

Syukur Alhamdulillah to Allah S.W.T for giving me the spirit to complete this project. Deepest thanks to my mum Saripah Bt Bakri and my family. And not to forget, my beloved wife Maya Sofa Bt Ismail and my naughty kids; Muhammad Haikal Syahmi, Muhammad Haziq Najmi, and Nurin Maya Hawani.

I love you all.

**PART COMBINATION OF DESIGN FOR ASSEMBLY
USING EFFORT FLOW ANALYSIS (EFA)**

MOHD RUZI BIN HJ HARUN

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**Faculty of Mechanical Engineering
Universiti Teknologi Malaysia**

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ABSTRACT

Design For assembly (DFA) is an important tool used to review the design for product evolution. It is aimed at reducing number of parts to be assembled in a product. This may lead to reduction of part cost achieved through reduction of assembly time and material used. The main focus in this project is to study and analyze the use of Effort Flow Analysis (EFA) method in reduction of parts of product. EFA is a method that combines more than one part by taking into consideration various degrees of relative motion of the parts in product. EFA uses an effort flow diagram that indicates flow of effort between each part with respect to its relative motion. The guidelines for EFA are based on four types of relative motion link that are N, C, R, and I-Links. The details of each link are covered in this thesis. To visualize the application of EFA for part reduction in product assembly, one particular product, which is Iron Water Nozzle, is presented. The old design was reviewed and redesign effort is done for the product evolution. As a result, new design of water nozzle is achievable with fewer parts and cost efficient. In future, it proposed to develop a software application by employing knowledge based approach into the software system.

ABSTRAK

Reka bentuk untuk Pemasangan “*Design For Assembly*” (DFA) adalah merupakan satu alat yang penting yang digunakan untuk penambahbaikan reka bentuk bagi peningkatan produk. Matlamatnya adalah untuk mengurangkan bilangan komponen yang perlu dipasang di dalam produk. Pengurangan komponen ini dapat dicapai melalui pengurangan masa pemasangan dan bahan yang digunakan. Fokus utama projek ini adalah untuk mengkaji dan menganalisa penggunaan kaedah Analisa Aliran Usaha “*Effort Flow Analisis*” (EFA) di dalam pengurangan komponen di dalam produk. EFA ialah satu kaedah yang dapat mencantumkan lebih daripada satu komponen di dalam produk dengan mengambilkira berbagai darjah pergerakan relatif antara bahagian. EFA menggunakan Rajah Aliran Usaha “*Effort Flow Diagram*” bagi menunjukkan aliran usaha yang mengalir di antara setiap bahagian. Garis panduan EFA ini adalah bergantung kepada empat jenis hubungan pergerakan relatif iaitu N, C, R dan I. Setiap jenis hubungan pergerakan relatif ini ada terkandung di dalam kajian tesis ini. Bagi memperlihatkan penggunaan EFA untuk pengurangan komponen di dalam pemasangan produk, satu produk dipilih iaitu Muncung Air Keluli “*Iron Water Nozzle*” telah dibentangkan. Reka bentuk asal diulangkaji dan usaha reka bentuk semula dilakukan untuk peningkatan produk tersebut. Hasilnya, satu reka bentuk muncung air yang baru telah dicapai dengan kurang komponen dan kos yang efektif. Pada masa depan, kaedah ini dapat dibangunkan dengan sistem analisis berkomputer dengan memuatkan asas pengetahuan ke dalam sistem perisian tersebut.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Design For Assembly (DFA) is an approach to designing products with ease of assembly in mind. By making things easier to assemble, one also makes the assembly process faster and more cost-efficient. This result in higher profit to the manufacturer, which is used to assess one of the performances of a product development effort, is confirmed by Ulrich, 2004 (17). Besides it can also add value for the customer. From the definition itself, design process is an iterative, complex, and decision making engineering activity, which tremendously requires the design team to be creative, innovative, and productive. This chapter is about the introduction to the problem of one whom designing products with or without a DFA methodology. Reflects to the problem, there are the objectives and scopes targeted. To make things well organize, a methodology of study is designed in order to achieve the significant of the finding.

1.2 Problem Statement

In the era of globalization, competitive-based advantage has become increasingly important for the product successfulness in the market place. To remain competitive in capturing market demand, companies are competing with each others based on the three factors that are price of product, quality of product, and product delivery time. According to Dr M. Nawaz Sharif (20) study, “to survive in the globalization business, evolving from factor cost based comparative advantage, i.e. labor, raw material, etc. to technology advantage value based competitive advantage, i.e. technology, is a must”.

