	1.43	1.69	1.84	2.17	2.45
360 <= sym < 540	1	1.5	1.8	2.06	2.25	2.57	3.0
540 <= sym < 720	2	1.8	2.1	2.36	2.57	2.9	3.18
sym = 720	3	1.95	2.25	2.51	2.73	3.06	3.34

for parts that can be lifted with one hand but require two hands because they severely nest or tangle, are flexible or require forming etc.

	alpha <= 180		alpha = 360
	size > 15mm	6mm < size <15mm	size > 6mm
	0	1	2
4	4.1	4.5	5.6

Figure 3.4: Selected manual handling time standards, seconds (parts are within easy reach, are no smaller than 6mm, do not stick together, and are not fragile or sharp).

Source: (Boothroyd et al., 2002)

part inserted but not secured immediately or secured by snap fit

		secured by separate operation or part				secured on insertion by snap fit	
		no holding down required		holding down required			
		easy to align	not easy to align	easy to align	not easy to align	easy to align	not easy to align
		0	1	2	3	4	5
no access or vision difficulties	0	1.5	3.0	2.6	5.2	1.8	3.3
obstructed access or restricted vision	1	3.7	5.2	4.8	7.4	4.0	5.5
obstructed access and restricted vision	2	5.9	7.4	7.0	9.6	7.7	7.7

part inserted and secured immediately by screw fastening with power tool
(times are for 5 revs or less and do not include a tool acquisition time of 2.9s)

		easy to align	not easy to align
		0	1
no access or vision difficulties	3	3.6	5.3
restricted vision only	4	6.3	8.0
obstructed access only	5	9.0	10.7

Figure 3.5: Selected manual insertion time standards, seconds (parts are small and there is no resistance to insertion).

Source: (Boothroyd et al., 2002)

	screw tighten with power tool	manipulation, reorientation or adjustment	addition of non solids
	0	1	2
6	5.2	4.5	7

Figure 3.6: Selected separate operation times, seconds (solid parts already in place).

Source: (Boothroyd et al., 2002)

After manual insertion and handling code are determined, the insertion and handling time are obtained. Then, the assembly times for each part are summed and the total assembly time can be estimate.

3.3.5 Generate a New Design

The project required to modified or redesign the product design. The design analysis data techniques and Boothroyd-Dewhurst DFA Suggestion for Redesign are used to get good design result. By using DFA guidelines and methodology of Boothroyd-Dewhurst DFA, model the 3D modified design by using SolidWorks software. The aim of modification design is to reduce number of part and improve the design efficiency. The new design are then analyzed by using MoldFlow Plastics Insight (MPI) software to simulate the plastics injection molding process and determine the estimated cycle time of the process.

CHAPTER 4

DESIGN EVALUATION AND MODELING

4.1 INTRODUCTION

Design for assembly (DFA) analyzes product designs to improve assembly ease and reduce assembly time. Often this is accomplished through a reduction in part count. The implementation of DFA techniques has played an important role in reducing costs of manufacturing over the last two decades. It is apparent that for both manual and automated assembly, the effective methods to reduce assembly costs were those applied during design; manufacturing and production changes have less impact on product cost.

DFA addresses assembly quality largely through product structure simplification and reduction in the total numbers of parts in a product. Redford, A and Chal, J. (1994) state that any DFA method should have the following features:

i. It should be a complete method as regards to procedures for evaluating assemblability and should be creative enough to obtain procedures for improving assemblability.
ii. It should be a systematic step-by-step procedure, which considers all relevant issues.
iii. It should be able to measure assemblability objectively, accurately, and completely.
iv. It should be user friendly and should have good quality.

4.2 PRODUCT DESCRIPTION

4.2.1 Product Specification

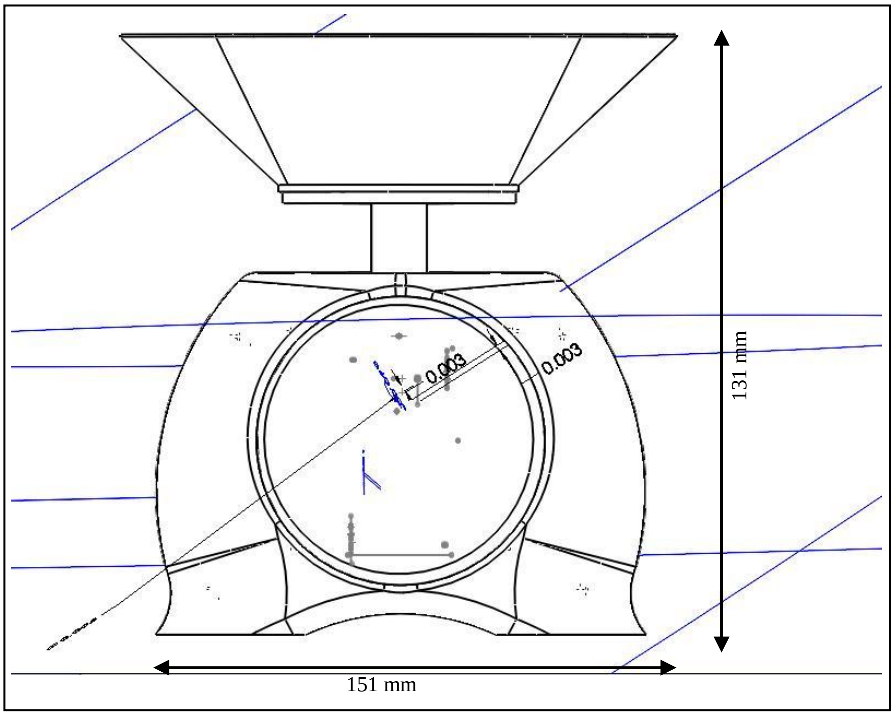
Kitchen scale is chosen in this study for determine the optimization of the cost and assembly efficiencies. Nowadays, the kitchen scale is being widely used especially for household use for measure cooking ingredients during cooking activities.

The kitchen scale was imported by Seng Huat Hang Sdn Bhd, 1473, Lorong Perusahaan Maju 8, Perai Industrial Estate 4, 13600 Prai, Penang. The kitchen scale product is considered as a medium cost mechanical appliance. For more detail of specification please refer to Table 4.1. The kitchen scale original product is shown in Figure 4.1.

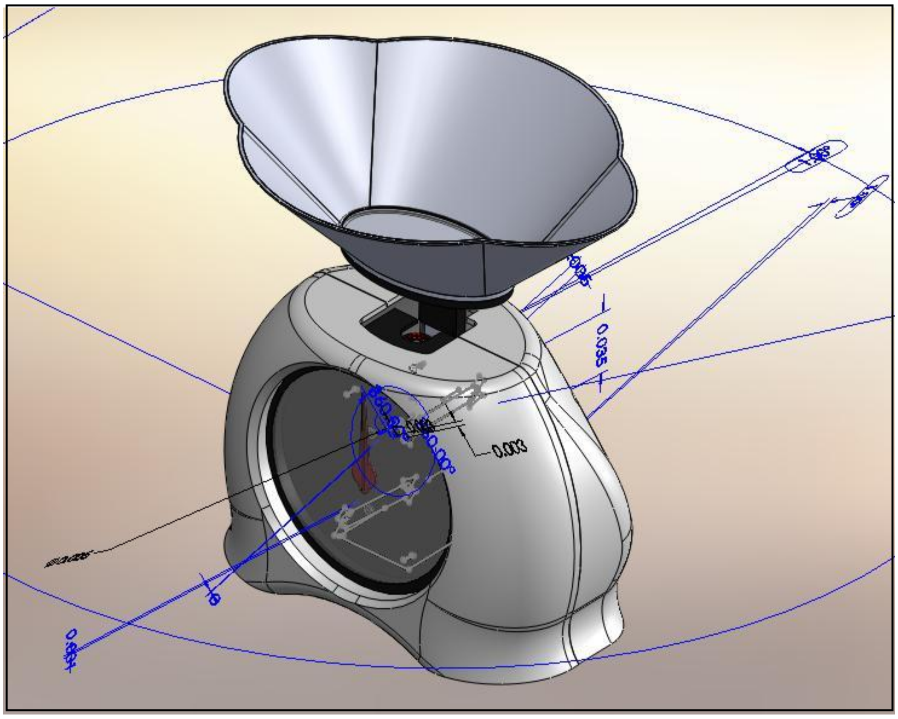
Table 4.1: Kitchen scale specification.

Product Characteristic	Product Specification
Manufacturer /Model	Seng Huat Hang S/B, Penang /THC-3000A
Product Name	3Kg Family Round Kitchen Scale
Dimension	131(H) x25(W) x 151(L)mm
Load Capacity	3Kg (6.6Lbs)
Type of function	Manual
Features	Removable weight bowl
	Different Colour Choice
Applications	Weighing food ingredients
No. of Part	24

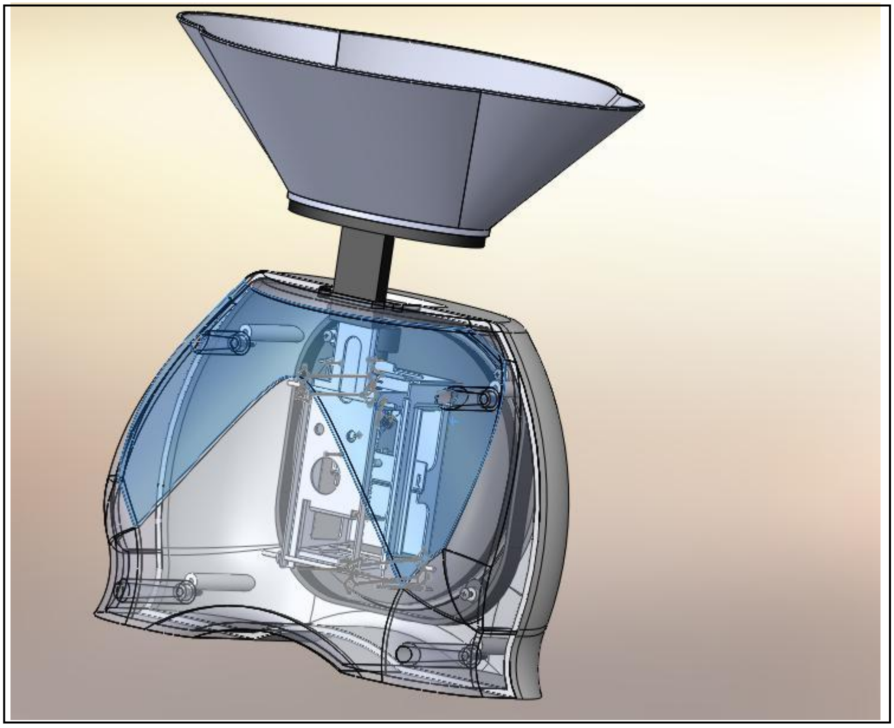
(a)



(b)



(c)



(d)

Figure 4.1: Kitchen scale photo and CAD drawing. (a) Picture illustrates the photo of Kitchen Scale in the market. (b) Picture illustrates the 2D dimension of overall products (131x151mm). (c) Picture illustrates the isometric view of CAD drawing. (d) Picture illustrates the transparent view into the inner components and assembly of the kitchen scale.

Source: SolidWorks Version 2009

4.3 ORIGINAL DESIGN EVALUATION

Figure 4.2 shows the kitchen scale product tree. By understanding the product structure, the assembly evaluation can be done more successfully. The product tree is divided into 3 major sub-assemblies, which are Front Bracket, Rear Bracket and Front Cover. It is found that Weight Base and Weight Bowl do not have sub assembly.

