PRODUCT DESIGN OF CAN OPENER BY USING EFFORT FLOW ANALYSIS APPROACH

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ABSTRACT

In this project, Effort Flow Analysis has been carried out on can opener. The can opener available in market are usually manufactured in many parts that is including manufacturing cost and assembly time have been wasted, this factor create opportunity the product evolution of can opener for engineer to invent simple can opener with minimized parts. The evolution of can opener in a new proposed design creates an opportunity to manufacturing of can opener with low assembly cost and labor time saving which is very important to industry nowadays. The new proposed design is functional and very user friendly for customer. Before the Effort Flow Analysis has been done, preliminary finding of can opener parts must be implemented to determine the goal of product evolution. After the Effort Flow Analysis has been done, brainstorming on modeling is carried out, using the result of analysis as guidance. The proposed design will be compare with original design by using Design for Assembly tool, Boothroyd and Dewhurst method, to determine the assembly cost and labor time. The proposed design will refine into fabrication prototype to compromise with the manufacturing process. The prototype will be fabricated with Rapid Prototyping machine which is very suitable for prototyping products. From the analysis and design, the results of this project will be reported.

ABSTRAK

Dalam projek ini, *Effort Flow Analysis* akan dilaksanakan ke atas pembuka tin. Pembuka tin yang sedia ada di pasaran lazimnya dibuat dalam komponen yang banyak dimana kos pembuatan dan masa pemasangan terbazir, dimana faktor ini telah menyebabkan lahirnya evolusi pembuka tin untuk jurutera mereka pembuka tin yang minimum komponen. Evolusi pembuka tin dalam cadangan rekabentuk memberi peluang kepada industri pembuatan pembuka tin dalam kos pembuatan yang rendah dan penjimatan masa pekerja yang penting ini. Cadangan rekabentuk pembuka tin ini dapat berfungsi dan sesuai untuk pengguna. Sebelum *Effort Flow Analysis* dilaksanakan, pencarian maklumat tentang pembuka tin mesti dilakukan untuk menentukan tujuan evolusi produk tersebut. Selepas *Effort Flow Analysis* dilaksanakan, rekabentuk akan diilhamkan berpandukan keputusan analisa tadi. Cadangan rekabentuk pembuka tin akan dibandingkan dengan pembuka tin yang asal dengan menggunakan perisian *Design for Assembly* iatu *Boothroyd* dan *Dewhurst* untuk menentukan kos pemasangan dan masa pekerja. Cadangan rekabentuk akan difabrikasikan dalam bentuk prototaip degan cara pembuatan. Prototaip ini akan dibuat dengan menggunakan mesin *Rapid Prototyping* yang bersesuaian. Daripada analisa dan rekabentuk, projek ini akan direkodkan.

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LIST OF SYMBOLS

C - Link	relative motion between the non-interfacial regions of components
DFA	Design for Assembly
DOF	degree of freedom
I - Link	relative motion at the interfaces only
N – Link	no relative motion between components
O^1	N - Link
O^2	C - Link
O^N	R - Link
R – Link	relative motion at the interface and between other regions

CHAPTER 1

INTRODUCTION

1.1 Project Background

Nowadays, manufacturing companies have invested a great deal of effort and resources into new manufacturing techniques. Assembly and manufacturing has drawn the attention, as the potential to improve product assembly time and associated profit margin have help DFA (Design for Assembly) into business. After Boothroyd and his colleagues invented their product design for assembly manual in 1982, many other research of DFA have contributed to this field.

As all known, traditional can opener can be fuss, where it leaves sharp edges on the can lid and too much forces is needed to operate can opener. Sometimes, it is painful to have big can opener for a small hand and heavy than mobile phone. Manufacturers on the other hand have to take a more time to manufacture the parts of can opener where as some parts can be eliminate to save cost and production time.

Effort Flow Analysis represents the transfer of effort through product components and reduction of devices part. After all the approach analysis has been done, Boothroyd-Dewhurst DFA plays an important part to determine the effectiveness of new improvement of can opener.