On the other hand, Hamid Noori (10) has reported “rapid changes in market trend and technology now are the main force that brings shorter product life cycle”. It has been accepted that over 70% of a product’s development cycle is committed during the product design stage by Boothroyd et al, 1989 (3). The parts associated in a product structure largely determine the product lifecycle cost and the time to market. Since the total number of parts in a product is a key indicator of product assembly quality, product structure simplification is one of important characteristic in DFA. Therefore, early cost estimates enable designer to search for design configurations that minimize cost while optimizing functionality, quality, and reliability in products.

Manufacturing costs will increase relatively, primary because of assembly, and market share will be lost. It is confirmed by Jan Chal, 1994 (1) “typically 50% of the manufacturing cost is a result of the cost of assembly”. This is because to manufacture each part requires material, labor and power, ultimately associate with time and money It also learnt that assembly strategy is not a top agenda of discussion while determine the manufacturing strategy in the past few decades.

It is believed that the ability to mass manufacture piece parts, which are interchangeable being able to show the economic benefits of improved assembly efficiency. Besides, everybody thinks people are good at assembly. Because of their instinctive ability to put together is often not even considered to be a discipline and therefore no need guidelines for assembly.

Basically, all DFA methodologies mentioned earlier addressing the aid of parts count reduction either in an existing product design or product conceptual design. Each of these methods had set their own guidelines to be followed. According to Boothroyd Dewhurst DFMA (4) method, they had set three criteria in order to give guidance to the designer in reducing part count by asking three questions:

1. Does the part move relative to another part
2. Are the material properties of the part necessary?
3. Does the part need to be separate entity for the sake of assembly?

If a part is justified by any one of these reasons, it is deemed to be a necessary part and thus, it thought to be un-combinable unless significant redesign effort has been done to overcome these reasons. The redesign effort actually requires a lot of time and money to be spent. It is learnt that the Boothroyd Dewhurst DFMA first guideline is too stringent and therefore, it is constrict for designer to be more creative and innovative for encouraging the product evolution. For Lucas DFA (4) method, the parts of the product is reviewed only for the function; parts are deemed to be essential to the product's function and parts are those not essential to the product's function. Clearly, those parts are deemed to be essential to the product's function are thought to be uncombinable. The only left for parts combination is the parts that are not essential to the product's function. A bit advantage of Lucas DFA method is that the function analysis is done at initial stage unlike Boothroyd Dewhurst method, which assumes a design is already available.

On the other hand, the Hitachi AEM method had kept pressure on designer to score 100%, which represent the perfect design efficiency. An overall design efficiency of 80% is acceptable. However, to achieve this score (>80%) required the designer and the rest of development team to push to the limit on redesign effort for every single part involved in the product until the acceptable score is achievable. Again, isn't this sound too stringent for a designing a product evolution? It can be observed that all current DFA methodologies require a lot of redesign effort but there is no systematic guidelines for part combination that having varying degrees of relative motion. Unlike Lucas DFA and Hitachi AEM, there is more on trial and error design practice but Boothroyd Dewhurst DFMA method is clear, those parts that experience relative motion are deemed un-combinable.

1.3 Objective of Project

The objective of this project is to analyze the use of Effort Flow Analysis (EFA) method for part count reduction through part combinations that having varying degrees of relative motion.

1.4 Scopes of Project

To make sure the project is in the right path, scopes of study are identified. The scopes of the study are:-

1. To study on the other DFA methodologies of manual assembly that aid in redesigning a product for piece count reduction.
2. To study exclusively the techniques of effort flow analysis (EFA)
3. To present an example of an existing product on how the application of EFA can be used to identify opportunities for part combination in the product assembly where relative motion exists between components.

1.5 Project Methodology

The methodology of study is shown in Figure 1.1.