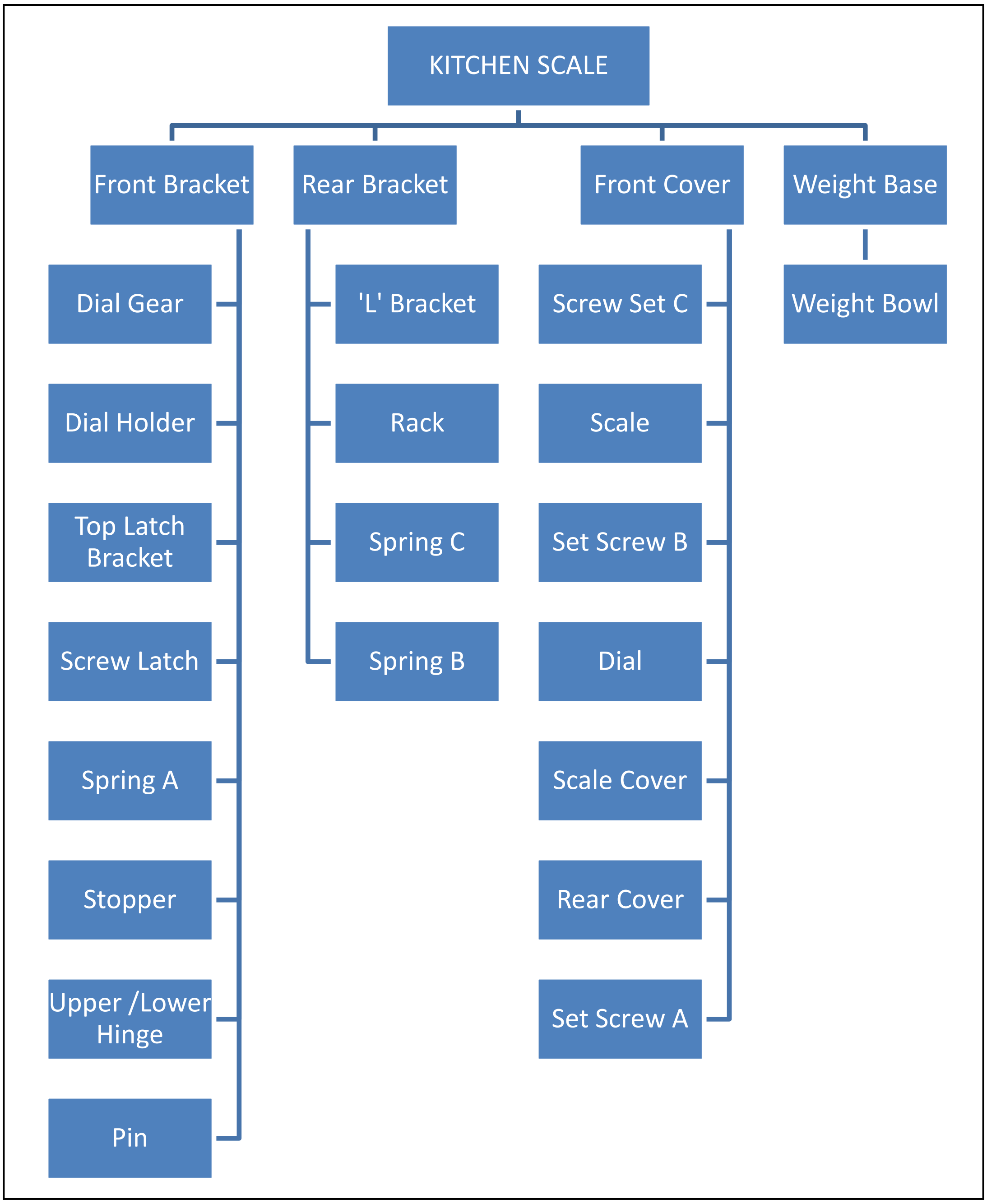


Figure 4.2: Product Tree of Kitchen Scale original design.

4.3.1 Parts Quantity, Function, and Materials in the Original Design

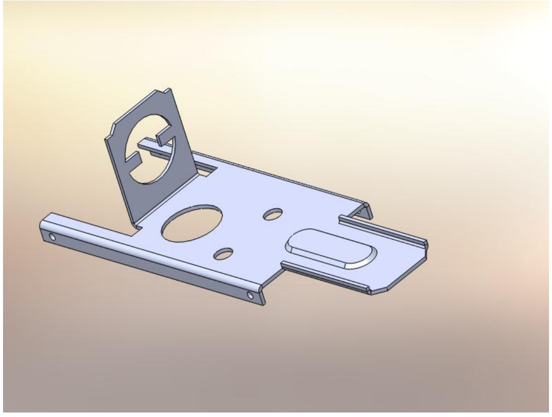
The kitchen scale has been dismantled and analyzed. Refer to Table 4.2. The product has 24 unique parts and 35 total parts number where this are 2 hinges, 2 Upper/Lower Bracket, and 3 type of screws which total number is 10 screws.

Table 4.2: The parts list for the original design.

No	Name	Qtty	Function	Material
1	Rear Bracket	1	Weight Mechanism	Steel
2	‘L’ Hinge	1	Hold Rack and Spring	Steel
3	Spring C	1	Tension	Spring Steel
4	Rack	1	Transmit movement	Steel
5	Spring B	1	Secure spring	Steel
6	Front Bracket	1	Weight Mechanism	Steel
7	Dial Gear	1	Transmit movement	Plastic
8	Dial Holder	1	Secure Dial	Plastic
9	Top Latch Bracket	1	Hold Spring Latch	Steel
10	Spring A	1	Tension	Spring Steel
11	Spring Latch	1	Hold Spring	Steel
12	Stopper	1	Adjusting Dial	Plastic
13	Upper/Lower Hinge	2	Weight Mechanism	Steel
14	Pin	4	Secure hinges and bracket	Steel
15	Scale	1	Visual Indicator	Plastic
16	Screw Set C	2	Secure main subassembly	Steel
17	Dial	1	Indicator	Plastic
18	Scale Cover	1	Protect Scale	Plastic
19	Front Cover	1	Casing	Plastic
20	Screw Set B	4	Secure both covers	Steel
21	Rear Cover	1	Casing	Plastic
22	Screw Set A	4	Secure both covers	Steel
23	Weight Base	1	Hold weight bowl	Plastic
24	Weight Bowl	1	Hold weight	Plastic
Total Component		35		

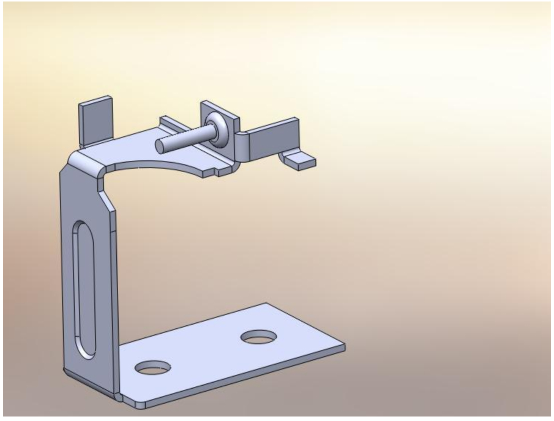
Figure 4.3 (a)–(x) shows a kitchen scale parts that has been dismantled. For more detail the exploded drawing of the original design is shown in appendix.

(a) Part No.1



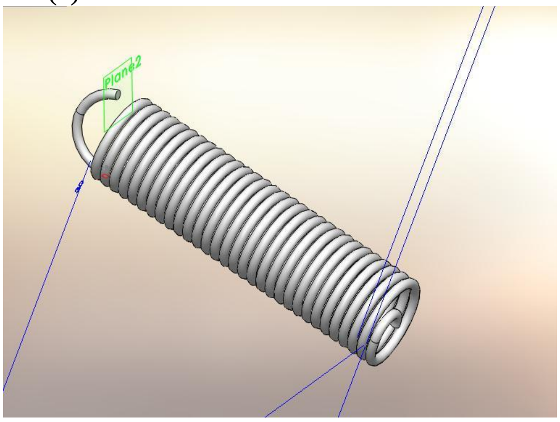
Part Name		Rear Bracket
Dimension in mm	**Size**	117
	Thickness	40
Rotary Symmetry	**Alpha**	360˚
	Beta	360˚

(b) Part No.2



Part Name		'L' Hinge
Dimension in mm	**Size**	45
	Thickness	30
Rotary Symmetry	**Alpha**	360˚
	Beta	360˚

(c) Part No.3

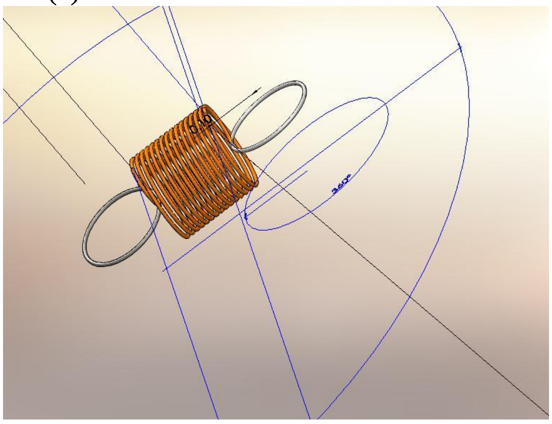


Part Name		Spring C
Dimension in mm	Size	45
	Thickness	7
Rotary Symmetry	Alpha	360˚
	Beta	0˚

(d) Part No.4

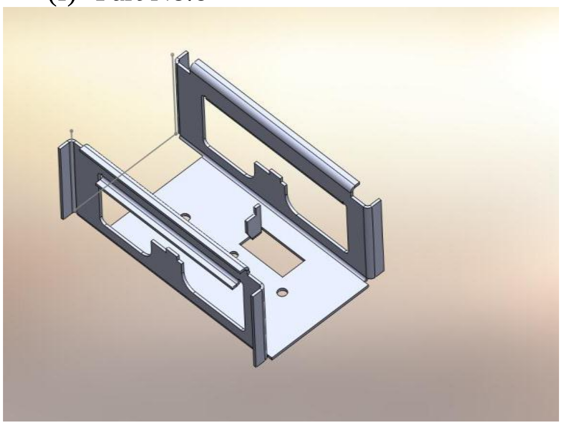
Part Name		Rack
Dimension in mm	Size	60
	Thickness	6
Rotary Symmetry	Alpha	360˚
	Beta	180˚

(e) Part No.5



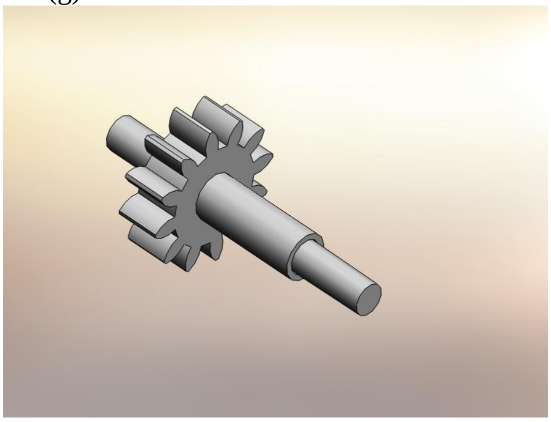
Part Name		Spring B
Dimension in mm	Size	15
	Thickness	2.5
Rotary Symmetry	Alpha	180˚
	Beta	0˚

(f) Part No.6



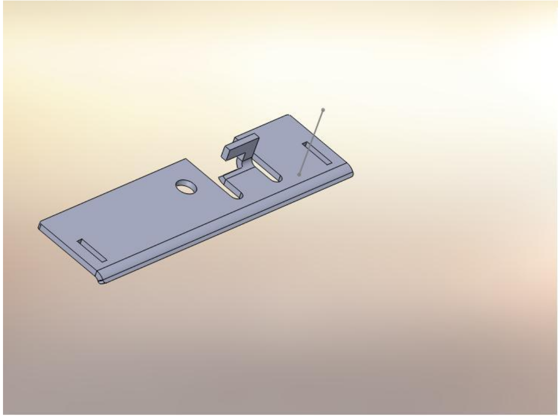
Part Name		Front Bracket
Dimension in mm	Size	100
	Thickness	40
Rotary Symmetry	Alpha	360˚
	Beta	360˚

(g) Part No.7



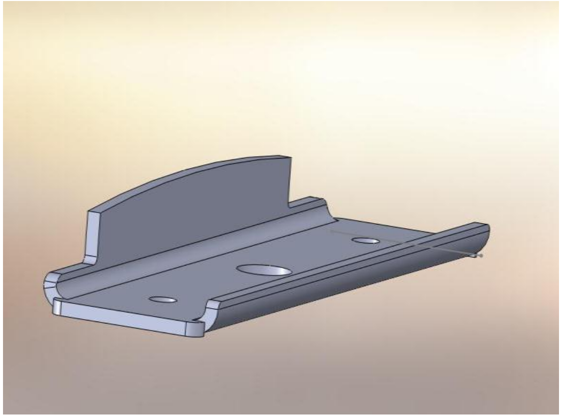

Part Name		Dial Gear
Dimension in mm	Size	25
	Thickness	4
Rotary Symmetry	Alpha	360˚
	Beta	0˚

(h) Part No.8



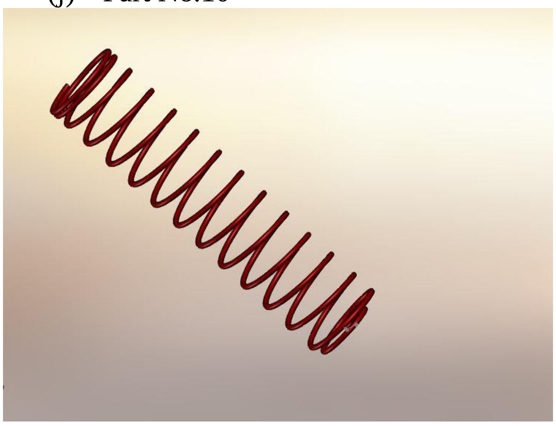

Part Name		Dial Holder
Dimension in mm	Size	52
	Thickness	8
Rotary Symmetry	Alpha	360˚
	Beta	360˚

