Faculty of Manufacturing Engineering

Integrated Analytical Hierarchy Process (AHP) and Design for Manufacture and Assembly (DFMA) in Concept Generation of Portable Material Pouring Mechanism

Syukran bin Zainol

Master of Manufacturing Engineering
(Manufacturing System)

2019

DECLARATION

I declare that this thesis entitled “Integrated Analytical Hierarchy Process (AHP) and Design for Manufacture and Assembly (DFMA) in Concept Generation of Portable Material Pouring Mechanism” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Manufacturing System Engineering)

Signature :…….....

Supervisor Name :……. .....

Date :…….. .....

DEDICATION

To my beloved mother, father and family

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Professor Madya Ir. Dr. Hambali Bin Arep @ Ariff from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this thesis.

Special thanks to all my peers, my late father, beloved mother and siblings for their moral support in completing this degree. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

ABSTRACT

Non-mathematical comprehensive calculation which ignores some of the critical items results mostly unrecognized or blinded by the customer and the manufacturer on decision making. In AHP, a complex decision will be devided into explicit goals, alternatives and criteria. Then the criteria will be prioritized and available alternatives evaluated in light of those criteria. For this study, the integration of AHP and DFMA proved that it capable to reduce error by giving precise selection on decision making processes towards the best conceptual design of Portable Material Pouring Mechanism. The objectives of this project are to select the most optimum concept generation by using the integrated AHP and DFMA method and to compare the performance of selected conceptual design with propose redesign portable material pouring mechanism by using DFMA method. Five conceptual designs were proposed in this study and by using AHP approach. Conceptual Design 3 (CD-3) was selected as the best conceptual design based on AHP analysis and its goal criteria via Expert Choice software. The selected conceptual design then analyzed by using DFMA software to optimize the design. The DFMA analysis proved that the design efficiency of selected conceptual design has improved by 33.6%; from 34.24 to 45.76. The total parts of new design of CD-3 is 15 which is less than the original design; 19 parts.The estimated assembly labor time has reduced from 282.59 seconds to 211.45 seconds. Finally the product costs also reduced from $196.33 to $167.42. Implementation of AHP for selecting the best conceptual design in portable material pouring mechanism was successfully performed. The findings of this study have a number of important implications for future practice. Obviously the complexity of conceptual design due to many factors involved has been reduced by integrating AHP and DFMA method. The findings of this study have a number of important implications for future practice. Integrated of AHP and DFMA proved as a powerful tool that can simplify the complex decision making process especially in early design stage. Therefore, it is important for manufacturing teams to utilize this kind of integration methods in deciding the best and most optimum conceptual design.