1.2 Objectives

1. To improve design of can opener using Effort Flow Analysis by reduction parts
2. To compare current design with propose design in terms of using Boothroyd-Dewhurst DFA

1.3 Scope

1. Literature review of Effort Flow Analysis Approach
2. Gather information of can opener
   2.1. Modeling
   2.2. Analysis
   2.3. Parts information
   2.4. Dimension
   2.5. Pre Analysis (DFA before Effort Flow Analysis)
3. Develop a framework and Gantt chart
4. Analysis the can opener product using Effort Flow Analysis
5. Compare the best alternative with current design using Boothroyd-Dewhurst DFA
6. Fabrication prototype for the new design

1.4 Expected Outcome

1. Improve design and parts reduction of can opener
2. Can opener with reducing assembly time and cost

1.5 Project Flow Chart

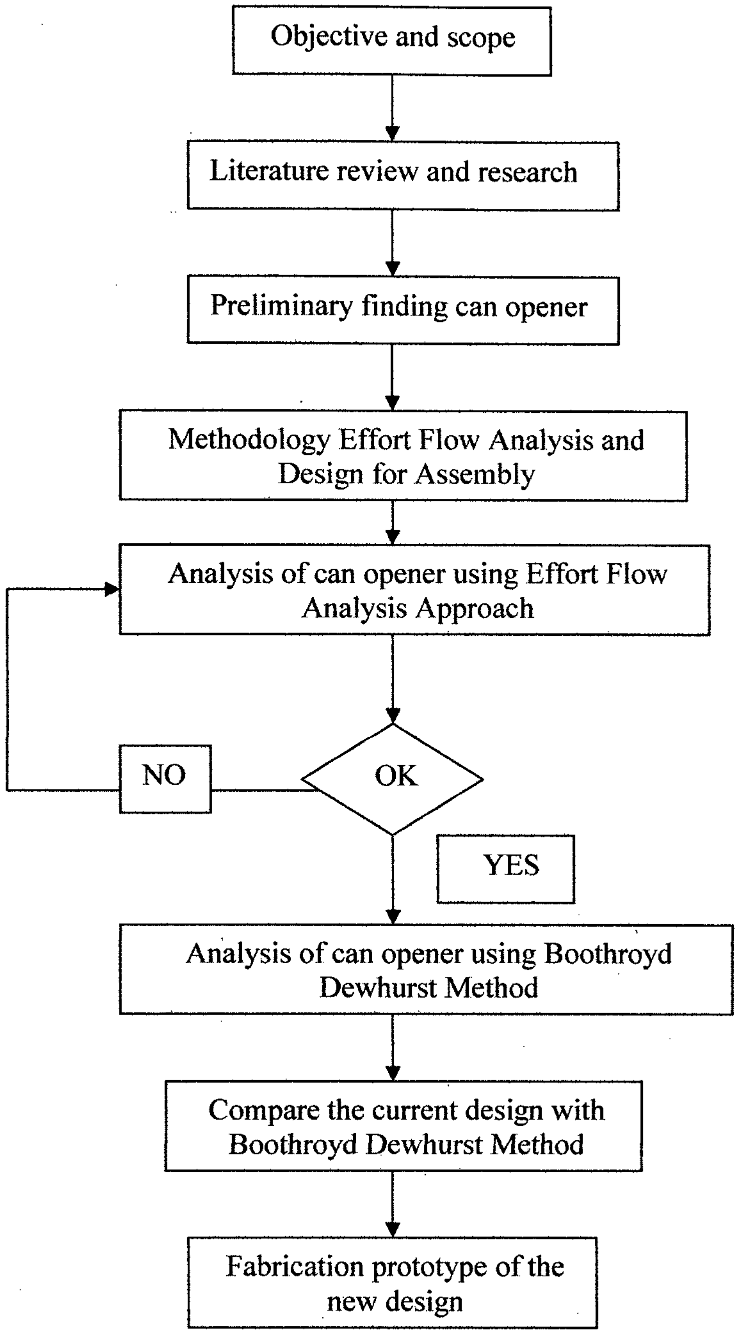

Figure 1.1: Project flow chart

The Figure 1.1 shows the separation of work and study step by step accordingly. The Projeck Sarjana Muda 1 will cover only until methodology Effort Flow Analysis and Design for Assembly because of complexity of designing the task. The complete analysis and fabrication will commence during Projeck Sarjana Muda 2.