(i) Part No.9



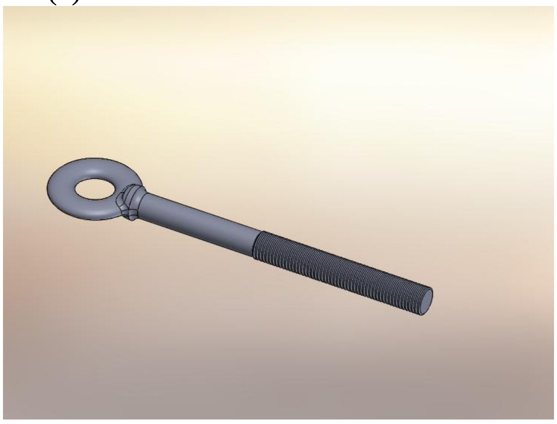
Part Name		Top Latch Bracket
Dimension in mm	Size	42
	Thickness	10
Rotary Symmetry	Alpha	360˚
	Beta	360˚

(j) Part No.10



Part Name		Spring A
Dimension in mm	Size	35
	Thickness	18
Rotary Symmetry	Alpha	0˚
	Beta	0˚

(k) Part No.11

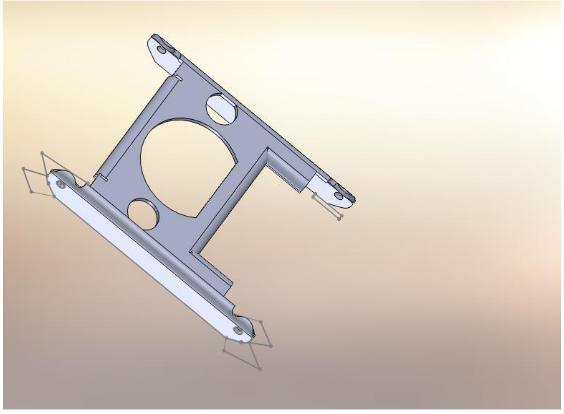


Part Name		Spring Latch
Dimension in mm	Size	43
	Thickness	3
Rotary Symmetry	Alpha	360˚
	Beta	0˚

(l) Part No.12

Part Name		Stopper
Dimension in mm	Size	20
	Thickness	7.5
Rotary Symmetry	Alpha	360˚
	Beta	0˚

(m) Part No.13

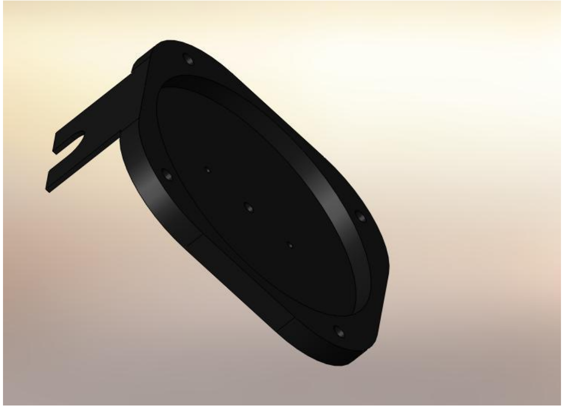


Part Name		Upper/Lower Hinge
Dimension in mm	Size	54
	Thickness	7
Rotary Symmetry	Alpha	360˚
	Beta	360˚

(n) Part No.14

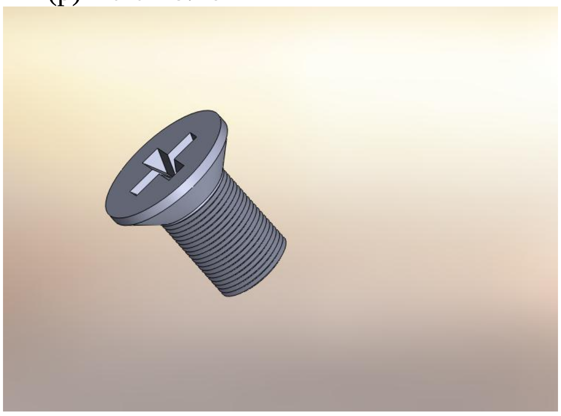
Part Name		Pin
Dimension in mm	Size	60
	Thickness	1
Rotary Symmetry	Alpha	180˚
	Beta	0˚

(o) Part No.15



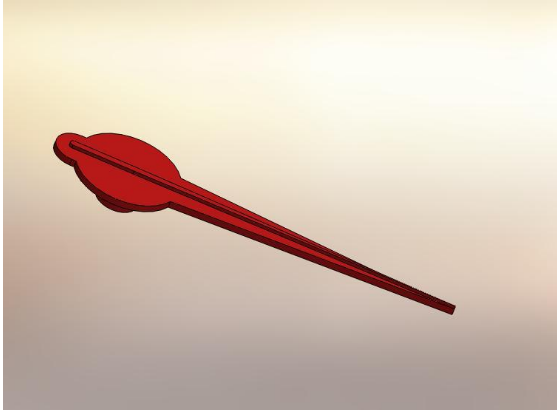
Part Name		Scale
Dimension in mm	Size	133
	Thickness	10
Rotary Symmetry	Alpha	360˚
	Beta	180˚

(p) Part No.16



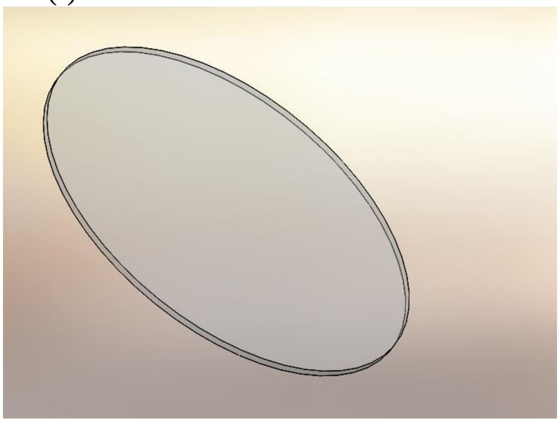
Part Name		Screw set C
Dimension in mm	Size	6
	Thickness	3
Rotary Symmetry	Alpha	360˚
	Beta	0˚

(q) Part No.17



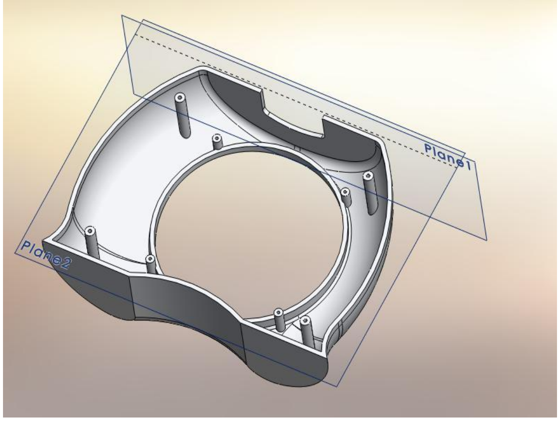
Part Name		Dial
Dimension in mm	Size	58
	Thickness	6
Rotary Symmetry	Alpha	360˚
	Beta	0˚

(r) Part No.18



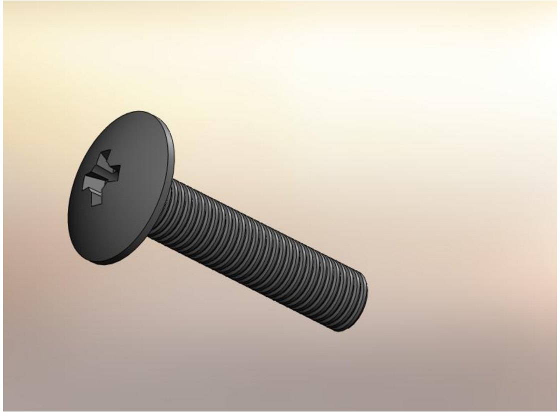
Part Name		Scale Cover
Dimension in mm	Size	124
	Thickness	2
Rotary Symmetry	Alpha	180˚
	Beta	0˚

(s) Part No.19



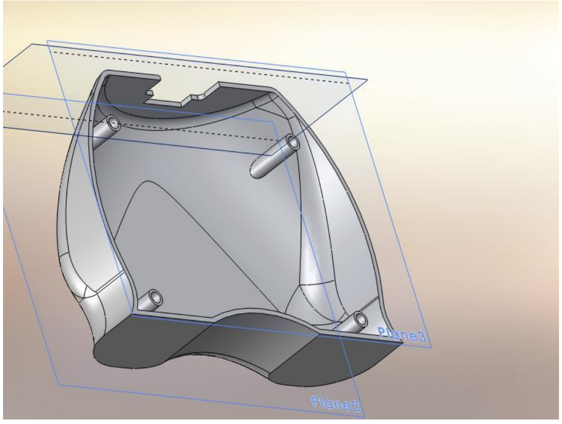
Part Name		Front Cover
Dimension in mm	Size	213
	Thickness	60
Rotary Symmetry	Alpha	360˚
	Beta	360˚

(t) Part No.20



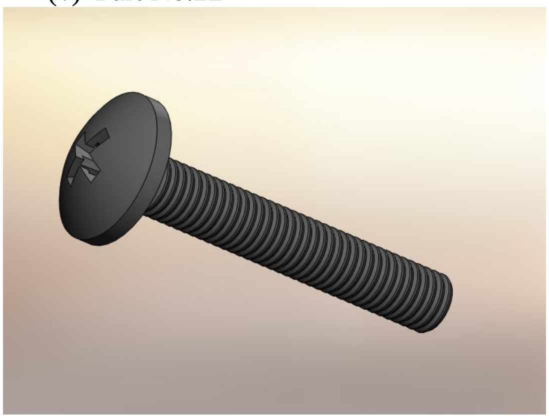
Part Name		Screw set B
Dimension in mm	Size	14
	Thickness	2.5
Rotary Symmetry	Alpha	360˚
	Beta	0˚

(u) Part No.21



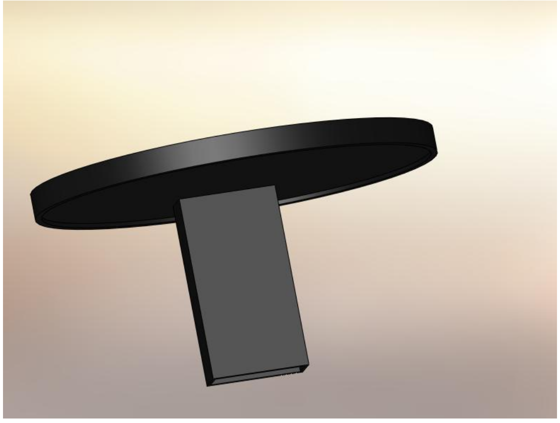
Part Name		**Rear Cover**
Dimension in mm	**Size**	213
	Thickness	60
Rotary Symmetry	**Alpha**	360˚
	Beta	360˚

(v) Part No.22



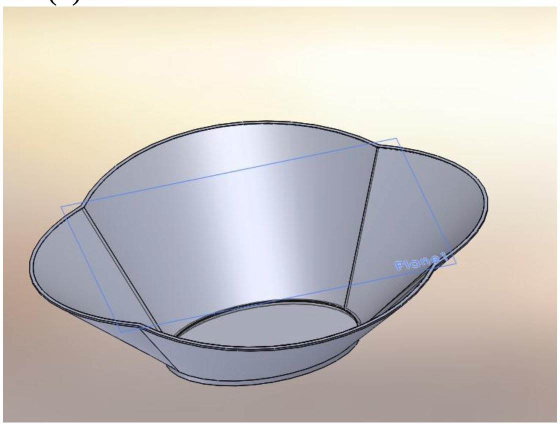
Part Name		**Screw set A**
Dimension in mm	**Size**	11
	Thickness	2.5
Rotary Symmetry	**Alpha**	360˚
	Beta	0˚

(w) Part No.23



Part Name		Weight Base
Dimension in mm	**Size**	100
	Thickness	45
Rotary Symmetry	**Alpha**	360˚
	Beta	360˚

(x) Part No.24



Part Name		Weight Bowl
Dimension in mm	**Size**	230
	Thickness	65
Rotary Symmetry	**Alpha**	360˚
	Beta	180˚

Figure 4.3(a)–(x): Picture and Dimension of all Kitchen Scale Parts.

