"I hereby declared that I have read through this thesis and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechanical Engineering (Structure & Material)"

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Date : MAY 2006

OPTIMIZING THE STIFFNESS AND STRENGTH IN BUMPER BEAM DESIGN

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May 2006

"I hereby declare that the thesis is based on my original work except for questions and citations, which have been duly acknowledgment"

Signature :.....

Name : **MOHD AZIZI BIN ABD AZIZ**

Date : MAY 2006

DEDICATION

To my beloved mother, father, sister and family and friends

Do You Have Time to Pray?
God Have Time to Listen

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In the name of Allah, the most Gracious and most Merciful

Thanks to Allah, for giving permission to complete my thesis. Many people have made contribution to this thesis. I would like to acknowledge and express my gratitude to my supervisor, Mr Mohd Nizam Bin Sudin and Mr Ahmad Rivai for his wisdom endurance and encouragement during his supervision period. Besides the accomplishment of this project, I learn from him how to lead a meaningful life. Not to forget are my friends Mr. Ahmad Tajudin Hamzah who helped in giving constructive ideas and opinions on how to conduct a better thesis and ways in collecting resourceful information, I would like to thank them for their kindness in supporting me along the way when I'm completing my thesis. I would also like to thank all my fellow friends for their help and co-operation. Not to forget, my parents, brother and sisters who supported me throughout the year. Thanks for their concern, encouragement and understanding. Last but not least, to those who have contributed directly or indirectly to the success of this project whom I have not mentioned their name specifically. Without them, this project would not be successful.

ABSTRACT

The main purpose of an automotive bumper beam is to protect the passengers of vehicle from injuries in a low speed collision. The automotive bumper system also to protect the hood, trunk, fuel, exhaust and cooling system as well as safety related equipment. The best way to increase the performance of the bumper beam by optimizing the stiffness and the strength and employing polymeric based composite bumper beam of the passenger car. The polymeric based composite material has high specific stiffness and high specific strength. The cross sectional shape and material selection of new bumper beam was designed to provide a lower mass and good impact performance, reduce part count and recyclable. The **'I'** type of cross section of the automotive bumper beam has been chosen because it gives high stiffness and strength to the beam and the polymeric based composite material selected for the bumper beam is Sheet Moulding Compound (SMC) composite. This material was selected because of easily to manufactured, high specific strength and specific stiffness, chemical resistance, good cycle times and good low temperature ductility.

ABSTRAK

Fungsi utama sesebuah automotif rasuk bamper ialah untuk memberi perlindungan kepada penumpang daripada kecederaan semasa pelanggarn pada kelajuan yang rendah.Sistem automotif rasuk bamper juga adalah untuk menlindungi penutup enjin, bonet kereta, ekzos dan system penyaman udara keselamatn peralatan yang berkaitan. Cara terbaik untuk meningkatkan keupayaan rasuk bamper mengoptimumkan kekukuhan dan kekuatan dan mengunakan komposit penguat fiber untuk kenderaan penumpang. Bahan komposit penguat fiber mempunyai kekukuhan specific dan kekuatan spesifik yang tinggi. Bentuk keratan rentas dan pemilihan bahan rasuk bamper direka supaya ianya mempunyai jisim yang rendah, kupayaan pelanggaran yang baik, mengurangkan jumlah komponen dan boleh dikitar semula. Keratin rentas bentuk **'I'** dipilih untuk automotif rasuk bamper kerana ia memberikan kekukuhan dan kekuatan kepada rasuk dan komposit penguat fiber merupakan bahan yang dipilih iaitu komposit jenis campuran membentuk kepingan (SMC). Bahan ini dipilih kerana ia senang dihasilkan, spesifik kekukuhan dan specific kekuatan yang tinggi, rintangan kimia yang baik, masa kitaran yang baik, dan kemuluran yang baik pada suhu rendah.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

LIST OF SYMBOL

SYMBOL	DEFINITION
□	Cross Sectional Area of □ Profile
C	Cross Sectional Area of C Profile
H	Cross Sectional Area of H Profile
├	Cross Sectional Area of ├ Profile
P	Load
σ	Stress
SMC	Sheet Moulding Compound
M_c	Maximum Bending Moment
y	Distance From the Neutral Axis
I_x	Moment of Inertia of the Cross Section

