UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

DEVELOPMENT OF AN INTEGRATED FAILURE MODE EFFECT AND CRITICALITY ANALYSIS (FMECA) AND ANALYTICAL HIERARCHY PROCESS (AHP) FOR AUTOMOTIVE STAMPING PART

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DEVELOPMENT OF AN INTEGRATED FAILURE MODE EFFECT (FMECA) AND CRITICALITY ANALYSIS AND ANALYTICAL HIERARCHY PROCESS (AHP) FOR AUTOMOTIVE STAMPING PART

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
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2015

DECLARATION

I declare that this thesis entitled "Development of an Integrated Failure Mode Effect and Criticality Analysis (FMECA) and Analytical Hierarchy Process (AHP) for Automotive Stamping Part" 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.

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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 Science in Manufacturing Engineering.

Signature	:	………………………..
Supervisor's Name	:	………………………..
Date	:	………………………..

DEDICATION

Especially for my beloved family, thanks for giving me the fully support. For my respective lecturer and supervisor, thanks for the lesson, knowledge and guidance. For my friends and every person participated., I really appreciate for your support.

ABSTRACT

In competitive business world, organizations must be able to respond to changing market needs quickly, efficiently and responsively. Therefore, the shortcomings of the conventional approach that can contribute to inefficiency, time-consuming and not being able to provide the required performance should be improved in order to respond to the current situation. Thus, the main objective of this research is to propose a new integration of the Failure Mode Effect and Criticality Analysis (FMECA) and the Analytical Hierarchy Process (AHP) so that can be used in the automotive stamping part (known as tie plate) manufacturing industry. A case study was performed in order to reduce the number of processes, time, and labour by implementing the proposed integration approach. FMECA was used to identify the failure in tie plate stamping process and four design concepts of packaging jig were proposed to eliminate and reduce the failure. AHP was used to determine the best design concept of the packaging jig as variety of aspects have to be considered in the selection such as performance, maintenance, development time, development cost, safety and potential cause of failure. Design concept 3 was selected as the best design concept with the highest score of 31.9%. The research shows that the proposed integration approach was used to generate and select the best design concept of packaging jig while the jig had reduced the number of stamping processes by 33.3% (from 6 to 4 processes), time by 50% (from 20 to 10 minutes for packaging per box) and labour by 50% (from 4 to 2 persons). This research presents the importance of considering the integrated approach in the design stage in order to improve the manufacturing process activities, especially in the automotive stamping parts industry.

ABSTRAK

Dalam dunia perniagaan yang kompetitif, organisasi harus mampu untuk bertindak balas kepada perubahan keperluan pasaran dengan cepat, cekap dan responsif. Oleh itu, kelemahan pendekatan konvensional yang boleh menyumbang kepada tidak efisien, memakan masa dan tidak mampu memberikan prestasi yang diperlukan, perlu diperbaiki untuk bertindak balas kepada keadaan semasa. Justeru itu, tujuan utama kajian ini adalah untuk mencadangkan integrasi baru FMECA dan AHP supaya boleh digunakan di industri pembuatan komponen hentakan automotif (dikenali sebagai "tie plate"). Satu kajian kes telah dilakukan untuk mengurangkan jumlah proses, masa, dan tenaga kerja dengan melaksanakan pendekatan integrasi. FMECA telah digunakan untuk mengenal pasti kegagalan dalam proses hentakan "tie plate" dan empat konsep reka bentuk jig pembungkusan telah dicadangkan untuk menghapuskan dan mengurangkan kegagalan. AHP telah digunakan untuk menentukan konsep reka bentuk terbaik jig pembungkusan kerana pelbagai aspek yang perlu dipertimbangkan dalam pemilihan seperti prestasi, penyelenggaraan, masa pembangunan, kos pembangunan, keselamatan dan potensi punca kegagalan. Reka bentuk konsep 3 telah dipilih sebagai konsep reka bentuk terbaik dengan skor tertinggi iaitu 31.9%. Kajian ini menunjukkan bahawa pendekatan integrasi yang dicadangkan telah digunakan untuk menghasilkan and memilih jig pembungkusan yang terbaik yang mana jig itu dapat mengurangkan sebanyak 33.3% proses hentakan (dari 6 ke 4 proses), 50% masa (dari 20 ke 10 minit untuk bungkusan per kotak) dan 50% daripada tenaga kerja (dari 4 ke 2 orang). Kajian ini menunjukkan pentingnya mempertimbangkan pendekatan integrasi dalam peringkat rekabentuk untuk melaksanakan aktiviti-aktiviti penambahbaikan bagi proses pembuatan terutamanya dalam industri komponen hentakan automotif.