4.3.2 Criticism for All Part Component

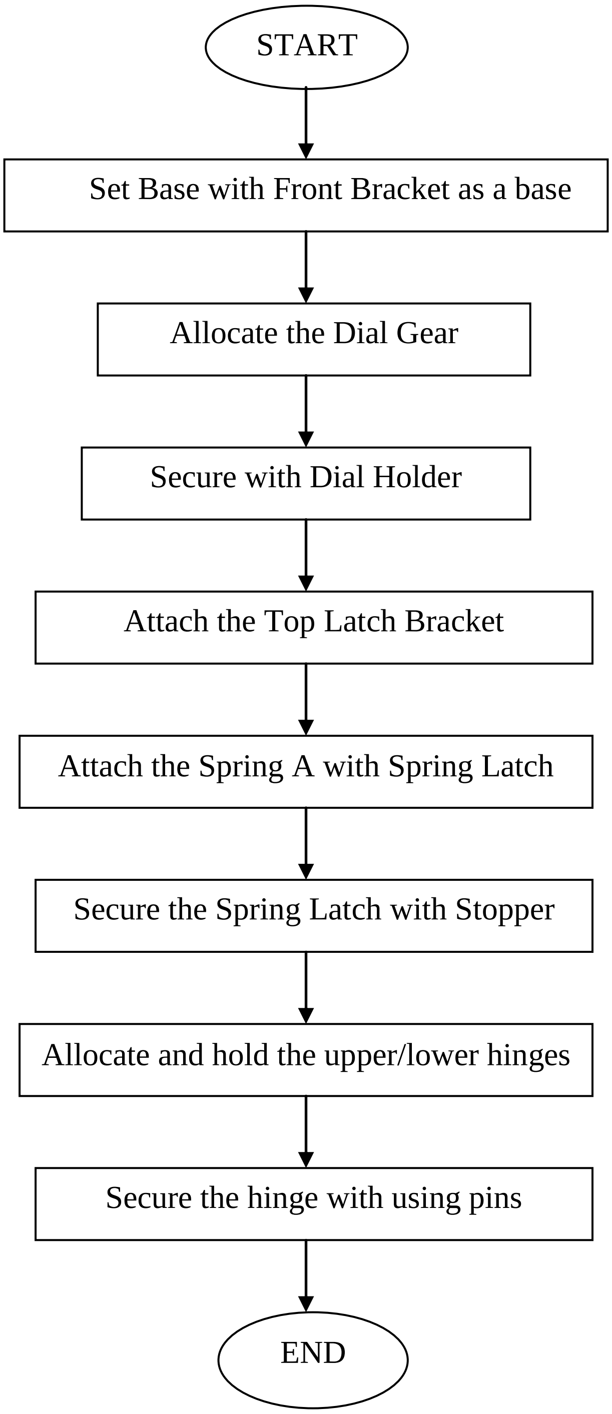
In Design for Assembly, it is important to critics each component of the product to determine ideas for design improvement. Referring to Table 4.3 are critics for each component for Kitchen Scale, together with some suggestions and recommendations.

Table 4.3: Criticism of each part component.

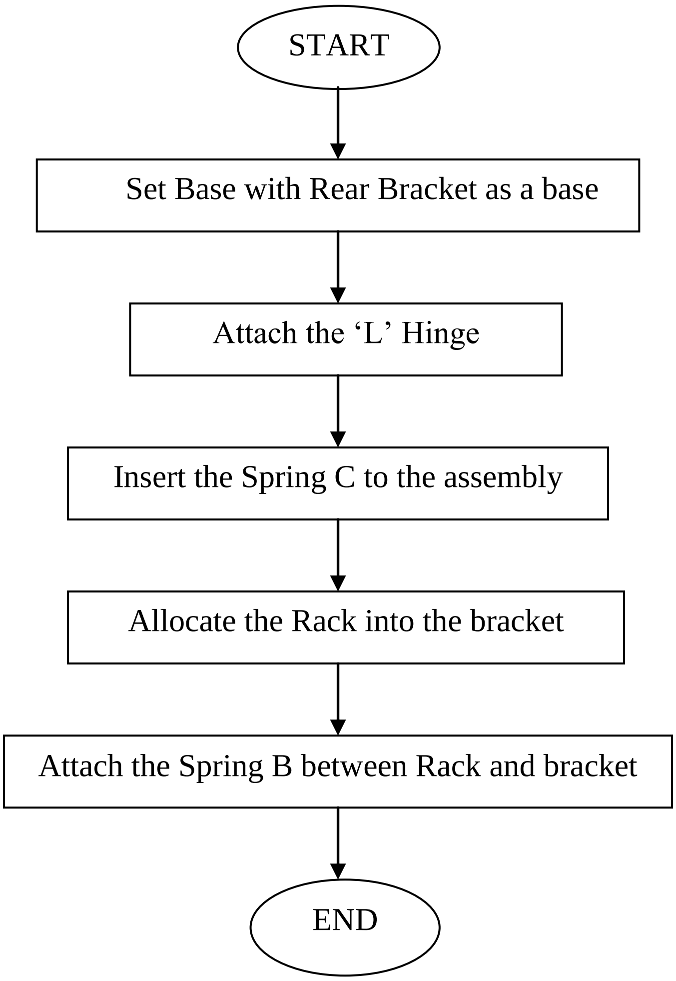
No	Name	Critics
1	Rear Bracket	This part hinge to front bracket assembly. Some modification needs to make the upper/lower hinge easier to assemble.
2	'L' Hinge	This additional part merely functions to hold rack and spring for the dial gear movement.
3	Spring C	This is a standard part; no modification can be done at this point.
4	Rack	Very hard to assemble the rack into front bracket. Need some modification for the rack (press fit approach).
5	Spring B	This is a standard part; no modification can be done at this point.
6	Front Bracket	This part could be eliminated, after combine it with rear cover.
7	Dial Gear	No modification for this part.
8	Dial Holder	Small size and use snap fit.
9	Top Latch Bracket	Part could be eliminate by combining with front bracket which also combine to new rear cover
10	Spring A	This is a standard part; no modification can be done at this point.
11	Spring Latch	Difficult to assemble spring latch to the spring.
12	Stopper	This part together with spring latch is used to setting the scale.
13	Upper/Lower Hinge	Not symmetry shape. Hard to assemble. Use press fit approach. Need to reduce the thickness to 2mm, to make it more flexible.
14	Pins	Part function to secure upper/lower hinge to the front bracket. It is hard to assembly the pins into the hinges and bracket. Candidate for elimination.
15	Scale	Use 4 screws to assemble with the front cover. Part could be eliminated by combining with new front cover design.
16	Screw Set C	This is standard part, suggested for elimination.
17	Dial	No modification for this part.
18	Scale Cover	No modification for this part
19	Front Cover	Very big size, purposely for stability. Difficult to assemble weight mechanism to the front cover. Suggestion is to combine it with the front bracket, to reduce the part and assembly activity.
20	Screw Set B	This is standard part, suggested for elimination.
21	Rear Cover	Very big size, purposely for stability. Use 4 screw ribs to assemble with the front cover. Change to snap fit to assemble with the front cover.
22	Screw Set A	This is standard part, suggested for elimination.
23	Weight Base	No modification for this part.
24	Weight Bowl	No modification for this part. Purposely differentiate with weight base for user friendly.

4.3.3 Assembly Operation Sequences

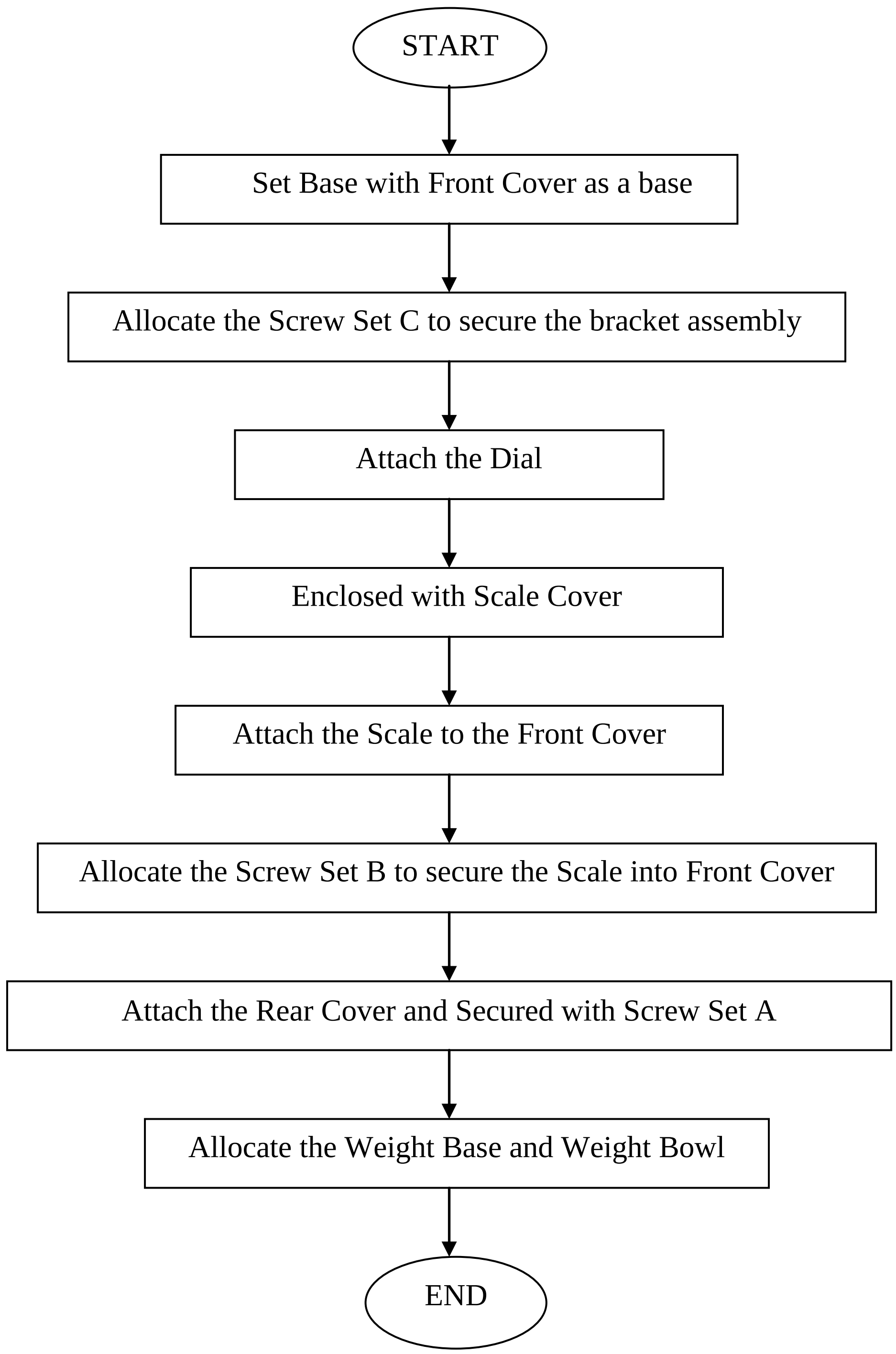
4.3.3.1 Front Bracket



4.3.3.2 Rear Bracket



4.3.3.3 Front Cover



4.3.4 Current Design Analysis

The analysis of current design is done after the kitchen scale has been draw into CAD model. The analysis is done by using Boothroyd-Dewhurst DFA method. This current design analysis is very important to obtain the DFA suggestion on part elimination and improved design.

4.3.4.1 Boothroyd-Dewhurst DFA Analysis

The analysis data are calculated and arrange in table or DFA Worksheet (Table 4.5). Table 4.4 shown set of data for total number of different parts, total time of assembly and design efficiency of current design analysis.

Table 4.4: Analysis of Current Design.

Per Product Data	Entries (Including Repeats)	Number of Different Parts	Time, s	Labor Cost, RM
Necessary Item	18	17	127.04	0.15
Fasteners	14	4	116.50	0.14
Unnecessary Item	3	3	17.91	0.02
Totals	35	24	261.45	0.31
DFA Index				19.50
Labour Rate, RM/hr				4.375

From the table 4.4, the analysis shown that the number of different parts of kitchen scale is 24 and the entries which including the repeat parts is 35 parts. Then the total time to assemble the current kitchen scale is 261.45 second with the total of estimate assembly cost per part of RM0.31. The design efficiency (DFA Index) is 19.5 percent with the labor rate per hour RM4.375.

Table 4.5: Design for Assembly (DFA) Worksheet.