1.6 Summary

This chapter discuss on a project background where every problem statement and introduction has been underline. Objectives, scopes and expected outcome also been highlighted to comprehend on this project more vividly. Project flow chart has been drafted to assist in making this project working smoothly.

CHAPTER 2

LITERATURE REVIEW

2.1 Effort Flow Analysis

Effort Flow Analysis is a systematic tool that guide designer toward piece count reduction through part combination and relative motion (Greer and Wood, 2004). This analysis enhances the evolution in products from mechanical energy domain by identifying component combination opportunities that are achieve through using rigid body or compliant mechanism. The technique is originally from force flow analysis which basically the terminology had change to effort flow analysis as the word effort implies a broader class of physical phenomenon than the force itself. Effort Flow Analysis uses an effort flow diagram to represent the transfer of effort through product components.

The effort flow diagram is a semantic network composed of nodes and links that are described using the fundamentals of graph theory (Greer and Wood, 2004). The nodes of the diagram represent the components of the product, while the links represent the interfaces between the components. The main benefits of modeling a product using effort flow diagram are to determine the possible component combination opportunities (Greer and Wood, 2004).

These opportunities are obvious when the relative motion at the interfaces between connected components is characterized. Labels are added to the links to identify relative motion characteristics across the link. The links are defined as follows:

i. 'N - Link': no relative motion between components
ii. 'R - Link': relative motion at the interface and between other regions.
iii. 'C - Link': relative motion between the non-interfacial regions of components
iv. 'I - Link': relative motion at the interfaces only

Table 2.1: Link type and relative motion (Greer and Wood, 2004)

Link Type	Relative Motion	
	Between Interfaces	Between Component
N- Link	0	0
C- Link	0	1
R- Link	1	1
I- Link	1	0

These groups of components are the starting point for further investigation of component combination (Table 2.1). Like power flow analysis and functional modeling, effort flow analysis in the mechanical domain focuses on flow or effort (force or torque) through the product (Erdman, AG, Sandor, GN and Kota, 2001). Relative motion identifies locations within the product model where something interesting is happening. Relative motion represents an easily identifiable characteristic of the interaction between the components of the product, and provides a convenient classification scheme for components and interfaces within the mechanical domain (Greer and Wood, 2004).

2.1.1 The non-relative motion link 'N - Link' (O^1)

N-Links are first order (O^1) candidates for combination. An N-Link represents interaction between components where there is no relative motion between components and no relative motion at the interfaces. These groups of parts move as a rigid body, and represent the simplest opportunities for component combination. The interface between a rivet and the two pieces of sheet metal that it fastens together is an example on an N-Link. Application of the N-Link guideline provides the highest likelihood of success with the least impact on product function and mechanical properties. This is true because, by definition, no relative motion can exist across the N-Link. Hence, the N-Link guideline is applied first before further effort flow analysis is carried out (Greer and Wood, 2004).

2.1.2 The component relative motion link 'C - Link' (O^2)

Groups of components connected by C-Links are second-order (O^2) candidates for combination. A C-Link represents interaction between components where there is relative motion between the non-interfacial regions but no relative motion at the interfaces. This interaction implies deformation of one or more components as force is transmitted. The interface between a coil spring and the spring perch, or perches, on which it rests is an example of a C-Link (Greer and Wood, 2004). C-Links may represent either elastic or plastic behavior in the interfacing components. Groups of components connected by C-Links are classified as second-order likelihood for successful component combination when compared to the more fundamental approach of the N-Link combination. Component combination has the potential to impact these deformation based product function, and hence the likelihood of producing a successful combination using compliant components is high, as compliance issued in the original design. However, satisfaction of the three necessary functional conditions is more difficult to ensure simply due to the presence of relative motion.