ABSTRAK

Pengiraan komprehensif bukan matematik yang mengabaikan beberapa hasil kritikal kebanyakannya tidak diiktiraf atau diabai oleh pelanggan dan pengeluar ketika membuat keputusan. Dalam AHP, keputusan yang rumit akan dibahagikan kepada matlamat, alternatif dan kriteria yang jelas. Kemudian kriteria akan diberi keutamaan dan alternatif yang tersedia dinilai berdasarkan kriteria tersebut. Untuk kajian ini, penyepaduan AHP dan DFMA membuktikan bahawa ia mampu mengurangkan kesilapan dengan memberikan pemilihan tepat pada proses membuat keputusan ke arah reka bentuk konseptual yang terbaik dalam Mekanisme Pengangkut Bahan Mudah Alih. Objektif projek ini adalah untuk memilih penjanaan konsep yang paling optimum dengan menggunakan kaedah AHP dan DFMA bersepadu dan membandingkan prestasi reka bentuk konseptual yang dipilih dengan mencadangkan reka bentuk semula mekanisme pengangkut bahan mudah alih dengan menggunakan kaedah DFMA. Lima reka bentuk konsep dicadangkan dalam kajian ini dan menggunakan pendekatan AHP. Reka Bentuk Konsep 3 (CD-3) dipilih sebagai reka bentuk konseptual yang terbaik berdasarkan analisis AHP dan kriteria sasaran melalui perisian Expert Choice. Reka bentuk konseptual yang dipilih kemudian dianalisis dengan menggunakan perisian DFMA untuk mengoptimumkan reka bentuk. Analisis DFMA membuktikan bahawa kecekapan reka bentuk konseptual yang dipilih telah meningkat sebanyak 33.6%; iaitu dari 34.24 hingga 45.76. Jumlah bahagian reka bentuk baru CD-3 adalah 15 yang mana berkurang daripada reka bentuk asal iaitu 19 bahagian. Masa pemasangan juga dianggarkan telah berkurang dari 282.59 saat menjadi kepada 211.45 saat. Akhirnya kos produk juga berkurang dari $ 196.33 kepada $ 167.42. Pelaksanaan AHP untuk memilih reka bentuk konseptual terbaik dalam mekanisme menuang bahan mudah alih telah berjaya dilaksanakan. Penemuan kajian ini mempunyai beberapa implikasi penting untuk amalan masa depan. Jelasnya kerumitan pemilihan reka bentuk konseptual yang dipengaruhi banyak faktor telah dikurangkan dengan mengintegrasikan kaedah AHP dan DFMA. Penemuan kajian ini mempunyai beberapa implikasi penting untuk amalan masa depan. Integrasi AHP dan DFMA terbukti sebagai alat yang baik dalam mempermudah proses membuat keputusan yang rumit terutama pada peringkat reka bentuk awal. Oleh itu, adalah penting bagi pasukan pembuatan untuk menggunakan kaedah pengintegrasian seperti ini dalam menentukan reka bentuk konseptual terbaik dan paling optimum.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

This chapter describes on the integration and implementation of Design for Manufacture and Assembly (DFMA) and Analytical Hierarchy Process (AHP) on conceptual design of portable material pouring mechanism. This chapter will include the content of project background, problem statement, objectives, scope of study and the project summary.

1.1 Background

The designing process of each product in order to be manufactured and assembled smoothly before it even reaches the manufacturing phase is known as Design for Manufacture and Assembly (DFMA). When designing or redesign a product at the earliest stage, there are many aspects to consider beyond its core function. Researcher and innovator need to consider all the parts that are selected for the bill of materials (BOM), assembled parts and finally the finished product which will be analyzed and tested. These elements will contribute on the total cost to manufacture the final product. The parts that selected to be used in the conceptual design is very crucial especially in term of the ease of assembly, total product cost and time taken to assemble all parts. DFMA also optimizes the assembly process of

each product and its component parts. An assembly that is straightforward and simple in term of design will result in lower production costs.

One of the main challenges that organizations face today resides in their ability to choose the most correct and consistent alternatives in such a way that strategic alignment is maintained. Given any specific situation, making the right decisions is probably one of the most difficult challenges for science and technology (Triantaphyllou, 2002). In current manufacturing environment, the ability to make the right decisions based on adequate and aligned objectives constitutes a critical factor. Basically, the prioritization of projects is very important where the higher benefits will be focused compare with their costs.

The use of the AHP is a technique for decision making in complex environments in which many variables or criteria are considered in the prioritization and selection of alternatives or projects. AHP was developed in the 1970s by Thomas L. Saaty and has since been extensively studied, and is currently used in decision making for complex scenarios, where people work together to make decisions when human perceptions, judgments, and consequences have long-term repercussions (Bhushan & Rai, 2004). The application of AHP begins with a problem being decomposed into a hierarchy of criteria so as to be more easily analyzed and compared in an independent manner (Figure 1). After this logical hierarchy is constructed, the decision makers can systematically assess the alternatives by making pair-wise comparisons for each of the chosen criteria. This comparison may use concrete data from the alternatives or human judgments as a way to input subjacent information (Saaty, 2008).