Part ID No.	Part Name	Number of time the operation is carried out consecutively	Tool Acquisition Time, TA	Manual Handling Code	Manual Handling Time (s)	Insertion Code	Insertion Time (s)	Operation Time (s)	Theoretical Minimum No. of Parts
1.	Rear Bracket	1		30	1.95	00	1.5	3.45	1
2.	L-Hinge	1		30	1.95	36	8.0	9.95	1
3.	Spring C	1		82	5.10	43	7.5	12.60	1
4.	Rack	1		30	1.95	02	2.5	4.45	1
5.	Spring B	1		82	5.10	43	7.5	12.60	1
6.	Front Bracket	1		30	1.95	38	6.0	7.95	0
7.	Dial Gear	1		10	1.50	02	2.5	4.00	1
8.	Dial Holder	1		03	1.69	06	5.5	7.19	1
9.	Top Latch Bracket	1		33	2.51	90	4.0	6.51	0
10.	Spring A	1		81	4.50	44	8.5	13.00	1
11.	Spring Latch	1		80	4.10	08	6.5	10.6	1
12.	Stopper	1		10	1.50	38	6.0	7.50	1
13.	Upper/Lower Hinge	2		30	1.95	08	6.5	8.45	1
14.	Pin	4		08	2.45	41	7.5	39.8	0
15.	Scale	1		30	1.95	00	1.5	3.45	0
16.	Screw Set C	2	2.9	11	1.80	31	5.0	16.50	0
17.	Dial	1		30	1.95	01	2.5	4.45	1
18.	Scale Cover	1		18	3.00	42	6.5	9.50	1
19.	Front Cover	1		30	1.95	01	2.5	4.45	1
20.	Screw Set B	4	2.9	11	1.80	31	5.0	30.10	0
21.	Rear Cover	1		30	1.95	01	2.5	4.45	1
22.	Screw Set A	4	2.9	11	1.80	31	5.0	30.10	0
23.	Weight Base	1		30	1.95	11	5.0	6.95	1
24.	Weight Bowl	1		30	1.95	00	1.5	3.45	1
							Total	**261.45**	**17**

4.3.5 Estimation of Assembly Cost for the original design

Costing Assumption:

Labor Cost per Month	= RM 700
Working Day per Week	= 5 days
Working Hour per Day	= 8 hours
Working Hour per Month	= 160 hours
Labor Cost per Hour	= RM 4.375
Labor Cost per Second	= RM 0.001215

Table 4.6: Cost Estimates of Kitchen Scale.

Part ID No	Part Name	Operation Time (s)	Operation Costs (RM)
1.	Rear Bracket	3.45	0.004192
2.	L-Hinge	9.95	0.009659
3.	Spring C	12.60	0.020048
4.	Rack	4.45	0.004860
5.	Spring B	12.60	0.007910
6.	Front Bracket	7.95	0.010267
7.	Dial Gear	4.00	0.010267
8.	Dial Holder	7.19	0.048357
9.	Top Latch Bracket	6.51	0.012879
10.	Spring A	13.00	0.008736
11.	Spring Latch	10.6	0.009113
12.	Stopper	7.50	0.005407
13.	Upper/Lower Hinge	8.45	0.004192
14.	Pin	39.8	0.012089
15.	Scale	3.45	0.015795
16.	Screw Set C	16.50	0.005407
17.	Dial	4.45	0.015309
18.	Scale Cover	9.50	0.005407
19.	Front Cover	4.45	0.036572
20.	Screw Set B	30.10	0.011543
21.	Rear Cover	4.45	0.005407
22.	Screw Set A	30.10	0.036572
23.	Weight Base	6.95	0.008444
24.	Weight Bowl	3.45	0.004192
	Total	**261.45**	**0.312620**

4.3.6 Estimated Assembly Cost and Design Efficiency for the Original Design

Design efficiency of the original design

- Design Efficiency for Manual Assembly

$$= \frac{3 \times NM}{TM} \times 100\ \%$$

Where:

NM = Theoretical minimum number of part
TM = Total manually assembly time

From DFA worksheet;
NM = 17
TM = 261.45

Design Efficiency

$$= \frac{3 \times NM}{TM} \times 100\ \%$$

$$= \frac{3 \times 17}{261.45} \times 100\ \%$$

$$= 19.51\ \%$$

4.3.7 Selection of Parts Redesign

Based on analysis and design guidelines, there have some parts to be improved for better design. In this redesign phase, it focuses on parts elimination strategy which is eliminating the separate fasteners such as screw and pins. This is common example of candidates for elimination. The suggestion analysis from Boothroyd-Dewhurst DFA is shown in table 4.5.

Table 4.7: Suggestion for redesign.

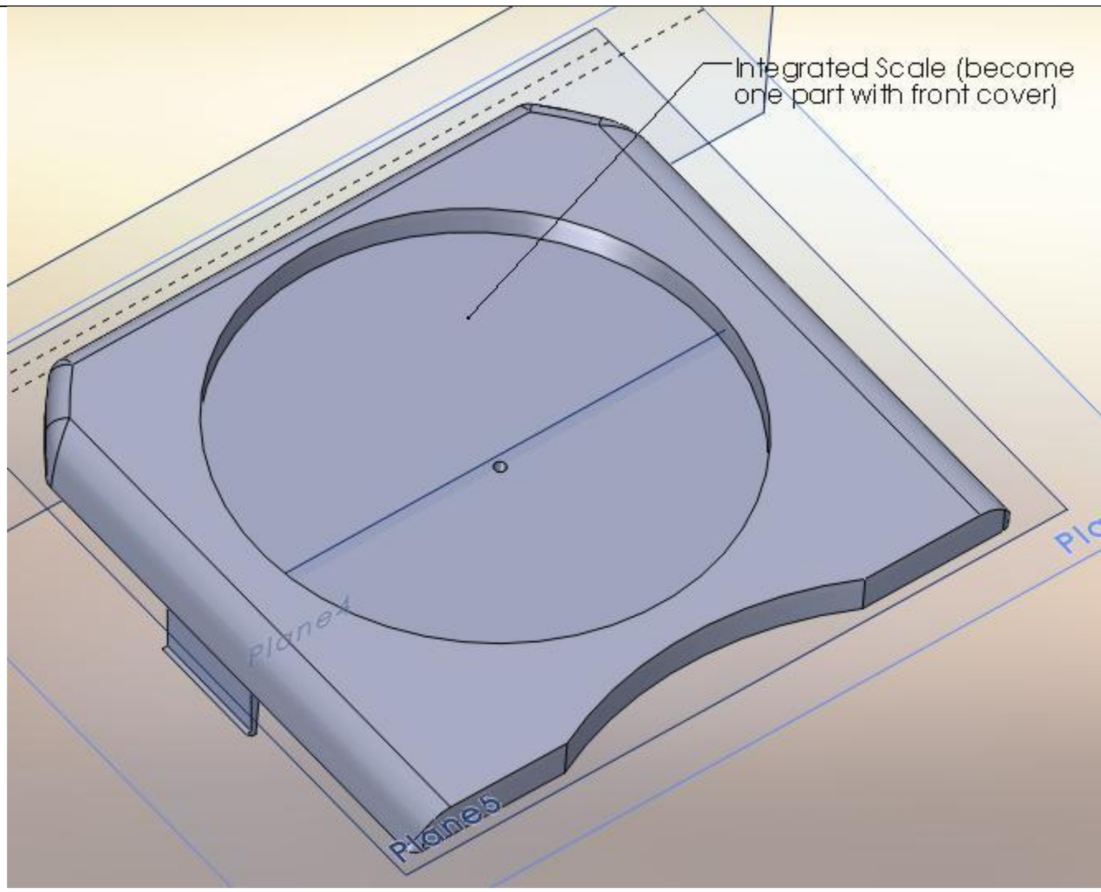
Suggestion for Redesign	Part name	Quantity	Time Savings, s	Percentage Reduction, %
Integral fastening element into functional parts or change the securing method	Screw A (Rear Cover)	4	30.1	11.5
	Screw B (Scale Cover)	4	30.1	11.5
	Screw C (Weight Mechanism)	2	16.5	6.3
	Pin	4	39.8	15.2
Reduce the number of items in the assembly by consolidate parts into integral design	Scale	1	3.45	1.3
	Front Bracket	1	7.95	3.0
	Top Latch Hinge	1	6.51	2.5
		Total of Assembly	**134.41**	**51.3**

From table 4.5, it shows that suggestion for redesign of the kitchen scale. Total fasteners in kitchen scale product are 14 parts and the total time to assemble all the fasteners in kitchen scale is 116.5 seconds. So, by reduce or eliminated the fasteners by using other joining process such as snap-fits and press-fits, the total time to assemble can be reduce about 2 times from the original time. Then 17.91 seconds from total time of assembly are reduced by eliminating and combining parts like the Scale, Front Bracket, and Top Latch Hinge from the original design.

4.4 PRODUCT REDESIGN EVALUATION

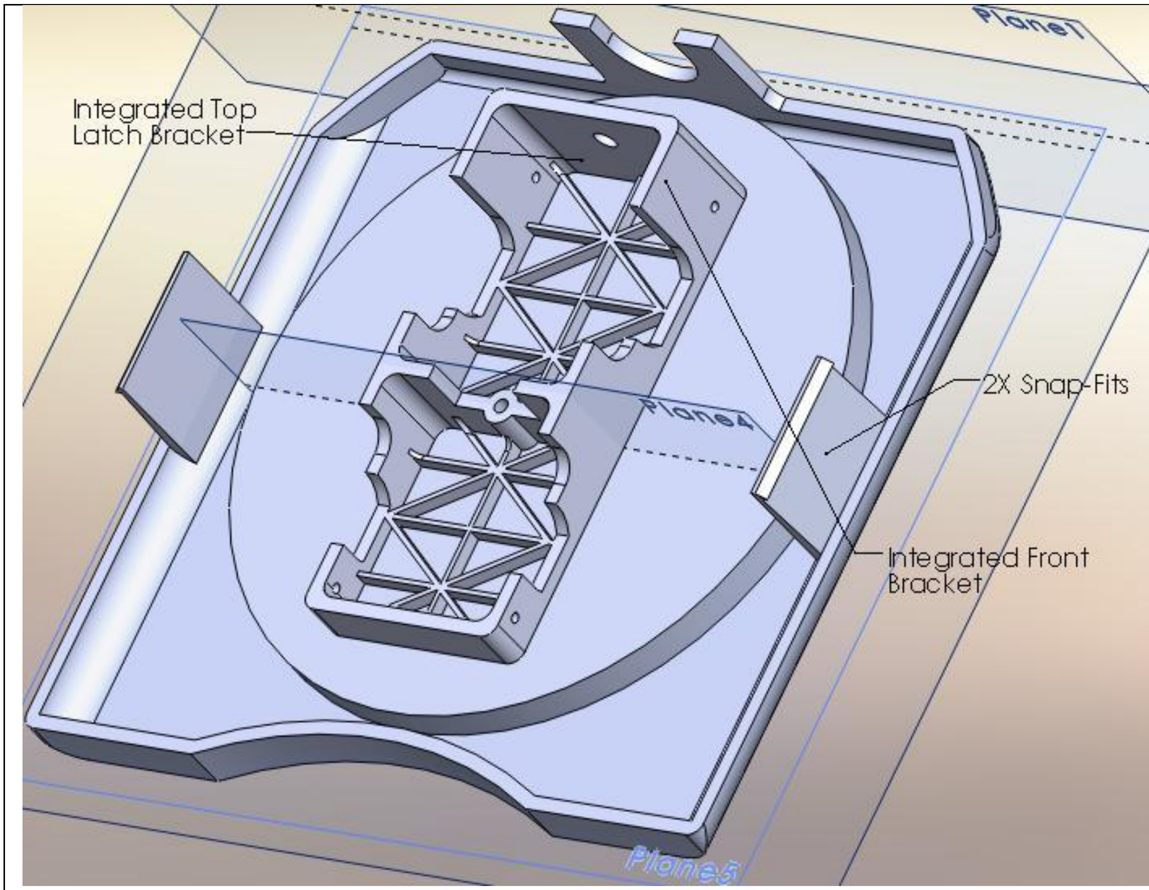
In this project, new parts designs are generated. Figure 4.4 (a)-(c) shows how the product that have been modified for improvement with the description of the redesign parts