2.1.3 The relative motion link 'R - Link' (O^N, N^{th} Order)

Groups of components connected by R-Links are Nth-order, three or higher, candidates for combination. An R-Link represents general relative motion occurring both at the interface and between the extents of the component as force is transmitted. The hypothesis that R-Links are 'combinable' only through significant redesign effort is modified here to reflect the fact that the level of effort required to achieve component combination across some R-Links is not as significant as originally thought. R-Links take many forms to include: kinematics joints of all kinds, sliding contact in slots and guides, gears, and bearings. R-Links may also represent the interface between a compliant member and a support member if that interface is not fixed. Groups of components connected by R-Links are classified as Nth-order, three or higher, candidates because they represent the least likelihood for successful component combination when compared to the N-Link and C-Link combinations (Greer and Wood, 2004).

2.1.4 The interface relative motion link 'I – Link'

An I-Link represents relative motion at the interfaces only. No relative motion exists within the extents, i.e. non-interfacial regions, of the components. While clearly a member of the basis set, this link has not appeared in any of the products evaluated in research, either conceptually or within empirical studies of products. For this reason, further discussion of the I-Link will be set-aside (Greer and Wood, 2004).

2.1.5 Solid mechanics criteria for successful component combination

Any redesigned must satisfy the original product functions. In addition the fundamentals of physical laws must be abided. The 3 solid-mechanics laws that form basics for the fundamental functional criteria are given as follow:

1. Strain- displacement
2. Stress- strain law(material constitutive relationship)
3. Equation of equilibrium (force or stress)

The necessary functional conditions proposed for component combination areas follows:

1. Degree-of-freedom condition: the original degree-of-freedom based functions must be maintained
2. Energy transmission condition: the material of the combined component must satisfy the energy transmission functions required for the product.
3. Actuation force condition: the actuation force of the resulting rigid or compliant mechanism must be within the reasonable and achievable bounds of the actuating component.

The degrees-of-freedom condition is based on the premise that if motion is provided in the original components, the motion-based function of those components must be preserved in there designed component. For mechanisms, the motion has two fundamental requirements, the first is path generation, and the second is end-point positioning (Erdman, AG, Sandor, GN and Kota, 2001).

Based on this model, efforts will flow through the material of combined components derived from effort flow analysis, and the material strength of these combined components must be sufficient to provide the 'transmit energy' function (Wood and Otto, 1998). This strength criterion necessitates invocation and satisfaction of the stress–strain law.

The actuation force condition is a bounding relationship where the force has a minimum for sensitivity reasons and a maximum for achievability reasons (Greer and Wood, 2004). Equilibrium and strain displacement laws are again vital.

2.1.6 Relative motion guideline

If the interaction between two components can be represented by an N-Link, those components maybe combined directly. N-Linked components typically provide the following functions: transmit effort, allow DOF for assembly and material-based functions such as resist loads or transfer heat. Combination is contingent upon the satisfaction of the material and assembly/disassembly functions. Assuming these are satisfied, the primary performance function for the combined N- Link component is to transmit effort.

If the interaction between two components can be represented by a C-Link, those components can be combined directly into a compliant mechanism by making parametric changes to the geometry of the components involved (Greer and Wood, 2004). C-Linked components typically provide the following functions: transmit force, store/supply energy, allow DOF and material based functions such as secure solid and inhibit energy.

Combination is contingent upon satisfaction of the material and assembly/disassembly functions, as well as functional relationships to include the necessary deformation and or energy storage properties provided in the original product design. Assuming these are satisfied, the primary performance functions for the combined C-Link component is to allow DOF, transmit force, and store energy.