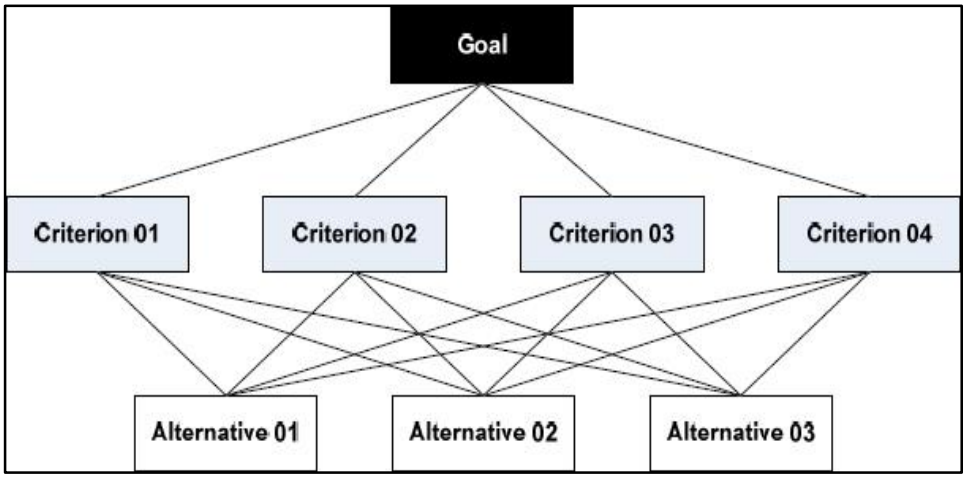

Figure 1.1: Example of a Hierarchy of Criteria/Objectives (Saaty, 2008)

AHP transforms the comparisons of empirical data into numerical values that eventually will be evaluated and compared. The assessment of each element inside the hierarchy will be based on the set weightage. This capability of converting empirical data into mathematical models is the main distinctive contribution of the AHP technique when compared to other techniques.

The comparisons and relative weights between each of the criteria will be evaluated then the numerical probability of each alternative is processed. These probabilities will determine on the alternatives that supposed to achieve the expected goal. The higher probability, the better chances of each alternative has to fulfill the final goal of the portfolio. The more complex cases in AHP, the analyses and calculations become deeper and more comprehensive.

1.2 Problem Statement

Major changes in product design practices are occurring in all phases of the new product development process. These changes will have a significant impact on how all products are designed and the development of the related manufacturing processes over the next decade. The high rate of technology changes has created a dynamic situation that has been difficult to control for most organizations. The key to achieving benchmark time to market, cost, and quality is in up-front technology, engineering, and design practices that encourage and support a wide latitude of new product development processes. These processes must capture modern manufacturing technologies, piece parts that are designed for ease of assembly, and parts that can be fabricated using low-cost manufacturing processes. Optimal new product design occurs when the designs of machines and of the manufacturing processes that produce those machines are congruent. The obvious goal of any new product development process is to turn a profit by converting raw material into finished product (John Wiley & Sons, 2006).

A material pouring mechanism is used during the material handling of slurry clay from the mixing container into the ball mill at Kolej Kemahiran Tinggi MARA Masjid Tanah Melaka. The rate of this process is very high which approximately two to three times in a week. During the material pouring process, lifting and pushing the 40kg – 50kg container are among the most common work activities which technically can contribute to minor injuries and obviously non-ergonomic. Previously, there are no proper injuries data collected from the material pouring process.

Some common injuries related to this process are low back pain, slip and fall from the support platform.

According to Hui Nee A. (2014), the occupational accidents in Malaysia showed a continuous decline from the year 2000 to 2008. However, the statistics seemed stagnant since year 2009. Construction industry and manufacturing industry accounted for 37% and 22% of all fatal injuries investigated by the Department of Occupational Safety and Health (DOSH). Hearing and back diseases accounted for 34% of the occupational diseases.