SUBSCRIPT	DEFINITION
Maks	Maximum
Mins	Minimum

CHAPTER 1

INTRODUCTION

1.1 Background

The function of automotive bumpers has changed considerably over the past 70 years. The later performance is achieved by a combination of careful design and materials selection to obtain a particular balance of stiffness and strength and energy absorption that is unique to each platform. Stiffness is an important performance criterion, because vehicle design considerations limit the packaging space for the bumper to deform under load. Energy absorption is an important criterion, because the bumper must limit the amount the impact force it transmits to the surrounding rails and vehicle frame. Automotive bumper plays a very important role not only in absorbing impact energy (original purpose of safety) but also in styling stand point.. A great deal of attention within the automotive industry has been focused upon light weight and sufficient safety in recent years. Therefore, the bumper system equipped with bumper beam and energy absorbing element is a new world in the market.

Steel and aluminium were to conventional metals that commonly used in bumper beam design. Recently, to reduce the weight of car and increase energy absorption capacity, most passenger car employ engineering plastics bumpers that is usually made of polymeric based composite. The reinforced plastics bumper beams made by compression with SMC (Sheet moulding compound), RTM (Resin transfer moulding) and RIM (Reaction Injection moulding) are successful applied (Cheon, S.S., et al., 1995).

The fuel efficiency and emissions gas regulation are the main causes for reducing the weight of passenger cars by using a composite structure, since they have high specific stiffness and specific strength.

Bumper beams are one of the main structures of passenger cars that protect them in front or rear collisions. Thus, the car bumper system has designed to absorb energy thus to prevent or reduce physical damage of the front or rear ends of an automobile at low speed collisions. Automobile bumper system is not usually designed not to be structural component that would significantly contribute to vehicle crashworthiness occupant protection during front or rear collision at high speed. The bumper beam should be designed as safety future since it is intended to reduce the magnitude of deceleration during impact. The bumper system are only designed to protect the hood, trunk, frame, fuel, exhaust and cooling system as well as related equipment, such as parking light, headlamp and taillight at low collisions. Therefore, the engineering plastic bumper beam made of polymeric based composite was investigated to increase the energy absorption capability of the bumper beam during crash, reduce weight of the car and to protect the passenger of the cars.

1.2 Statement of Problems

The statements of the problem are:

1. The property damage during the collisions. A proportion of motor vehicle accidents occur at low speed less than 10 kilometers per hour (km\h). These low speed accidents cause a proportion of the total property damage which results from all motor accidents vehicles. In addition to minimizing the property damage, improve bumper system can also minimize injuries to pedestrians and to passengers of vehicles involved in collisions.

2. The conventional bumper system has a heavy weight. The material of conventional bumper beam usually is aluminum and steel. The weight of the bumper system can influence the impact of the collisions and can also minimize injuries to passengers of vehicles involved in accident.

3. The cost also issues or problem that the engineers must consider during the design phase. Both initial bumper cost and repair cost are important. The formability of material is important for high-sweep bumper system.

1.3 Research Objectives

The research objectives are:

1. To provide and improve stiffness and strength performance of the bumper beam system.

2. To provide a bumper beam that is compact and light in weight.

3. To provide the bumper system an effectively absorb energy.

4. To proposed the material for the bumper beam system.

1.4 Structure of Thesis

Literature review in various relevant areas is presented in chapter 2. The review started with the bumper beam design and a brief description of bumper system and component. The review than explain the manufacturing of bumper systems and polymeric based composite bumper system and it is end with the comparison between polymeric based composite material with conventional material and lastly review about the information technologies (IT) tool used in this research. The structure and methodology of design process is described in chapter 3. It concentrates on proposed design methodology for the design system; propose structure of the design system, tools required for the design, the design process, product design specification (PDS) and the material selection for the bumper beam. The design profile of polymeric based composite bumper beam is described in chapter 4. It is concentrate on the optimizing the stiffness and strength and the finite element method to aid profile evaluation.

