APPLICATION OF INTEGRATED ANALYTIC HIERARCHY PROCESS (AHP) AND TECHNIQUE OF ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS) IN MATERIAL SELECTION FOR AUTOMOTIVE FENDER DESIGN

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This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) (Hons.)

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This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the Degree of Manufacturing Engineering (Manufacturing Design) (Hons.). The member of the supervisory committee is as follow:

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ABSTRACK

Laporan ini merupakan kajian tentang Integrasi AHP dan TOPSIS dalam proses pemilihan bahan untuk reka bentuk fender automotif. Bahan-bahan untuk pembinaan kenderaan automotif telah ditukar dari besi tuang dan keluli karbon rendah kepada bahan-bahan yang ringan seperti rencam matriks polimer, aloi magnesium dan aloi aluminium. Oleh itu, pemilihan bahan fender automotif dalam laporan ini akan memberi tumpuan kepada bahan-bahan ringan kerana trend baru dalam menghasilkan kenderaan ringan dalam industri automotif. Objektif utama adalah menentukan bahan yang terbaik bagi fender automotif dengan menggunakan kaedah integrasi AHP-TOPSIS dan megenalpastikan kriteria yang penting dalam pemilihan bahan untuk fender automotif. Pemilihan bahan adalah berdasarkan rekabentuk sedia ada dan proses pembuatan untuk fender automotif. Sifat-sifat bahan penting yang perlu dipertimbangkan dalam pemilihan bahan adalah prestasi, kos, berat dan pembuatan untuk fender automotif. Sepuluh bahan calon yang dicadangkan adalah keluli kekuatan tinggi, Aluminium aloi dan termoplastik. Pertama, kaedah AHP telah digunakan untuk menentukan keberatan untuk setiap kriteria. Kemudian, kaedah TOPSIS digunakan untuk melaksanakan kedudukan alternatif dalam pemilihan bahan untuk fender automotif. Kaedah integrasi AHP-TOPSIS telah membuktikan sangat berguna semasa membuat keputusan yang melibatkan pelbagai kriteria dan alternatif seperti proses pemilihan bahan untuk fender automotif. Kesimpulannya, resin PPE/PA/989 telah dipilih sebagai bahan yang terbaik bagi fender automotif dengan mengunakan kaedah integrasi AHP-TOPSIS.

ABSTRACT

This report was study about integration of AHP and TOPSIS in the material selection process of an automotive fender design. The materials for the construction of automotive vehicles are rapidly changed from cast iron and low carbon steel towards lighter materials such as polymer matrix composites, magnesium alloys and aluminium alloys due to greater emphasis on the weight reduction vehicles. The material selection of the automotive fender will focused on lighter materials due to new trend in producing light weight vehicles in automotive industry. The main objective was to determine the best material for automotive fender using integrated AHP-TOPSIS method by identified important criteria in material selection of the automotive fender. The material selection was based on existing design and manufacturing process of the automotive fender. The material property needs to be considered in the material selection was Performance, Cost, Weight and Manufacturing criteria. Ten candidate materials proposed were High Strength Steel, Aluminium Alloy and Thermoplastic. First, AHP method was used to determine the weight of the selection criteria. Then, TOPSIS method was used to perform the ranking of alternatives. The integrated AHP-TOPSIS method was proven very successfully in multi-criteria decision making processes which involved many criteria and alternatives in the material selection of the automotive fender. As a conclusion, the PPE/PA/989 resin was selected as the best material for the automotive fender using integrated AHP-TOPSIS method.

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DEDICATION

Dedicated to my beloved father, Goh King Chong,
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and my adored sisters and brother, Goh Chia Nee, Goh Chia Han and Goh Chia Chia for giving me moral support, cooperation, encouragement and also understandings.

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LIST OF ABBREVIATIONS

AA2036T4	-	Aluminium Alloy 2036 in the T4 temper
AA6010T4	-	Aluminium Alloy 6010 in the T4 temper
AHP	-	Analytic Hierarchy Process
AR/PC	-	Acrylic/Polycarbonate Alloy
CTE	-	Linear Coefficient of Thermal Expansion
D	-	Density
D1000DP	-	Docol Cold Rolled Steel 1000 Dual Phase
D600DP	-	Docol Cold Rolled Steel 600 Dual Phase
EB	-	Elongation at Break
ER	-	Electrical Resistivity
IP	-	Izod Impact, Notched
MC	-	Material cost
MCDM	-	Multiple-criteria Decision Making
NY66/40CF	-	Nylon 66 with 40% Carbon Fiber Filled
PC/PBT	-	Polycarbonate with Polybutylene Terephthalate Blend
PPE/PA/989	-	Polyphenylene Ether with Polyamide Blend
PPO/PA66	-	Polyphenylene Oxide with Nylon 66
PPS/40CF	-	Polyphenylene Sulfide with 40% Carbon Fiber Filled
SHC	-	Specific Heat capacity
TOPSIS	-	Technique of Order Preference by Similarity to Ideal Solution
UTS	-	Ultimate Tensile Strength
YM	-	Young's Modulus
YS	-	Yield Strength