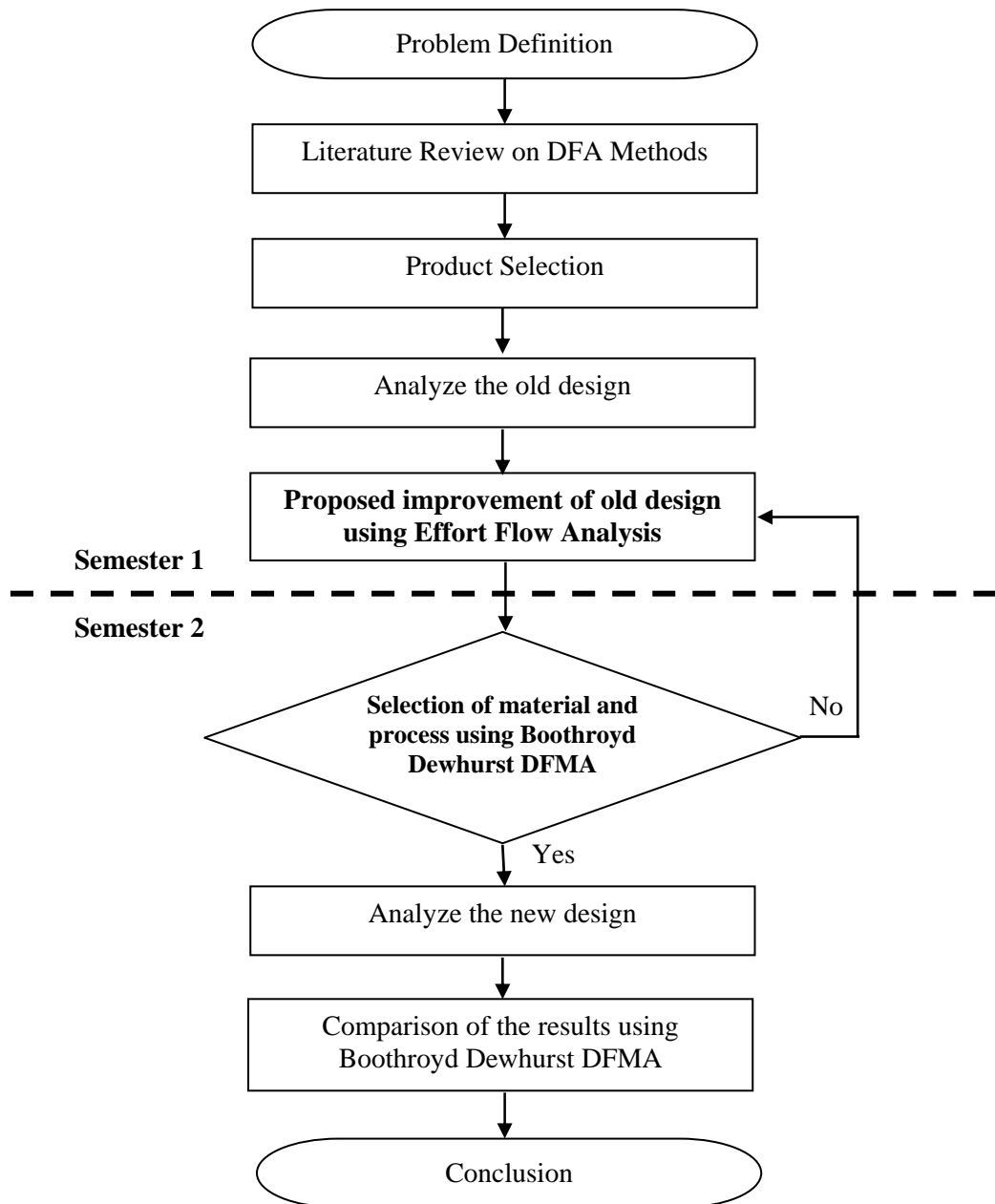


Figure 1.1: The project flowchart

The project will be accomplished in two continuous semesters. The milestones of project activities are shown in Gantt Chart in Appendix A1. In the first semester, the project starts with the problem definition arises with the current DFA methodologies that aid in redesigning a product for part combination. This matter also has been looking into the perspective of global issues currently debate among the technological practice. To investigate these problems, literature review on several DFA methodologies is done on; the Boothroyd Dewhurst DFMA Method, the Lucas DFA Evaluation Method, and the Hitachi Assemblability evaluation Method (AEM), and the Effort Flow Analysis (EFA) Method. However, the study of EFA will be discussed exclusively, which aligns with the scopes of study.