Chapter 5 deal with the conceptual design of polymeric based composite for bumper system is described in It is comprise on the generating, developing and design evaluation of automotive bumper beam for achieving final design concept. The detail design of polymeric based composite is described in chapter 6. This chapter comprise to main parts, the component design and the design analysis. The component design was developed and analysis using computer aided design software such as Solid Works 2005 links with COSMOSXpressStudy.

In the chapter 7, conclusion is made on the design aspect of bumper beam design and recommendations for the future improvement are identified and explained.

CHAPTER 2

LITERATURE RIVEIW

2.1 Introduction

Automobile bumper beam is a structural component of an automotive vehicle, which contribute to vehicle crashworthiness or occupant protection during front or rear collisions. The bumper systems also protect the hood, engine, trunk, cooling system, fuel tank, and exhaust as well as safety related equipments. A brief description about the bumper component is since late the 70's, bumper car system assemblies on passenger cars have typically been two piece systems comprised of a structural beam and a decorative fascia (plastic), with either hydraulic energy absorbing units (shock absorbers) or an energy absorber over the beam. This design often required separate fascia supports, attachments of light and steel reinforcements to meet corner impact requirements. Material costs for these rear bumpers were high and mass were higher; due to meet the Federal Motor Vehicle Safety Standard (FMVSS) impact requirements. Responding to deficiencies, some automakers began switching to injection molded engineering thermoplastic bumper fascia featuring bumper beam. As plastic bumper beam proliferated, other OEMs thermosetting structural reaction molding (SRIM) beams attached to soft RIM fascia, or compression molded, glass mat thermoplastic (GMT) composite beams coupled with a thermoplastic polyolefin (TPO) fascia. Plastic bumper systems offered lighter weight, lower costs, and greater styling flexibility than previous steel systems, while still meeting FMVSS impact requirement (Minaudo B.P., et al., 1997).

A bumper beam is a shield normally made of from steel that use in the front or rear bumper of an automotive vehicle. When a low speed collision takes place, the bumper system absorbs the shock or energy to prevent or reduce damage to the vehicle. However, during the late '80s, styling preferences took a definite turn toward polymeric based composite give high tensile strength, pricing the metal more effectively, and becoming more creative with design. While the weight of conventional bumper systems becomes more weight, mass of this system was lower than the conventional material such as steel and aluminium and becoming more creative design by applied polymeric based composite bumper systems. During the same period, some automakers switched to a system featuring polymeric based composite bumper beams. In this design, a rigid expanded polymeric based composite foam provided impact absorption between the beam and the elastomeric fascia. Although the aluminum system weighed significantly less than steel, there was no reduction in the part count and no improvement in assembly (Minaudo B.P., et al., 1997).

Bumper systems have been changing drastically over the last 20 to30 years. More demanding government safety regulations and different styling concept have resulted in new designs. For example, reinforcing bumper beam covered by plastic fascias ware introduced in the early 1970's. Styling fashion has changed appearance values from almost 100% chrome plate face bars to predominately fascia systems that are colour coordinate with the body. The growth of light trucks, minivans and sport utility vehicles has created two classes of bumper in the eyes of the engineering world: one for passenger's car and another for the broad grouping of light trucks. Safety concern has resulted in the bumper beam becoming a part of the structural load path (Kelman et al., 1990).

There are several factors to be considered when selecting a bumper system. The most important consideration is the bumper system has high stiffness and strength and the ability of the bumper system to absorb enough energy to meet the original equipment manufactures (OEM's) internal bumper standard (Bernert et al,.2001). Another is the requirement to stay intact at high speed impact. Weight, manufacturing process ability and cost are also the factors that have to be considered during the design phase. Both initial bumper cost and repair cost are important. The

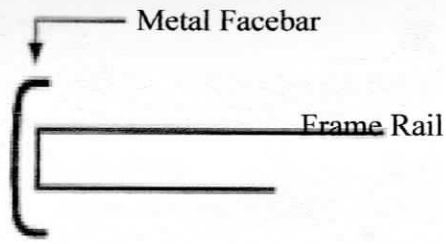
formability of materials is important for high-seep bumper systems. Another factors considered at the material selection stage is recyclability of material, which is an advantages for steel, but yet the evolution of carbon dioxide (CO_2) during recycling or re-melting of steel has been taken into consideration (Bernert et al.,2001).