4.4.1 Generate New Design



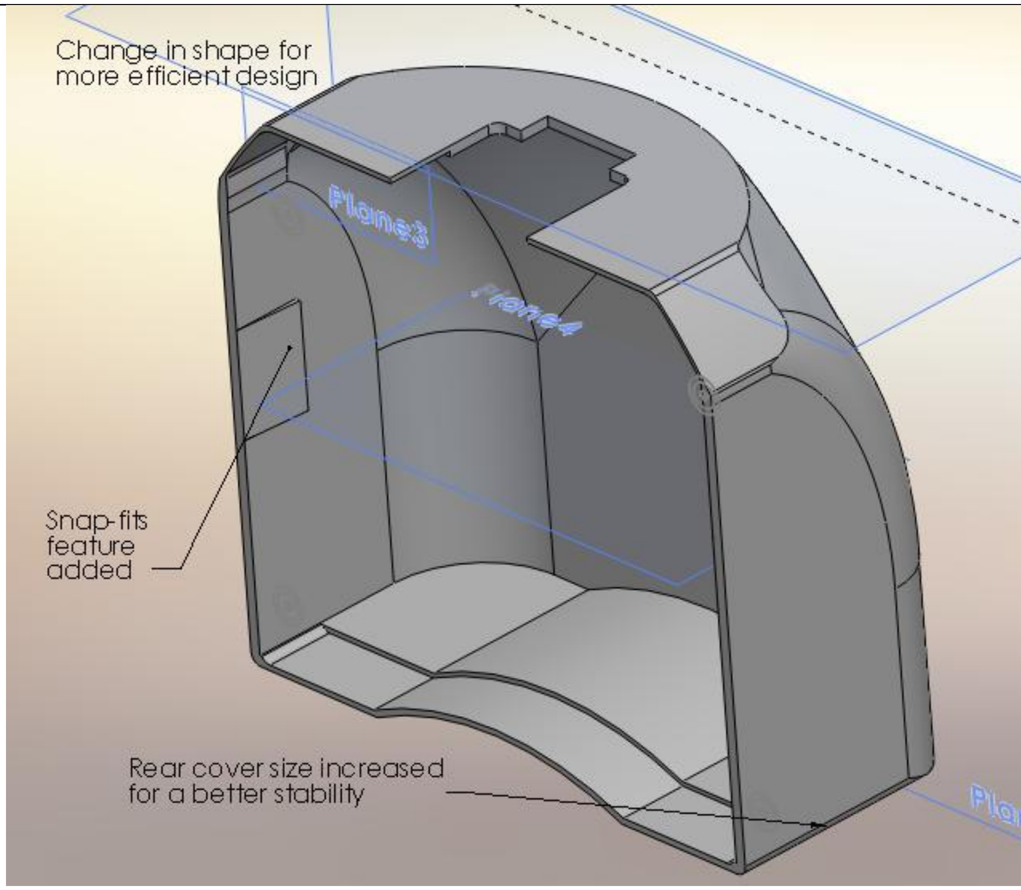
No	Description	Modification
1.	Difficult to assemble scale to front cover.	Combine the scale with front cover to become one part.
		Eliminate screw ribs and holes.

(a)



No	Description	Modification
2.	Difficult to assemble front bracket to front cover.	Integrate the front cover design with front bracket as one part.
		Change into same material with front cover. (plastics)
	Unnecessary assembly on top latch bracket to front bracket.	Integrate the top latch spring with front bracket as one part.
		Change into same material with front cover. (plastics)

(b)



No	Description	Modification
3.	Difficult to assemble front cover and rear cover.	Modify the rear cover to improve stability
		Eliminate screw ribs and hole for the front cover
		Use 2 snap fits and eliminate the 4 screws
		Reduce the size of front cover

(c)

Figure 4.4 (a)-(c): Description of redesign parts.

Table 4.8: Design for Assembly (DFA) Worksheet for New Design.

Part ID No.	Part Name	Number of time the operation is carried out consecutively	Tool Acquisition Time, TA	Manual Handling Code	Manual Handling Time (s)	Insertion Code	Insertion Time (s)	Operation Time (s)	Theoretical Minimum No. of Parts
1.	Rear Bracket	1		30	1.95	00	1.5	3.45	1
2.	L-Hinge	1		30	1.95	36	8.0	9.95	1
3.	Spring C	1		82	5.10	43	7.5	12.60	1
4.	Rack	1		30	1.95	02	2.5	4.45	1
5.	Spring B	1		82	5.10	43	7.5	12.60	1
6.	Dial Gear	1		10	1.50	02	2.5	4.00	1
7.	Dial Holder	1		03	1.69	06	5.5	7.19	1
8.	Spring A	1		81	4.50	44	8.5	13.00	1
9.	Stopper	1		10	1.50	38	6.0	7.50	1
10.	Upper/Lower Hinge	2		30	1.95	08	6.5	8.45	1
11.	Dial	1		30	1.95	01	2.5	4.45	1
12.	Spring Latch	1		80	4.10	08	6.5	10.6	1
13.	Scale Cover	1		18	3.00	42	6.5	9.50	1
14.	Front Cover	1		30	1.95	01	2.5	4.45	1
15.	Rear Cover	1		30	1.95	01	2.5	4.45	1
16.	Weight Base	1		30	1.95	11	5.0	6.95	1
17.	Weight Bowl	1		30	1.95	00	1.5	3.45	1
							Total	**127.04**	**17**

4.4.2 Estimation of Assembly Cost for the New design

Costing Assumption:

Labor Cost per Month	= RM 700
Working Day per Week	= 5 days
Working Hour per Day	= 8 hours
Working Hour per Month	= 160 hours
Labor Cost per Hour	= RM 4.375
Labor Cost per Second	= RM 0.001215

Table 4.9: New Cost Estimates of Kitchen Scale.

Part ID No	Part Name	Operation Time (s)	Operation Costs (RM)
1.	Rear Bracket	3.45	0.004192
2.	L-Hinge	9.95	0.009659
3.	Spring C	12.60	0.015309
4.	Rack	4.45	0.005407
5.	Spring B	12.60	0.015309
6.	Dial Gear	4.00	0.004860
7.	Dial Holder	7.19	0.008736
8.	Spring A	13.00	0.015795
9.	Stopper	7.50	0.009113
10.	Upper/Lower Hinge	8.45	0.010267
11.	Dial	4.45	0.005407
12.	Spring Latch	10.6	0.009113
13.	Scale Cover	9.50	0.011543
14.	Front Cover	4.45	0.005407
15.	Rear Cover	4.45	0.005407
16.	Weight Base	6.95	0.008444
17.	Weight Bowl	3.45	0.004192
	Total	**127.04**	**0.148160**

4.4.3 Design Efficiency for the New Design

Design efficiency of the new design

- Design Efficiency for Manual Assembly

$$= \frac{3 \times NM}{TM} \times 100\,\%$$

Where:

NM = Theoretical minimum number of part

TM = Total manually assembly time

From DFA worksheet;

NM = 17

TM = 127.04

Design Efficiency

$$= \frac{3 \times NM}{TM} \times 100\,\%$$

$$= \frac{3 \times 17}{127.04} \times 100\,\%$$

$$= 40.14\,\%$$

4.5 COMPARISON BETWEEN ORIGINAL AND NEW DESIGN

Table 4.10 shows the comparison between the previous and modification design in term of number of component, labor time, cost estimation, and design efficiency.

Table 4.10: Totals comparison between original and modification design.

Per Product Data		Original Design	New Design
Entries (Including Repeats)	Necessary Item	18	17
	Fasteners	14	0
	Unnecessary Item	3	0
	Totals	35	17
Time, s	Necessary Item	127.04	127.04
	Fasteners	116.50	0
	Unnecessary Item	17.91	0
	Totals	261.45	127.04
Labor Cost	Necessary Item	0.15	0.15
	Fasteners	0.14	0
	Unnecessary Item	0.02	0
	Totals	0.31	0.15
	DFA Index, %	**19.5**	**40.1**

From table 4.10, it can be conclude that by applying the Boothroyd-Dewhurst DFA, the total number of components is decreased from 35 components to 17 (the theoretical minimum number of parts). The objective of the project was achieved by reduced number of component and also integrating between parts.

The total time per product is decreased from 261.45 to 127.04 seconds. That is due to elimination of fasteners (screws and pins) and replacing with snap-fits. This reduction in assembly time also affected the assembly cost for one product. From this project, the cost is reducing up to 48% which is from RM0.31 to RM 0.15 per product. This is proved by design efficiency (DE) obtained after redesign is 40.1% from 19.5% design efficiency of original design.

So, the estimation of total product assembled in one hour for both designs are calculated in table 4.11.

Table 4.11: Total of product assembled in 1 hour.

Original Design	**New Design**
Total Assembly Time = 261.45 Sec	Total Assembly Time = 127.04 Sec
= 4.3575 min	= 2.1173 min
1 Hour = 60 min,	1 Hour = 60 min,
So one hour produced =60/4.3575 min	So one hour produced =60/2.1173 min
= 13 product/hr	= 28 product/hr
Labor Rate = RM4.375/hr	Labor Rate = RM4.375/hr
Labor Cost per product = 4.375/ 13	Labor Cost per product = 4.375/ 28
= RM 0.3365	= RM 0.1563

From table 4.11, it can be concluded that the productivity of manufactured is increased after redesign the kitchen scale. It is because in one hour, the manufactured can assemble 28 products after redesign compared than original design, which only manage to assemble 13 products per hour. The labor rate of production assumed same for both design, which is RM4.375 per hour. The calculated labor costs per product are also proved to be similar like the estimated cost before which are RM 0.31 per new design product and RM 0.15 per old design product.

4.6 SUMMARY

This chapter discussed the result of the project which based on applying Boothroyd-Dewhurst DFA method in optimizing kitchen scale design. The evaluation results show the design efficiency is increasing 19.5% from 19.5% to new DE, 40.1%, after number of parts were eliminated from 35 parts to 17 parts.

CHAPTER 5

EXTENSIVE ANALYSIS ON PART DESIGN

5.1 INTRODUCTION

This chapter provides a review of part analysis on the plastics injection molding cycle time by using MoldFlow Plastics Insight (MPI) Software. Starting from the brief discussion on the assumption that had been made in the simulation, the analysis is then proceeds with the material selection process for the new part design.

Next, the analysis proceeds with the design comparison focusing on injection cycle time onto the old and new kitchen scale cover design and production target output based on one hour production period. The analysis result is stated in order to support the design of new part that had been developed to replace the old cover design to be less in manufacturing time consumption. Thus, the combination of front cover and scale of kitchen scale are being analyzed to obtain some data.

5.2 ASSUMPTIONS

There are a few assumptions that have been made before performing the MPI software simulation analysis for the kitchen scale part. They are:

i. The selections of material are to be chosen from 4 types of commonly selected thermoplastics including ABS, PP, PPO and PC.
ii. Cycle time is in seconds and one cycle time of injection molding process are includes of close and open mold time, fill time, pack and hold time, and part cooling time.
iii. Close and open mold times are defined by default setting of MPI software that both are 3 seconds and 2 seconds.
iv. Part design models used in the simulation are significance for the shape attributes only without considering any details like the shape accuracy, locations of gates, and defects occurred during the injection process.
v. The molding machine process parameters (such as temperature and pressure) are same in both design simulations.

5.3 MATERIAL SELECTION

The cover parts of kitchen scale are analyzed using the ABS material in which the trade name is ABS 780 from Kumho Chemical Incorporated. This type of material is set in the MPI software analysis and has amorphous material structure. The ABS is selected because of it is commonly used, lower cost (Figure 5.1), and easy to find in the market.

The ABS resins have a well balanced set of properties for molding close dimension control articles with an outstanding surface finishing, good impact resistance (Figure 5.2), and metal plating characteristics. ABS resins belong to a very versatile family and thermo plastic polymers.

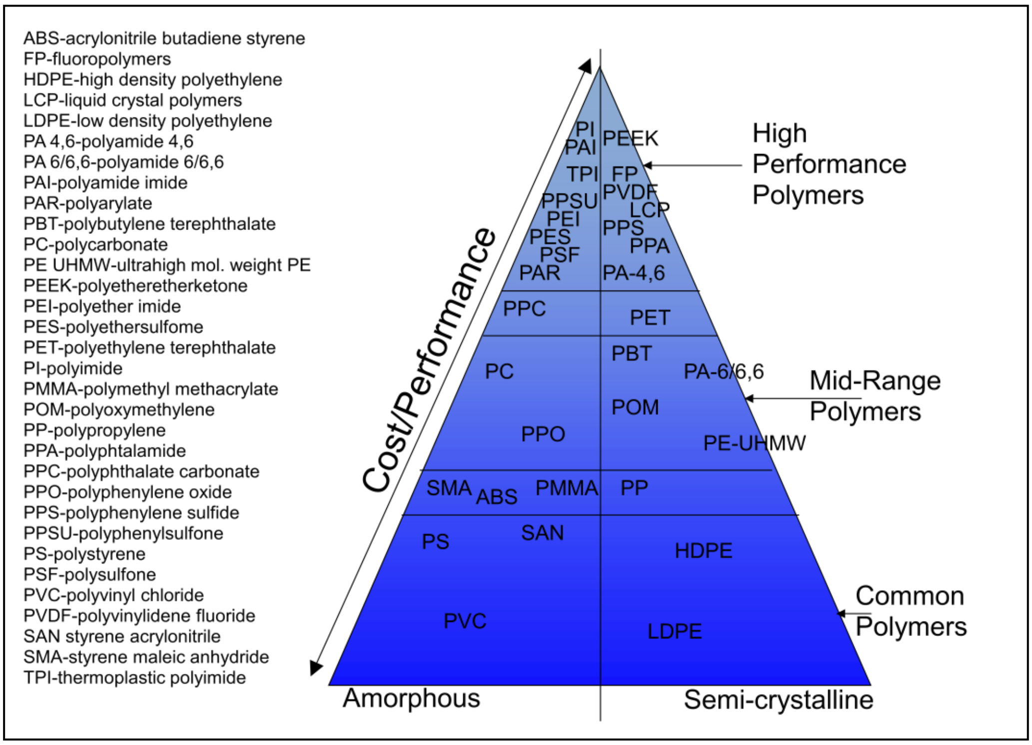


Figure 5.1: Thermoplastics Cost/Performance Diagram.