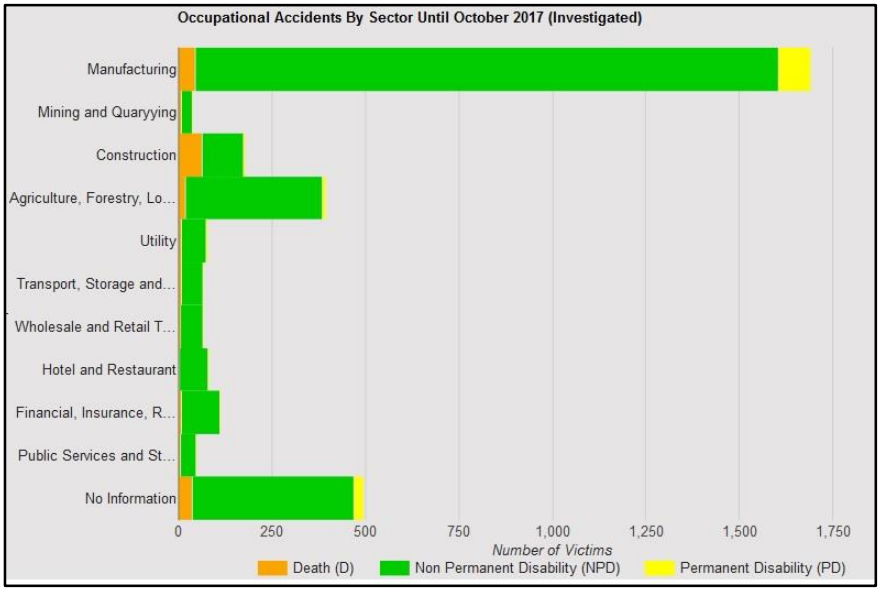

Figure 1.2: Occupational Accidents by Sectors in Malaysia (DOSH, 2017)

According to NIOSH Malaysia, (2016), many studies in the past have found the association between low back pain and factors such as working environment, exposure to physical hazards, ergonomic hazards such as awkward posture, forceful activities and psychosocial factors such as low work satisfaction and poor work control.

Many workers who are suffering from low back pain usually continue to do their same job and use the same techniques. This causes the pain to recur and results in prolonged sick leave and condition becoming chronic.

The life of a product begins with defining a set of product needs, which are then translated into a set of product concepts. Design engineering takes these product concepts and refines them into a detailed product design. DFMA method should start at the early concept development phase of the project. DFMA is used as a tool to drive specific assembly benefits and identify drawbacks of various design alternatives, as measured by characteristics such as total number of parts, handling and insertion difficulty, and assembly time. DFMA converts time into money, which should be the common metric used to compare alternative designs, or redesigns of an existing concept. Meanwhile, the AHP method will be utilized to analyze the alternatives of conceptual design for portable material pouring mechanism.

1.3 Objectives

The objectives of this project is to study on the integration of AHP and DFMA in optimizing the concept generation of portable material pouring mechanism. The project objectives are as follows:

i. To select the best conceptual design by using the integrated AHP and DFMA method.

ii. To compare the performance of current design and redesigned portable material pouring mechanism by using DFMA method.

1.4 Scope

The scope of this project is to optimize the concept generation of portable material pouring mechanism by using two methods; DFMA and AHP. Boothroyd-Dewhurst DFMA methodology will be used to develop the most suitable concept generation and at the same time to generate new design solutions. Next, AHP will be applied to analyze and select the best available design alternatives. Tools that will be used in this project are DFMA software, AHP software and Solidworks CAD software. The project will also benefit the Production Based Education System of Ceramic Engineering Technology Department at Kolej Kemahiran Tinggi MARA Masjid Tanah.

CHAPTER 2

LITERATURE REVIEW

This chapter provides the overview of understanding on project title and related to the scope of study. In this chapter, all keywords related to the project such as conceptual design, optimization, DFMA, AHP have discussed. All the information is collected based on the available research obtained from scholarly texts including journals, proceedings, academic papers and books.