LIST OF SYMBOLS

\$/kg	-	Cost per kg
$\$/m^3$	-	Cost per metre cubic
^{o}	-	Degree
^oC	-	Degree celcius
ρ	-	Density
κ*e*	-	Electrical conductivity
ρ*e*	-	Electrical resistivity
GPa	-	Giga pascal
J/cm	-	Joule per centimeter
kg/m^3	-	Kilogram per metre cubic
MPa	-	Mega pascal
µm/m-℃	-	Micro meter per meter per celsius degree
µohm-cm	-	Micro ohm centimeter
N/m	-	Newtons per metre
N/m^2	-	Newtons per metre square
Ω·m	-	Ohm metre
Pa	-	Pascal
%	-	Percentage
$10^{-6}/K$	-	Per million per kelvin
:	-	Ratio
$(\Omega \cdot m)^{-1}$	-	Reciprocal of ohm metre
S/m	-	Siemen per meter

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, new materials are used to replace traditional materials to achieve weight reduction and performance improvement in engineering application especially in automotive industry (Rao, 2008). The materials currently used in automotive industry such as advanced steels, light alloys such as magnesium alloys, aluminium alloys and titanium alloys, plastics and composites to produce lightweight vehicles. Design modification, material substitution and efficient manufacturing process are alternative solutions need to be considered in producing lightweight vehicles with the increasing demand of improving fuel economy and emission control. Fuel economy improvement strategies must consider vehicle weight reduction as the key factor. Several options to achieve significant reduction in vehicle weight are downsizing of vehicles and reducing the weight of automotive components using design optimization, parts consolidation and also material substitution (Mallick, 2010a).

New trends of lightweight vehicles not only can enhance fuel efficiency; the driving performance improvement can also lower the emissions (Fuchs et al., 2008). Reducing the weight of vehicle can cause a significant reduction of vehicle power requirement and hence increase the fuel economy. Studies have shown that every 10% of vehicle weight reduction can cause 5 to 8% greater fuel efficiency (Brooke and Evans, 2009). Weight reduction of automotive components becomes a new trend because it can meet the customer expectation in terms of fuel economy, emission reduction, vehicles safety and performance. Redesigning existing components with lightweight materials is one method to reduce weight in vehicle body construction. Weight saving in automotive components such as power-train, chassis and suspension, body panels and body structure might be achieved by using lightweight materials to replace high density materials like steels (Mayyas et al.,2011).

Material scenario in automotive industry are rapidly changed from cast iron and low carbon steel towards lighter materials such as polymer matrix composites, magnesium alloys and aluminium alloys due to greater emphasis on the weight reduction vehicles. Table 1.1 shows that the materials used in large quantities in automotive industry are cast iron and low carbon steel as compared to other materials.

Table 1.1: Material distributions in typical automobiles (Mallick, 2010a)

Material	Percentage of vehicle weight(%)	Main application
Steel	55	Body panels, body structures, engine and transmission components, driveline components, suspension components
Cast iron	9	Engine components, suspension and brakes
Aluminium	8.5	Wheel, engine block
Copper	1.5	Wiring, electric components
Polymers (plastics) and polymer matrix composites	9	Interior components, electric components, fuel line components, under-the hood components
Elastomers	4	Trims, tires, gaskets
Glass	3	Glazing
Other	10	Fluids, carpes, lubricants

In the last 20 years, many manufacturing processes and new materials have been developed to decrease the weight of the body panels, body structure, and suspension components. Existing component weight reduction opportunity in the body and chassis components is about 60% of a vehicle's weight, engine and transmission in the Power-train weight is around 25 to 30% of the vehicles weight (Mallick, 2010a).

An integrated Analytic Hierarchy Process (AHP) and Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) are the multiple-criteria decision making problem (MCDM) methods that can be applied in the material selection decision making process of automotive fender. The AHP method is used to determine the weight of the selection criteria, while TOPSIS method is used to perform the ranking task and it proposes the best solution among the candidate materials (Mansor et al., 2014b). This was proven very successfully in many decision making processes especially involving multiple criteria and alternatives with attributes need to be analyzed simultaneously to get the best solution. This method can also apply in other areas that are related to engineering, design and manufacturing system (Bahraminasabet al., 2014).

The AHP which developed by Saaty in the 1970s (1980) has proven its efficiency in decision making process and has been widely used in manufacturing and production systems, business planning, economic planning, conflict resolution, logistics and capital budgeting (Dweiri& Al-Oqla, 2006). The AHP hierarch model enables a decision maker to break a complex problem into smaller sub-problems. Objectives, criteria and sub-criteria are structured from highest level to lowest level of the model which can help the decision maker to understand more about the problem. Pair-wise comparison between sub-criteria or alternatives at the same level with respect to the objectives or criterion of the higher level can reduce the inconsistencies that possible made by the decision maker. The AHP also helps the decision makers to evaluate the relative importance of the multiple criteria. The relative weightage of each criterion tells the decision makers which criterion is the most important and selects the highest weighted criteria as the best alternatives. (Mansor et al., 2014b).