Source: (Malloy R.A, 1994)

Impact Toughness Guide

(Increasing Toughness ↑)

Resin	Izod (ft-lb)	Reasoning
Polyurethane (x-link)	25	High elongation and strength
Polycarbonate	16	High strength
SMC	7	Reinforced and toughened
ABS	6	Toughened with rubber
HDPE	3	High elongation, flexible
Acetal	2	Can be toughened
Nylon 6/6	2	Can be toughened
PET	1	Can be alloyed
PP	1	Some crystallinity
LDPE	1	Low strength
Polystyrene	0.3	Pendent group
Acrylic	0.3	Short link, large pendent group
Phenolic, w/fiberglass	0.3	Crosslinked
Epoxy, unreinforced	0.2	Crosslinked
Crosslinked polyester	0.2	Crosslinked

Figure 5.2: Thermoplastics Impact/Toughness Guide.

Source: (Malloy R.A, 1994)

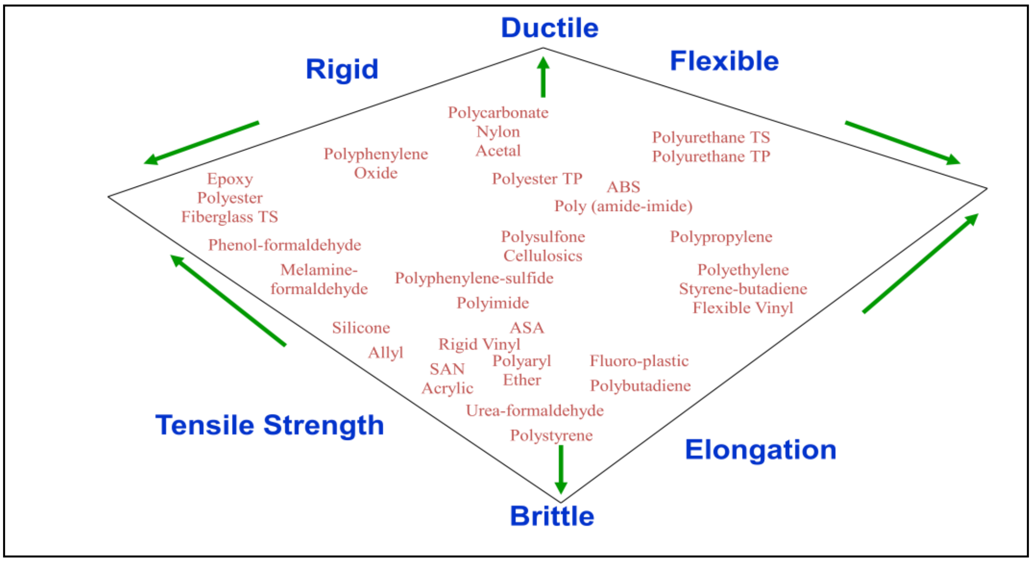


Figure 5.3: Thermoplastics Ductile/Brittle Guide.

Source: (Malloy R.A, 1994)

Refer to Table 5.1 to see the general properties of ABS. Acrylonitrile contributes heat resistance, chemical resistance, and surface hardness to the system. The butadiene contributes toughness and impact resistance, while the styrene component contributes processibility, rigidity, and strength.

Table 5.1: General properties of ABS.

General Properties Of ABS	Values
Specific Gravity	1.05
Tensile modulus @ 73 ˚F (Mpsi)	0.3
Tensile strength @ yield (Kpsi)	5.0
Notch Izod Impact @ 73 ˚F (ft-lb/in)	2.50-12.0
Thermal Limits Service temp. (˚F)	167-185
Shrinkage (%)	0.4-0.7
T_g (˚F)	185-240
Vicat Point (˚F)	237
Process temp. (˚F)	410-518
Mold temp. (˚F)	122-176
Drying temp. (˚F)	176-185
Drying time (h)	2.0-4.0

Source: MoldFlow Plastics Insight version 5.0

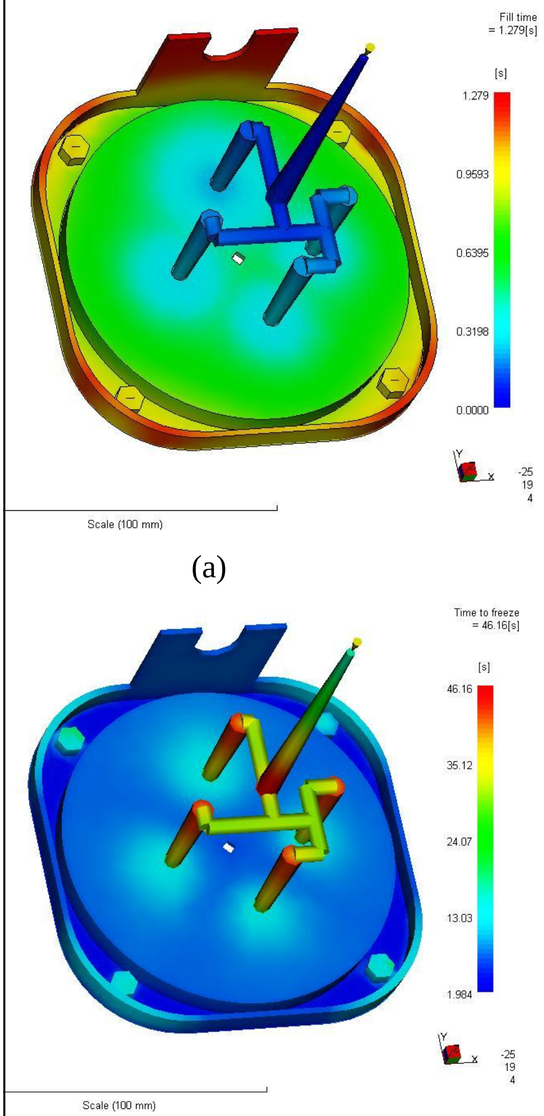
For this simulation analysis, 4 types of different thermoplastics are take into consideration. There are Acrylonitrile-Butadiene-Styrene (ABS), Polypropylene (PP), Polyphenylene Oxide (PPO), and Polycarbonate (PC). To select the best thermoplastics material, the matrix selection in the Table 5.2 is used with weighing factor of Toughness, Surface finished, and cost.

Table 5.2: Material Selection Matrix.

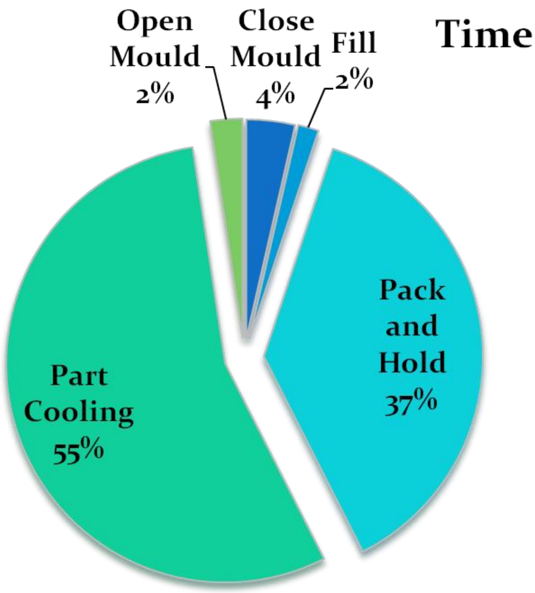
Resins	**Properties**						
	Property 1: Toughness		**Property 2: Cost**		**Property 3: Surface Finish**		
	Value/ Rank	**WF= 4 Score**	**Value/ Rank**	**WF= 5 Score**	**Value/ Rank**	**WF= 2 Score**	**Total Score**
PC	1	4	1	5	1	2	10
ABS	**3**	**12**	**4**	**20**	**1**	**2**	**34**
PPO	2	8	2	10	1	2	20
PP	4	16	3	15	1	2	33

5.4 MPI SIMULATION ANALYSIS

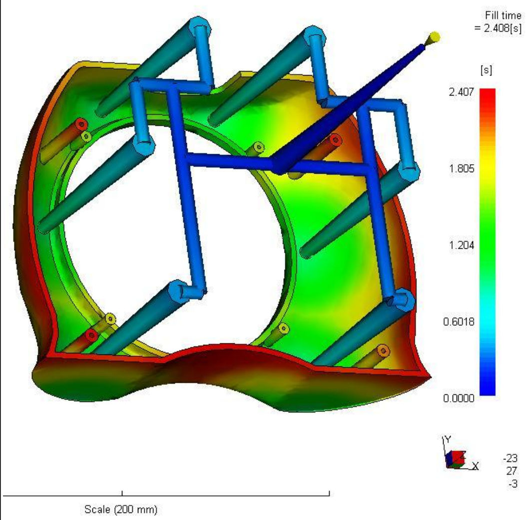
MPI software are used in simulate the plastics injection flow into the part cavity. By using this simulation, the filling time can be estimated. Figure 5.4 below are the result from the analysis on scale and front cover (original part design). While, Figure 5.5 are the result from the analysis on integral design of scale and front cover (new design).



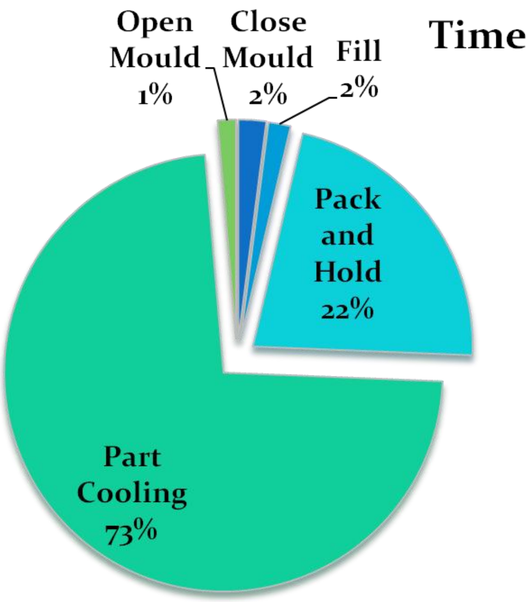
(a) (b)

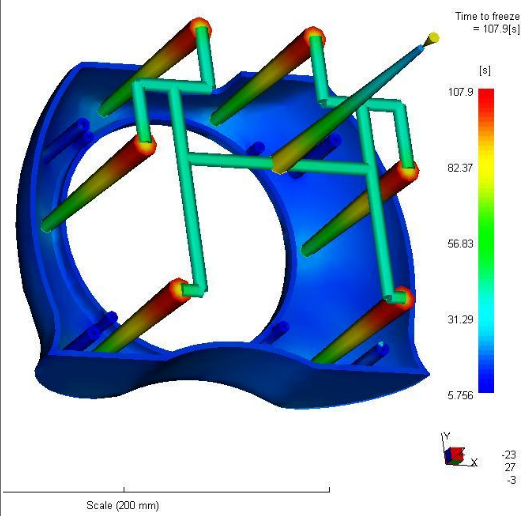


Cycle Process	Time (s)
Close Mould	3
Fill	1.297
Pack and Hold	31.37
Part Cooling	46.165
Open Mould	2



(c)



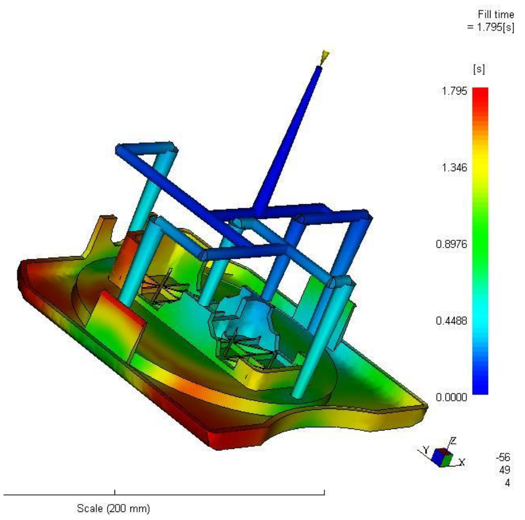


Cycle Process	Time (s)
Close Mould	3
Fill	2.408
Pack and Hold	32.47
Part Cooling	107.9
Open Mould	2

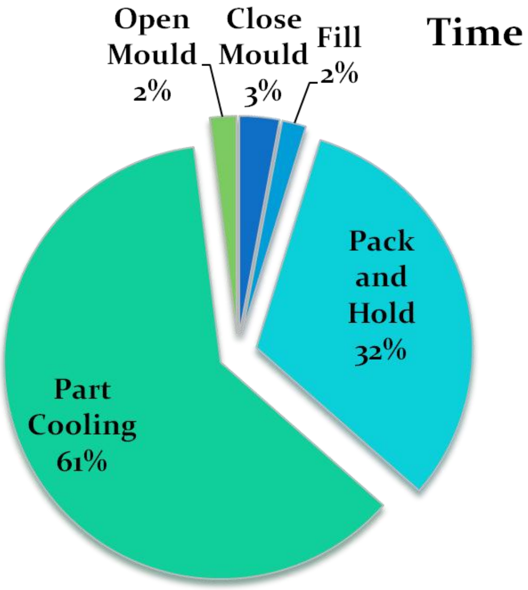
(d)

Figure 5.4: Estimated (a) filling time for original scale design is 1.279 second and (b) cooling time is 46.16 second while (c) filling time for original front cover design is 2.408 second and its (d) cooling time is 107.9 second.

