OPTIMIZATION OF PRODUCT ARCHITECTURE BY USING DESIGN FOR MANUFACTURE AND ASSEMBLY

Submitted in accordance with the requirement of University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **OPTIMIZATION OF PRODUCT ARCHITECTURE BY USING DESIGN FOR MANUFACTURE AND ASSEMBLY**

Sesi Pengajian: **2019/2020 Semester 1**

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I hereby, declared this report entitled “Optimization of Product Architecture by using Design for Manufacture and Assembly” is the results of my own research except cited in reference.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as partial fulfillment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

…………………………………………

(Associate Prof. Ir. Dr. Hambali binArep @ Ariff)

ABSTRACT

Product architecture choice deserves careful consideration, which would be facilitated by the ability to represent and assess alternatives at an early stage. To optimize the manufacturing cost and product development throughout time, manufacturers have to increase commonality among products and eliminate redundant components from their product ranges, without losing functionality and quality. This study investigates a product architecture through a case study of an existing furniture caster wheel by using Design for Manufacture and Assembly. The aims is to proposed a new caster wheel design. Bill of Materials, Analytical Hierarchy Process and Boothroyd and Dewhurst Software were used as a tool to analyze the design. The new design is then develop by using Solidwork CAD and validate through Solidworks Simulations feature. The results of this study is the data comparison between the existing product design and new design in terms of mechanical perspective such as number of components, assembly time and assembly cost used. As a conclusion, the performance in terms of mechanical perspective the new design is improved.

ABSTRAK

Pilihan seni bina produk patut dipertimbangkan dengan teliti, yang akan difasilitasi oleh keupayaan untuk mewakili dan menilai alternatif pada peringkat awal. Untuk mengoptimumkan kos pengeluaran dan pembangunan produk sepanjang masa, pengeluar perlu meningkatkan kesamaan antara produk dan menghapuskan komponen yang berlebihan daripada rangkaian produk mereka, tanpa kehilangan fungsi dan kualiti. Kajian ini menyiasat senibina produk melalui kajian kes roda perabot sedia ada dengan menggunakan Reka Bentuk untuk Pembuatan dan Perhimpunan. Tujuannya adalah untuk mencipta reka bentuk roda kastor baru. *Bill of Materials*, Proses Hierarki Analisis dan Perisian Boothroyd dan Dewhurst digunakan sebagai alat untuk menganalisis reka bentuk. Reka bentuk baru kemudiannya dibangunkan dengan menggunakan Solidwork CAD dan disahkan melalui ciri Soliwork Simulasi. Hasil dari kajian ini adalah perbandingan data antara reka bentuk produk yang ada dan reka bentuk baru dari segi perspektif mekanikal seperti jumlah bilangan komponen, masa perhimpunan dan kos perhimpunan yang digunakan. Sebagai kesimpulan, prestasi dari segi perspektif mekanikal, reka bentuk baru dapat diperbaiki.

DEDICATION

To my hero father, Abu Zarin bin Jalaluddin

My supportive mother, Yuhainis binti Mohd Yusop

My siblings,

Helpful friends

For giving me moral support, time, encouragement and also understandings.

ACKNOWLEDGEMENT

In the name of Allah, the most gracious and the most merciful with the highest praise that I manage to complete this study successfully in spite of the difficulty. My respected supervisor, Associate Prof. Ir. Dr. Hambali bin Arep @Ariff for the understanding throughout the study.

Besides that, I would like to express the gratitude towards my caring, patient and resilience parents for standing beside me throughout my life with all the encouragement, moral support and love. If there was a word in the world whose meaning to conveyed more gratitude and respect than thank you, I would saying that word a million times over to both of you.

Finally, I would like to thank my dear friends Wan Syarif, Zulhilmi Aidil and all the people who was important to me in completing this study. I would sincerely apologize for all the things that I would have intentionally or unintentionally wrong to you guys. And for all of that, I thank you.

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DFA	-	Design for Assembly
DFM	-	Design for Manufacture
DFMA	-	Design for Manufacture and Assembly
FYP	-	Final Year Project
AHP	-	Analytical Hierarchy Process
FEA	-	Finite Element Analysis

CHAPTER 1

INTRODUCTION

This chapter describes the background of study, problem statement, objectives of study and scope of study. The background of study focuses on modifying of product architecture design by using Design for Design for Manufacture and Assembly based on previous research. The problem statement reveals the issues are happen in recent years where. The scope of study emphasizes in the detail design of product development.

1.1 Background of study

A product's architecture can influence many aspects from the design phase to the recycling of a product and the reuse of fragments of its design. Therefore, the selection of product architecture surely deserves careful consideration, which would be facilitated by the ability to represent and evaluate alternatives early on. To optimize the manufacturing cost and product development throughput time, manufacturers have to increase commonality among products and eliminate redundant modules and components from their product ranges, without losing functionality and quality. At the same time, product differentiation should not be sacrificed by excessive commonality.