2.2 A Brief Description of Bumper System and Component.

There are four different of types of bumper systems commonly used in the automotive vehicle as show in the Figure 2.1(Bernert et al.,2001). A brief description of each system is as follows.

a) Metal facebar system
b) Plastic fascia and reinforcing bumper beam system
c) Plastic fascia, reinforcing beam and energy absorbers
d) Plastic fascia, reinforcing beam and foam or honeycomb energy absorbers

(a)



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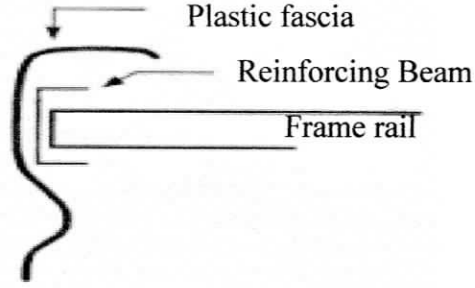

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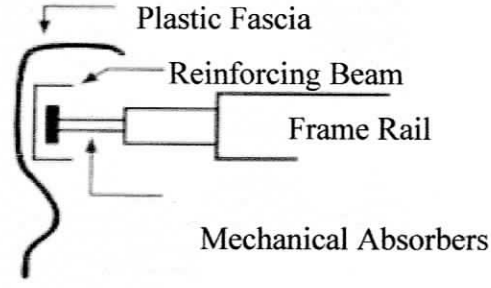

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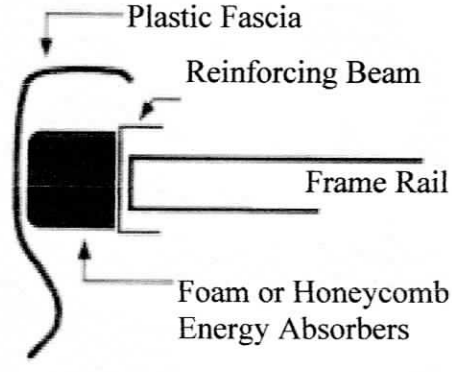

Figure 2.1: Four different types of automotive bumper systems: a) Metal facebar system, b) Plastic fascia and reinforcing beam system, c) Plastic fascia, reinforcing beam and energy absorbers and d) Plastic fascia, reinforcing beam and foam or honeycomb energy absorbers

2.2.1 Metal face Bar System

A metal face bar system consist a single metallic bumper that decorates the front or rear end of the vehicle and acts as the primary energy absorber in a collisions (Figure 2.1a). The bumper regulations in the United State required passenger car to withstand a 4 km/h impact of the curb position plus or minus 50 mm with no visual damage and no damage to safety related items. The Canadian passenger car regulations call for an 8 km/h impact, however limited damage is permitted. The North American OEM's voluntarily design their passenger car bumpers to withstand at 8 km/h with no visual damage and no damage to safety items. Current facebar systems can only withstand a 4 km/h impact at the curb position plus or minus 50 mm with no visual damage and no damage to safety items. For the reason, the use of current facebar systems is restricted to the light truck. The aesthetics of face bars matches the styling trend for full size vans, pickups and sport utilities. Thus, most face bars are presently being applied to these vehicles (Dubensky R. G., et al., 1989).

If the design standard for the light truck bumpers were to rise to the 8 km/h voluntary passenger car standard, then the face bar systems used on full size vans, pickup and sport utilities would have to be redesigned. For the reason of weight, such redesigns would likely revert to systems that employ reinforcing beam. Face bars are usually stamped from steel with lots of plastic or stainless steel trim to dress them up. A small volume of face bars is produced from aluminum. Steel face bars, for formability reasons are usually made from steels with a low to medium yield strength. Thus, face bars are quite thick. This thickness (plus the fact face bars are deep and have large wrap around ends) gives face bars a relatively heavy weight. After stamping, steel face bars are chrome plated or painted for appearance and corrosion protection reasons (Bernert et al.,2001).