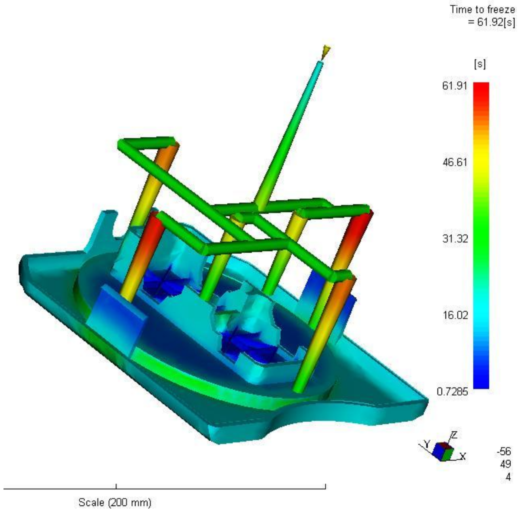
Source: MoldFlow Plastics Insight version 5.0



(a)



Cycle Process	Time (s)
Close Mould	3
Fill	1.7953
Pack and Hold	31.89
Part Cooling	61.92
Open Mould	2



(b)

Figure 5.5: Estimated (a) filling time for new integral design is 1.795 second and (b) cooling time is 61.92 second.

Source: MoldFlow Plastics Insight version 5.0

5.5 MPI SIMULATION COMPARISON

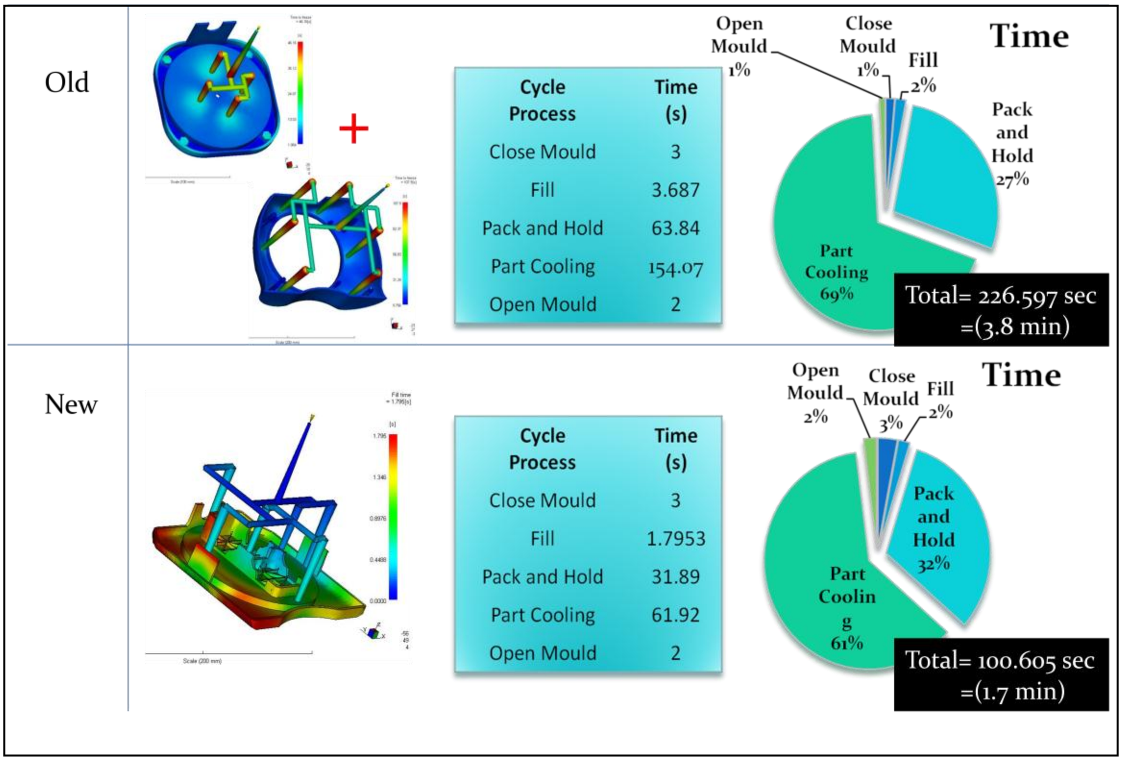


Figure 5.6: Comparison between the total estimated cycle time for both old and new design.

Source: MoldFlow Plastics Insight version 5.0

5.6 SUMMARY

This chapter discussed the result of the plastics injection molding cycle time. From the comparison of cycle time between old parts and new integral parts, it proved that the manufacture time are shorten by combining two or more parts together into a integral design. From the combination of scale and front cover, about two minute of manufacturing time are saved from 3.8 minute of old design to 1.7 minute of new integral design.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Projek Sarjana Muda (PSM) showed how to prepare the introduction of the case study, literature review of the project, methodology and evaluation or analysis. Conformation of the case study title is very important before starting the project. This includes identifying the problem statement, objectives, scope of the study, and the outline of the study that has been planned.

Seeking information in order to starting the study is very important. Required information like journal, article, and books of product design and manufacturing can be found either in library or internet.

Literature review are one of the chapter include in this study. It reviews the concept of product design, cost estimation, and technique and methods used to evaluate current product for improvement. Here, the definition of concurrent engineering, Design for X (DFX), Information Content, and how costs are related to number of parts are reviewed.

Performing the case study need one to know and plan the methodology of the project. Here, the frameworks of methodology are referred in general. These include the steps of performing evaluation of current product for determine chances for improvement. Finally product evaluation stages are really important where this stage is the way for one to obtain data and suggestion for parts elimination or redesign. Thus, that concludes how important strong concepts of product Design for Assembly (DFA) are.

Parts Evaluation is very important to obtain the information contents to performing a modeling and simulation. Before collecting the data, parts are being categorized into several sub-assemblies for better understanding on how each part function towards each other. Right understandings are leading towards accurate analysis on handling and insertion of the related parts thus can estimate the right assembly time.

Simulation of plastics injection molding on new design are done for validation. The new design shall consume less manufacturing time and this could be proven through the result obtain from the simulation. Accurate dimensional CAD model are important to get the accurate estimated cycle time.

6.2 RECOMMENDATION

Since the evaluation and new design are only based on Design for Assembly (DFA), thus many importance factors that also would affect the cost of product are neglect. As discussed in chapter 2, costs are affected by many factors, directly and indirectly.

To get the best suggestion of redesigning a product should also consider the manufacturing process required to produce the new design parts. This is by considering including research in Design for Manufacturing (DFM) and concurrent cost software by Boothroyd-Dewhurst Inc.

By using this method, a proper way towards material selection of the new design product could be perform. This should be more accurate if one to know the exact cost needed in redesign a new product.

Taking this project as example, recommendation are also suggest in detailed study about injection molding process and sheet metal forming as most of the kitchen scale product are made by plastics and sheet metals. More analysis in determining injection molding cycle time can be performing by using MoldFlow Plastics Insight (MPI) software, but this analysis needs more accurate CAD drawing to do the analysis.

Other extensive analysis like stress-strain distribution and Failure Mode Analysis by using Computer Aided Engineering (CAE) software like FEMPRO, ALGOR, and advance software like NASTRAN and PATRAN depending of the product being evaluated also suggested.

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APPENDICES

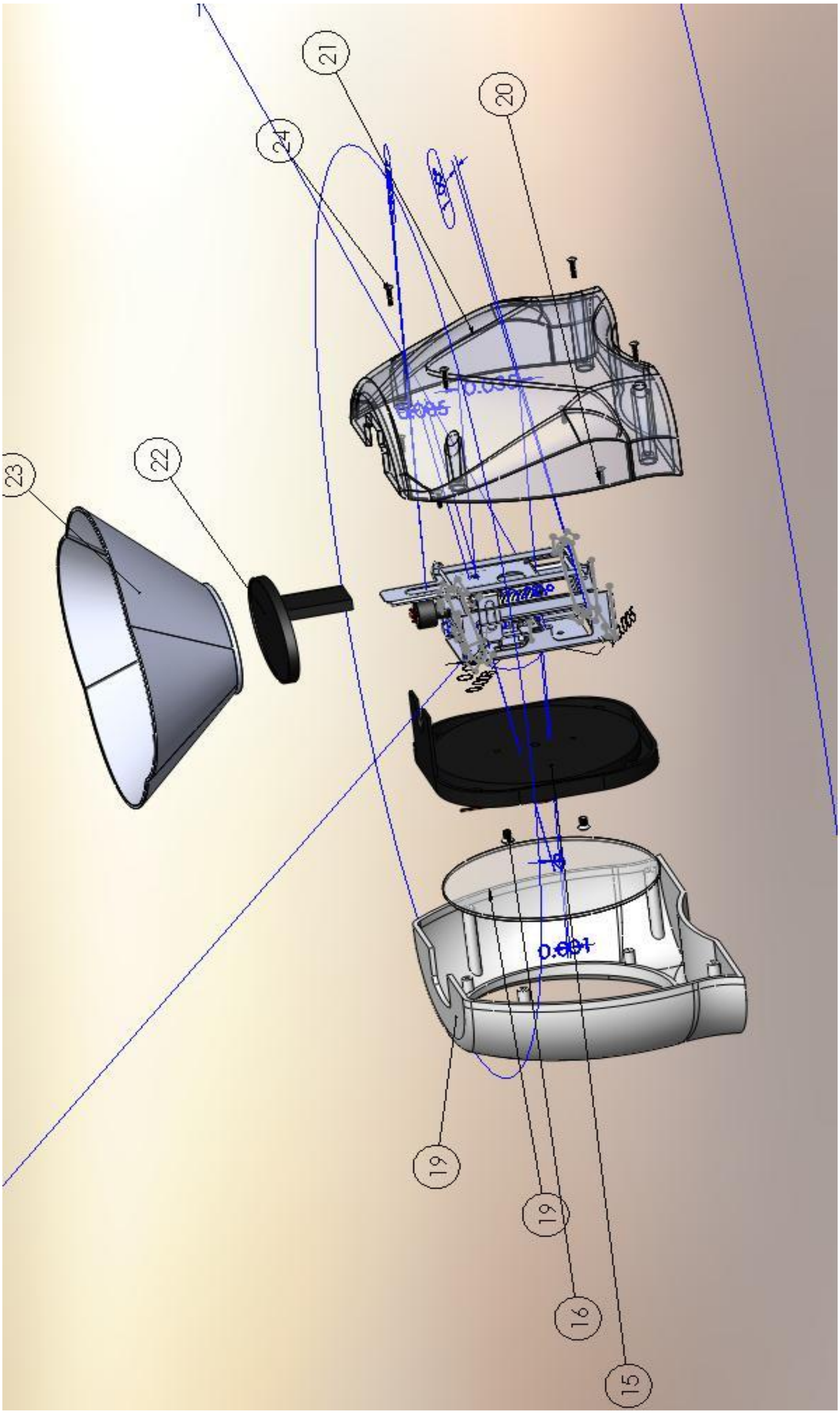
i. *Flow Chart for Final Year Project 1 & 2*

ii. *Gantt Chart for Final Year Project 1 & 2*

iii. *Exploded View of Kitchen Scale Assembly*

iv. *Exploded View of Weight Mechanism Assembly*

Exploded View of Kitchen Scale Assembly



Exploded View of Kitchen Scale Assembly (Weight mechanism)