The arrangement of functional element, the mapping from functional elements to physical elements, and the specification of the interfaces among interacting physical components is defined as product architecture (Ulrich, 1995). In this context, product architecture refers to the conceptual structure of a design. (Otto and Wood, 2001) extend the definition to include the division of a product into relationships between components and functional modules in the product family.

Using the product modeling language, product architecture can be represented. There are many such languages that vary in their types of information and how they do so. Models of the architecture of a product constructed in such languages may be used for different purposes, including communication between the customer and a design team or within a design team. The focus in this study are optimizing of product assembly time and cost development and quality of the product. Design for Manufacturing and Assembly is chose to prove either the investigation is suitable or not in this study.

1.2 Problem Statement

Product architecture design could be a challenge in conceptual design that affects a wide range of development goals such as cost, time, quality and satisfaction of consumer. However, existing methods of product architecture design often have a limited number of such effects. The range of design capability are often not been exploited to the full and the existing methods are highlighted to represent a limited view on product architecture. Without losing functionality and quality, manufacturers also have to increase commonality among products and eliminate redundant modules and components from their product ranges to optimize the manufacturing cost and product development throughput time. To optimize the product architecture of product, a study of DFMA widen the view on product architecture design, thus a design will be proposed. A caster wheel for furniture is selected as a product of the case study for this report.

Although casters are one of the smaller parts that make up a material handling cart, they play an integral role in how that product will move efficiently and safely. Also, premature caster failure can impact the company's bottom line. There are many reasons a caster can fail but the some that comes up most often are: choosing the wrong component replacement for maintenance. Many times, casters are selected based on upfront cost. What is not taken into account is that an inexpensive caster purchase can cost you much more in the long run.

1.3 Objectives

The objectives are shown below:

1) To investigate product architecture of furniture caster wheel.
2) To develop new design by using Design for Manufacture and Assembly
3) To validate the proposed design by comparing the old design and new design.

1.4 Scope of Study

This study focuses on modifying product architecture of an industrial product through a case study of furniture caster wheel. The existing top plate furniture caster wheel is chose as a case study for this report. Design for Manufacture and Assembly will be involved in these studies. The study is in detail design of design process. 3-D CAD modelling of the caster wheel will be designed using SolidWorks software.

1.5 Significant of Study

This study is intended to optimize the existing product by using Design for Manufacture and Assembly in product architecture either by combining or modify them. The new product of a case study is validated by comparing the old design and new design through Finite Element Analysis. Due to the scope is in industrial product, the industry also get benefits from the outcome of this study. The study then can be used as reference in developing their products. Other industry can also relate the outcome to their product.

CHAPTER 2

LITERATURE REVIEW

This chapter discusses on previous project or studies on Design for Manufacture and Assembly application in product architecture as well as method to investigate the feasibility of the framework to achieve the objectives. This chapter also provides the basic knowledge for report finding by other researcher and the methodology used was summarized. The project information can be obtained from the online-journals, articles, relevant project paper, books and electronic publication.

2.1 Product Architecture

In 1995. Ulrich and Eppinger has stated that the physical units and the way the unit interacted that were configured from the functional elements defined as Product architecture. Architecting consist of building a system and designing (Rechtin, 2000). Chen and Liu (2005) described Architecture as a method where the function of a product is allocated to its physical component. For any real product of architecture, it varies from modular to integral. In subsets product’s functional model that have a one-to-one correspondence from the existing multiple physical substructures is called modular architecture. An integral architecture occurs when achieving multiple functions by a physical substructure.

In the conceptual phase, Pahl et al.(2007) suggested a functional basis for product architecture. At this stage, no form details are required for the design. The inputs and outputs of the subsystem which associated with the environment are divided from the system or a product. The intended input/output relationship of a system whose purpose is to perform a task represents the function. Usually functions are represented in a verb-noun (function flow format). There are three types of flow which based from a function namely energy, material and signals. Branch, channel, connect, control magnitude, covert, provision, signal and support are the eight classes from which a function can be divided to.

Pahl et al. (2007) said by following the steps, product architecture in a functional model can be obtained. The case where black box diagram ignored the initial processes and sub-system given in the block are the overall function of the product which later are divided into sub-function of lower complexity. Overall function is then can be satisfied when the sub-functions able to produce an integrated function structure.

A functional basis that were developed from product architecture can be utilized for developing a modular architecture. In identifying modules for product architecture, Stone et al. (2000) suggested three heuristics where one function can be related to one module.

Dominant flow heuristics: A modules that define as a non-branching flow that passes through from the group of sub-functions with the initiation of the flow in the system to exit from the system without transformation.