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LIST OF ABBREVIATIONS AND SYMBOLS

a	-	Element
AHP	-	Analytical hierarchy process
ANC	-	Average of normalized column
CA	-	Criticality analysis
CI	-	Consistency index
CR	-	Consistency ratio
CT	-	Cost of development
D	-	Detection
DT	-	Detection
DFMA	-	Design for manufacturing and assembly
DFMEA	-	Design failure mode effect analysis
FMEA	-	Failure mode and effect analysis
FMECA	-	Failure mode effect and criticality analysis
i	-	Column
j	-	Row
MN	-	Maintenance
n	-	Number of matrix
n	-	Element in row
O	-	Occurrence
OC	-	Occurrence
OP	-	Output per jig
PD	-	Productivity
PDS	-	Product design specification
PF	-	Performance
PFMEA	-	Process failure mode and effect analysis
PM	-	Performance
QFD	-	Quality function deployment

RPN	-	Risk priority number
RI	-	Random index
S	-	Severity
SV	-	Severity
ST	-	Safety
™	-	Trademark
TM	-	Time of development
W	-	Priority vector
WS	-	Worker satisfaction
λmax	-	Maximum Eigen value
x	-	Multiply to
/	-	Divide to
=	-	Equal to
%	-	Percent

LIST OF PUBLICATIONS

Journal

1. **Azroy, M.R**., Hambali, A., Ab, Rahman, M., Isa, H., Masni, A.A., Sivaraos, Zolkarnain, M. and Ahmad, Y., 2014. Integration of Failure Mode Effect and Criticality Analysis (FMECA) and Analytical Hierarchy Process (AHP) to Improve the Packaging Process for Automotive Stamping part. *Applied Mechanics and Material Journal*.

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3. Hambali A., **Azroy M.R.**, Daleel M.I., Ab Rahman M., Isa H., Masni A.A., Sivaraos, Zolkarnain M., and Ahmad Y., 2013. Development of conceptual slicing machine using total design approach. *1st Knowledge Transfer Program Conference*, 21-23 August 2013.

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5. **Azroy, M.R**., Hambali, A., Ab, Rahman, M., Isa, H., Masni, A.A., Sivaraos, Zolkarnain, M., and Ahmad, Y., 2014. Application of the Integration of Failure Mode Effect and Criticality Analysis (FMECA) and Analytical Hierarchy Process (AHP) to Improve the Packaging Process for Automotive Stamping part. *3rd International Conference on Design and Concurrent Engineering*, 22 and 23 September 2014.

CHAPTER 1

INTRODUCTION

1.1 Background

Each organization involved in the business world has to deal with the current demands of competition. Any error or failure should be avoided to reduce the incurred losses. Making the right decision is very important in facing the situation. Therefore, the assistance of engineering techniques or tools is highly necessary.

Many concurrent engineering techniques have been successfully implemented in the industry including, Design for Manufacturability and Assembly (DFMA), Quality Function Deployment (QFD), Failure Mode and Effect Analysis (FMEA), and Analytical Hierarchy Process (AHP). Each tool has been applied at different stages of the product development process to assist the team, engineer and decision maker in making an appropriate decision (Tummala et al., 1997).

FMEA is an analysis methodology first developed in the 1960s by the aerospace industry for identifying and eliminating failure or potential failure for a system, design, process or service before reach the customers. It is also referred to as Failure Mode Effect and Critical Analysis (FMECA) when it is used for critical analysis (Liu et al., 2013). While, AHP is a multi-criteria decision technique developed by Thomas Saaty in the 1980s to assist a decision maker or engineer in solving a problem in decision making (Ho, 2007).