2.1 Perspectives on Concept Generation

In the field of design research, design is usually described as an activity to formulate a solution for a purpose (Simon, 1973). Indeed, the process of design has been understood to be the process of rational problem solving by transforming existing situations into preferred ones (Coyne RD et al., 1990). On the other hand, design has been viewed as a 'reflective practice' and a number of studies have investigated design processes in order to identify the features of the thinking process (Cross et al., 1996).

The meanings of design typically involve two phases; the mental plan for something followed by the creation of forms. The former phase is generally termed the conceptual design. In engineering design, conceptual design has been considered an 'early stage of design' in a systematic approach (Pahl G & Beitz W, 1995). Industrial design can be considered that which aims to create admired shapes and colours and which has been historically developed from art and craftwork.

In industrial design, the early stage of design played the role of being an ideation process for forming whilst drawing (Shah et al., 2003). In the stage of conceptual design, a suitable goal of product design is found as a result of ideation, which will also answer to social requirements (Ulrich & Eppinger, 2008). Market research and surveys on product trends have been believed to be effective supplemental methods for the ideation of a product design (Bloch, 1995). These investigations provide information on the gap between customer's needs and the existing product in a market. As mentioned earlier, the very early stage of design, during which an initial idea or specification is generated, is called concept generation.

To assist the concept generation, two types of methodological support techniques have been developed. The visual method and linguistic method. The visual method type is usually based on visual and spatial cognition using imagery resources or graphical media including 3-dimensional design and virtual information (Dahl et al., 1999). The visual method type is thought to be effective in assisting a designer's image aspect of concept. Perspectives on concept generation in the shape, interface or usage scene of a product for industrial design, as well as in the mechanical aspect for engineering design. The linguistic method type is based on language and uses lexicon technology, it is supposed to contribute more towards activating concept generation at the abstract level, such as the meanings or social values of a product. Both types are considered useful for accelerating or efficiently driving concept generation. With regard to another methodology on concept generation. Brainstorming is a popular method to facilitate the ideations quantitatively and is introduced to obtain the frequency of finding new solutions (Yang, 2010).

In addition, other general creativity support techniques are proposed to strengthen the originality in ideation process by providing a new method of seeing a situation. Synectics is a famous example of an operational theory for the conscious use of the psychological mechanisms of creative activity, particularly with regard to the roles of metaphor in the creative process (Gordon, 1961). Later, the roles of metaphor provided a computational cognitive model of analogy such as Copycat (Hofstadter, 1993).

For developing multiple viewpoints on seeing situations, flexibility is paid attention to and 'lateral thinking' is introduced as an effective creative thinking technique which is related to a flexibility developing skill. This is further developed into the Six Thinking Hats tool for human decision making. In order to obtain the meta-level skill of seeing a situation, not only human thinking but also the need for 'learning by doing' is highlighted from the viewpoint of practice. In the framework of learning in practice theory, the skill of reflection is introduced as an effective method to develop the creativity of 'practitioners' (Schön, 1983).

To improve the ideation support methods mentioned above, it is necessary to identify the theory of concept generation by gauging our understanding of human cognitive features including inspiration. Indeed, the generative process lying behind mysterious phenomena and its ability at the very early stage of design should be an interdisciplinary (beyond the existing academic disciplines and across multiple design domains) research theme.

Concept is defined as that which refers to the figure of an object, along with other representations such as attributes or functions of the object, which existed, is existing, or might exist in the human mind as well as in the real world. This definition is in line with previous considerations in the field of design study. Concept generation classified into two phase and thy are the problem–driven phase and inner sense-driven phase according to the following two factors; the basis of the concept generation and ability which enables the concept generation to proceed (Coyne et al., 1990).

Problem-driven-phase where the gap that exists between a goal of an object and its existing situation a problem, and define the problem–driven phase as the process of generating a new concept on the basis of the problem. In certain situations, there are obvious goals that need to be achieved, such as finding solutions for natural disasters.