For the purpose of the project, an existing product design is selected that consists of varying degrees of relative motion exist in its product's part and thus, makes the product evolution more challenge. The product's mechanism, function of each part, and the weaknesses of the mechanism have been critiques in order to investigate for the possibility of part combination. To guide toward piece count reduction through part combination, effort flow analysis method is used. There are several guidelines need to be followed, which are referred to the relative motion characterization. This topic will be discussed in details explanation and an example of the existing product is demonstrated in step by step manner. At the end of the process, several new designs are been proposed as initial product evolution.

For the second consecutive semester selection of material and processes using Boothroyd Dewhurst DFMA method is applied. This is to ensure the new design can be manufactured in the most easiest and economical manner. Again, the new design then needs to be analyzed in order to ensure the new design maintains its original functionality while optimizes the quality. Finally, the new design is compared to the old design in terms of the percentage of part count reduction.

1.6 Significance of Findings

The application of DFA guidelines is known to lengthen the concept development time because a lot of time was spent during the redesign effort but somehow it helps to shorten the other stages of product development. During the concurrent development of a product's parts, the product time-to-market is determined by the development of the most complex part. The manufacturing costs will increase relatively, primary because of assembly, and ultimately market share will be lost. In the era of globalization, everything needs to be faster, cheaper and better.

Design decisions made during product configuration and detail design largely determine the choice of material, process, product quality, and recycling method etc., all of which contribute to the product lifecycle cost. Early cost estimates enable designers to search for design configurations that minimize cost objectives while optimizing other design specifications. The search by manufacturers for the combination of low cost, high quality, and reliability in products is now become an essential characteristics for product's success in today's highly competitive global market. Therefore, the reduction of the number of parts in a product is the best opportunity for reducing manufacturing costs. Less parts implies less purchases, inventory, handling, processing time, development time, equipment, engineering time, assembly difficulty, service inspection, testing, etc.

In general, it reduces the level of intensity of all activities related to the product during its entire life. A part that does not need to have relative motion with respect to other parts does not have to be made of a different material, or that would make the assembly of other parts extremely impossible, is an excellent target for elimination. None of the current DFA methodologies so far provides systematic guidelines for parts combination in such manner unlike the effort flow analysis method.

The effort flow analysis has brought new generation of DFA methodologies to much broader scope, which addressing part combinations that experience varying degrees of relative motion. The effort flow analysis offer part count reduction is based on the use of one piece structures and selection of manufacturing processes such as injection molding, castings, and powder metallurgy, etc.

1.7 Report Structure

This report is attempted to strike a balance between theory and practice through the emphasis of the DFA methods. The report consists of seven chapters. Chapter 1 is about introduction to the project. An overall picture of the project can understand within this chapter. Objectives and scopes are developed in reflects to the problem statement while the significant of the project is described at the end of chapter.

Chapter 2 is devoted to a literature review on DFA Methodologies. The DFA methodologies of Boothroyd Dewhurst DFMA, Lucas DFA, Hitachi AEM, and Effort Flow Analysis are overviewed. In this chapter, the application of Boothroyd Dewhurst DFMA is used to evaluate the performances of the existing product design and for selection of processes and materials for design for manufacture.

Chapter 3 covers the information requirements on analyzing the old product design. The need for information from existing design performance is an essential for product improvement. The study of the product mechanism and part critique has brought an idea for part combination.

In Chapter 4, Effort Flow Analysis (EFA), the theory of evaluation complete with example is demonstrated in step-by-step manner. The coverage is to highlight the categories of relative motion and the systematic guidelines of the method for successful part combination.

Chapter 5 is discusses about the Design Concept Selection. Outcome from the EFA, there are several design concepts under consideration for further development. There is methodology called Pugh concept selection used to justify the best design concept selection.

Once it has been agreed to develop an idea for a product concept, the next step is to develop its design for ease of manufacture. This issue is discussed in chapter 6, Design for Manufacture (DFM). The methodology of Boothroyd Dewhurst DFMA is established for processes and materials selection.

Chapter 7 is about Discussion of project results. This report ends with Chapter 8 on Conclusions and Future Recommendations, is all about the overall progress of the study.

1.8 Summary

The project is aimed to use Effort Flow Analysis as the solution for part count reduction through part combination that having varying degrees of relative motion. By agreeing that, there is no such combination for parts experience relative motion, effort flow analysis is look to be the most effective tool for such purposes. To make things well organize, a methodology of study is designed in order to make sure the project is in the right path until the end of the final project.