Since failure identification and appropriate design selection are important in the early stages of a product development process, one of the strategies is to combine both approaches by proposing an integrated framework for FMECA and AHP.

1.2 Problem Statement

Quality control method such as FMECA practiced in the industry needs to be combined with other methods if enhancement in product quality is needed. In order to realize a high quality product, a designer needs to use an effective quality-related tool for example FMECA and QFD, which can be observed as tools under the umbrella of concurrent engineering (Sapuan et al., 2006).

Currently, a number of integrations between FMECA and other techniques are being developed by researchers to improve the function of traditional FMECA. The integration development to improve the traditional FMECA include the integration of FMECA and AHP (Braglia, 2000; Davidson and Labib, 2003; Ravid et al., 2011). The constructed integrations depend on the area and capabilities of the method to be used.

In order to realize a new integration of FMECA and AHP, the shortcoming of FMECA and the integration between FMECA and AHP need to be explored. One of the shortcomings in the traditional FMECA technique highlighted in this research is that there is no consideration on cost in the traditional FMECA evaluation. Ahsen (2008) stated the current FMECA is insufficient because the result does not reveal the costs that arise from an identified failure. Braglia (2000) also observed that the factor of failure does not consider economic issues in FMECA evaluation. To overcome the issue, the addition of AHP technique in FMECA is allowed due to the capability of AHP as a multi criteria decision making tool.

Basically, the FMECA is measured by the Risk Priority Number (RPN) calculated by the multiplication of three factors, severity (S), occurrence (O), and detection (D). Higher RPN value indicates higher chance of a product or a system to fail. FMECA looks at how bad the problem is indicated by a high value being very bad, while AHP looks at how good a solution is indicated by a high value being very good (Davidson and Labib, 2003). This situation creates a contrast between FMECA and AHP approach. To overcome the situation, a mathematical formula needs to be determined to ensure that the integration of FMECA and AHP can be realized.

1.3 Objectives

The objectives of this research are:

i) To develop a new integration of FMECA and AHP approach in order to enhance the current automotive stamping tie plate manufacturing process.

ii) To apply the developed integration framework in the automotive stamping tie plate manufacturing company through a case study.

iii) To determine the best design concept of an automotive stamping tie plate packaging jig in order to improve packaging process.

1.4 Scope of Works

The current technique in performing the FMECA and AHP approach was used in this research. The multiplication of severity (S), occurrence (O) and detection (D) to obtain the risk priority number (RPN) was used in this research. Since the case study was applied in the automotive industry, the ranking tables of severity (S), occurrence (O) and detection (D) were referred to FMECA criteria by Ford Motor Company (McDermott et al., 2009).

The capabilities of AHP as a multi criteria decision making tool were used to improve the implementation of FMECA in the automotive industry. The nine basic steps of AHP to identify the best alternative were used in this research. Meanwhile, a simple mathematical formula was used to integrate FMECA and AHP due to the different desirable levels between these two methodologies.

An automotive manufacturing company was selected to perform the case study. The case study was based on current issues or problems occurring in the company. The conventional approach that has been used by the company was identified as the problem. The conventional was determined as inappropriate product design activities which not considering the product design specification and failure analysis. Therefore, it will be improved or solved by implementing the newly integrated FMECA and AHP approach.

1.5 Chapter Outline

This thesis contains with six chapters. The first chapter is the introduction chapter, which describes the background, problem statement, objectives and scope of this research. Next, previous researches and works were reviewed and the gap of the study was identified in chapter two. The established principles, guidelines, tools and mathematical equations were determined in order to conduct the research.

Chapter three is the methodology chapter. The specific technique used in order to achieve the objective was described. The research work flow as the guideline was illustrated. The integrated framework, which becomes the novelty of the research, is shown in this chapter. The case study conducted to validate the integrated framework is detailed in chapter four. A case study based on the current issue in the company is illustrated to show how the integration of FMECA and AHP can assist the company to improve the automotive stamping part manufacturing process.

Chapter five contains the results and discussion. The results obtained from the case study are discussed in chapter five. The results are discussed in the forms of graph and table for clearer explanation. Finally, the thesis concludes with chapter six, which expresses that the objectives of this research were accomplished. The recommendations for potential future research are also proposed.