If the interaction between two components can be represented by a R-Link, those components can be combined directly into a compliant mechanism provided the original relative motion function can be provided through deformation of the combined components. R-Linked components typically provide the following functions: allow DOF and transmit force, and the primary material based function is to regulate friction (Greer and Wood, 2004).

Combination is contingent upon satisfaction of the material and assembly/disassembly functions, as well as functional relationships to include the necessary path generation and end point positioning properties provided in the original product design. Assuming these are satisfied, the primary performance functions for the combined R Link component is to allow DOF and to transmit force (Greer and Wood, 2004). A first cut at synthesis of the combined component is to fuse the components using their original material and geometry, then make parametric changes to refine the combination.

2.2 Designs for Assembly (DFA)

2.2.1 Boothroyd-Dewhurst DFA

Design for assembly (DFA) analyzes product designs to improve assembly ease and reduce assembly time (Boothroyd and Dewhurst, 1989). Often this is done through a reduction in part count and played an important role in reducing costs of manufacturing. 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. The majority of commercial DFA methodologies developed in the last 15 years are applicable only during the embodiment design phase. The ability to apply DFA analysis at the conceptual design stage has been neglected. As a result, the DFA methods then force another iteration on the design, thus consuming time, material, and financial resources.

Developing product models based on the functional basis and applying the module heuristics, modular product architectures are developed and used for part count reduction at the conceptual design stage (Stone, McAdams, and Kayyalethekke, 2004). This method also leads to creative solutions for product designs, and in the cases studies presented here, a greater reduction in part count then was achieved using the Boothroyd and Dewhurst methodology. This method is easily implemented and used by a design engineer for any product. Additionally, the product architecture method works with other quantitative methods to determine assembly time information. This method leads to savings in time and resources.

2.2.2 Boothroyd-Dewhurst DFA Methodology

This method relies on an existing design which is iteratively evaluated and improved. Generally, the process follows these steps (Boothroyd and Dewhurst, 1990):

1. Select an assembly method for each part
2. Analyze the parts for the given assembly methods
3. Refine the design in response to shortcomings identified by the analysis
4. Loop to step 2 until the analysis yields a sufficient design

When DFA began to be taken seriously in the early 1980s and the consequent benefits were appreciated, it became apparent that the greatest improvements arose from simplification of the product by reducing the number of separate parts. In order to give guidance to the designer in reducing the part count, the DFA methodology provides three criteria against which each part must be examined as it is added to the product during assembly (Boothroyd and Dewhurst, 1990).

1. During operation of the product, does the part move relative to all other parts already assembled. Only gross motion should be considered—small motions that can be accommodated by integral elastic elements, for example, are not sufficient for a positive answer.
2. Must the part be of a different material than or be isolated from all other parts already assembled? Only fundamental reasons concerned with material properties are acceptable.
3. Must the part be separate from all other parts already assembled because otherwise necessary assembly or disassembly of other separate parts would be impossible.

2.2.3 Principles of Boothroyd-Dewhurst DFA

This method is based on two principles:

1. the application of criteria to each part to determine if it should be separate from all other parts.
2. estimation of the handling and assembly costs for each part using the appropriate assembly process.

The first step is to reduce the total number of parts, a concept borrowed from DFM, but carried to a further extreme by computing the theoretical minimum number of parts for use as an optimization target.

The second step is to estimate the handling and assembly costs for the product using a number of assumptions about the manufacturing processes used. Cost estimation is an important product of DFA because it predicts the cost of the product before a great deal of capital resources have been consumed in its design. At this stage, basic design changes can be made relatively inexpensively. The estimated cost is then related to the theoretical minimum number of parts to generate an efficiency index for the design. This number is a weighted ratio of the efficiencies of the theoretical optimum design and the conceptual design. This quantitative measure of design efficiency can then be used to compare different design configurations and processes in an objective manner (Boothroyd and Dewhurst, 1990).