Furthermore, Hwang and Yoon (1981) has proposed TOPSIS method for solving MCDM problem with several alternatives. This method stated that an alternative which has the shortest distance from the positive ideal solution (PIS) and the longest distance from the negative ideal solution (NIS) is the most appropriate alternative. The alternative has the maximum similarity with PIS and minimum similarity with NIS. PIS maximizes the benefit criteria and minimizes cost criteria, whereas NIS minimizes the benefit criteria and maximizes the cost criteria. The TOPSIS method is very useful in material selection decision making process because it is a quick and easy decision where its ranking output gives a better understanding of similarities and differences among alternatives (Jahan et al., 2010). TOPSIS has been applied in many multi criteria decision making processes in different applications such as design selection and process selection.

In this project, integration of AHP and TOPSIS are used in the material selection process of automotive fender under certain criteria and a wide range of alternatives. By combining both methods, a more efficient way in analyzing the decision structure as well as determining the criteria weight can be achieved especially in dealing with practical and theoretical problem.

1.2 Problem Statement

The materials for the construction of automotive vehicles are rapidly changed from cast iron and low carbon steel towards lighter materials such as polymer matrix composites, magnesium alloys and aluminium alloys due to greater emphasis on the weight reduction vehicles. Most of these lighter materials are used in smaller quantities in automotive industry in different applications. However, these materials will be used in larger quantities in future vehicles in order to produce lightweight vehicles to fulfil fuel economy improvement and reduce environmental pollution. Material selection is not only affected by weight saving potential, other factors also need to be considered such as durability, safety, joining, processing, recycling and cost (Mallick, 2010a). These are the issues need to be considered in material selection of automotive fender as compared to current used steel fender. Steel fender's higher density contributes to high vehicle weight, fuel consumption, and associated energy and greenhouse gas (GHG) footprints. An effective way to choose the right lightweight material is to tailor with the suitable materials for the automotive fender as well as to select the best method for the material selection. Material selection for automotive fender is a multiple-criteria decision making problem, priority in selecting criteria and candidates for material selection of automotive fender, are therefore very important. The methodology used in material selection must be able to solve the multiple-criteria decision making problem.

1.3 Objectives

Main objective of the project was to determine the best material for automotive fender, to specify the objective was as follow:

- To identify important criteria in material selection of automotive fender.
- To integrate AHP- TOPSIS method in material selection of automotive fender

1.4 Scopes of Research

The material selection of automotive fender is based on existing design and manufacturing process of the automotive fender. The material of automotive fender focuses on lighter materials due to new trend in producing light weight vehicles in automotive industry. The suitable light weight candidate materials will be selected based on their performance, cost, service condition and weight requirements in order to achieve total weight reduction of the vehicle to produce lighter automotive fender. AHP is a powerful and flexible decision making process as it helps people set priorities to make the best decision when the both qualitative and quantitative aspects of a decision need to be considered. Therefore, this project will focus on the application of integrated AHP and TOPSIS methods in the material selection of automotive fender.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This chapter studies about literature review integration of AHP-TOPSIS method in material selection of automotive fender design. Secondary sources such as books, journals and online researches are used to get related information regarding the project. This chapter will provide a understanding about existing materials used in automotive fender and their related material properties, as well as the method that is most appropriate for material selection of automotive fender.

2.1 Introduction of Automotive Fender

Fender is a part of exterior body panels of vehicles that located at front and rear sides of the vehicles body to surround vehicles wheels. Fender is also known as wing or mudguard. Fender is the panels on the side of the vehicle, right by the door and over and around the front and rear wheels. Oftentimes they take the shape of the wheels. Some fenders are integrated into the anatomy of the automobile but some are stand alone panels which may be bought in dealer shops and installed easily.

Fenders are also designed to avoid wind resistance and make the vehicle more aerodynamic. Its primary purpose is to prevent sand, mud, rocks, liquids, and other road spray from being thrown into the air by the rotating tire. It also prevents other road debris from splashing on and scratching the coat of the vehicle. Fenders are typically rigid and can be damaged by contact with the road surface. Instead, flexible mud flaps are used close to the ground where contact may be possible as well as to keep off mud, pebbles,

Fenders of motor vehicles usually are one-piece structures made of sheet metal that is stamped to shape. In modern motor cars the fenders are of complex shape, thus requiring expensive, complicated, and relatively huge dies for the manufacture thereof. Vehicle fenders are subject to hard service, especially in the winter season when they are splashed with mud and ice, and frequently with salt that may be used on city streets for melting the snow thereon. Consequently the fenders usually deteriorate before the other parts of vehicle bodies. Furthermore, the fenders of vehicles are especially vulnerable to denting such as occurs from collision with obstructions or other vehicles while the vehicles are being driven or parked. Figure 2.1 shows an automotive fender design.

Figure 2.1: Automotive fender design

2.2 Existing Material Used For Automotive Fender

Fenders are usually made from sheet metal steel as metal provide best protection during a collision event. Other famous materials used for fenders are plastics, fibre glass, and carbon fibre. These non-ferrous materials are rust-resistance, light weight and provide better car design which has advantages over steel. Besides that, they can sustain damage more readily and easy repairs for small damage.