Branching flow heuristic: A module which branched from a flow constitute of a parallel function chain. A module at the branch location that interfaced with the other modules. Conversion-transmission heuristics: A module which represents a conversion sub-function or a conversion-transmission pair or a chain of conversion-transmission chains. In the case of conversion-transmission chains, only operate on the converted flow for the intermediate sub-functions between the convert and transmit sub-functions.

A method has been proposed where it can identify variety in product portfolios based on product function and customer needs to reduce the system impact of variety. It describes the entire set of products used by monolith function structure which merged from the individual product functions. Stone et al. (2000) then said the monolith later partitioned into modules according to function and product variety heuristics. A core platform module is then formed when the variety heuristics clusters functions across the portfolio by isolating the variety of the module and reducing the variety by grouping the remaining function. Different characteristic is achieved through optional modules for varying performance.

Diverse customer needs can be meet if platform-based design helps an industry to benefit by sharing the technology platform. In the case of mass-produced goods, the benefit product platform can be significant. A set of subsystem and interfaces that are shared among a group of products is called product platform where it develops derivative products. Target market segments that satisfied by common product platform that are shared from a group of products are defined as product family. Thus, the need of multiple product lines in the market is served by product platform. A product variant consists of individual product within a product family. Jiao et al. (2007) have provided a literature review on product family design and platform-based product development.

Companies can increase the flexibility, differentiated products developed efficiently and responsiveness of their manufacturing processes by sharing components and production processes across a platform of products . Companies can also gain market share away from competitors who develop only one product at a time. Further, it also improves ability to upgrade products, development cost, products and product development time. Commonality among product ranges will increase from the efficiencies of supply chain resulting in better negotiating terms with suppliers and reductions in direct and indirect manufacturing costs enhanced. Platform-based design helps to reap the benefits of mass customization at mass production efficiency by meeting the needs of diversified market segments.

Each product in the family that were compared with functional structure from shared interchangeable modules is one of the approached to architecting a product family suggested by Dahmus et al. (2001). Zhang et al. (2006) have suggested a function-based modularity approach for development of product families. Guidelines for improving commonality among product platforms in custom products have been specified by Farrell and Simpson (2003).

Optimization and product for family design approaches have been discussed by Simpson et al. (2006). Module-based method and/or scale-based method can be used to achieve the platform-based product design. For deriving individual products in a family in the module-based method, one or more functional modules are added, substituted and/or removed from the platform. In the case of scaled-based method, the platforms are scaled in one or more dimensions to meet the requirements. Top-down and bottom-up approaches can be used to achieve the product family design. In the top-down approach, a platform for a group of products are developed strategically by a company and in the bottom up approach, the technology shared were based from a platform developed from a company that groups its products. Marinelli et al. (2009) have introduced a mathematical programming-based modelling framework for the combined module-based and scale-based platform designs using the top-down approach.

2.2 Product Design and Development Process

The product design scope extends beyond industrial design. Industrial design focuses more on the "art" of a product such as esthetics, shape, color, texture and feeling. Product design is considered a mix of marketing, managing products, industrial design and engineering. (Sapuan, 2017).

Product development defined by Mazumdar (2002) as a process for translating customer requirements into product design and manufacturing involving the management of mutual dependency between all phases of the product life cycle, including design, manufacturing, distribution, technical support and disposal or recycling phases.

Sapuan and Maleque (2005) used total design model in the development of a household appliance, that is, a telephone stand from woven banana pseudo-stem fiber reinforced epoxy composites. The overall design as coined by Pugh (1991) is considered a key activity in the development of products. The overall design model is shown in Figure 2.1. It begins with market research, product design requirements (PDSs), conceptual design, detailed design, manufacturing and sales. This model can be easily used for engineering and consumer products, even in composite applications.

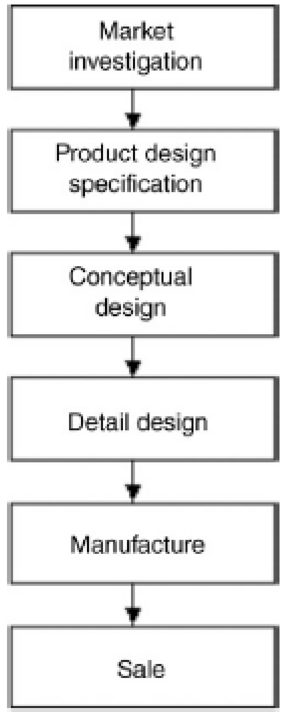

Figure 2.1: The overall design by Pugh (1991).

The model developed by Pugh (1991) has become increasingly popular with product designers, among others, due to the strong emphasis on product design specifications, the combination of conceptual and embodiment designs only as conceptual design and the introduction of a well- respected Pugh concept assessment method. Pahl et al. (2007) have developed a model that sometimes referred to as the German method. In 1984, their work was originally translated and published in English. It is well accepted that this work is the pioneering work in design engineering. It is because, they have written a very comprehensive and detailed book and this work is sometimes considered so much beyond what is normally needed.