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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

**AN INVESTIGATION OF CAR BUMPER WITH RESPECT TO IMPACT
ENERGY ABSORPTION**

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**Master of Mechanical Engineering
(Automotive)**

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**AN INVESTIGATION OF CAR BUMPER WITH RESPECT TO IMPACT
ENERGY ABSORPTION**

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**A master project report submitted
in fulfillment of the requirements for the degree of Master of Mechanical Engineering
(Automotive)**

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this report entitled "An Investigation of Car Bumper with Respect to Impact Energy Absorption" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : 

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APPROVAL

I hereby declare that I have read this report and in my opinion, this report is sufficient in terms of scope and quality as a partial fulfillment of Master of Mechanical Engineering (Automotive).

Signature



Supervisor Name: PROFESOR DR. MD RADZAI BIN SAID

Date

27/7/2016

DEDICATION

In the name of Allah, The most Gracious, The most Merciful.

To the great teachers and educator, My Prophet Mohammad (Allah blessings and peace be upon him and his family), which is the light and guidance for the world.

To my lovely parents, the greatest and most sacrifice;

To my family, my dear father, who has never spared any effort in our way, I aspire to make him proud of me as much as I am proud of him for his generosity. My beloved mother, which is my gates to paradise, that illuminating with her duaa and love, she removes all my worries by her smiles. Her love and sacrifice cannot be described by words, I did not get to what I am now without their love and sacrifices and their care. To my dear brother who has encouraged me all the time without any boring. To my lovely wife. For her patience and support, and its continuous assist for me. To my dearest sisters: Their love, support, duaa and encouragement are meant a lot for me, I ask the God to care and save you all.

For all of the dear friends who have encouraged me and supported me during my study times, Thank you for your friendship and the wonderful memories with all of them.

For every person who was care of me, even without to be related to me. For your motivation and duaa for me, I would like to say: thank you all.

ABSTRACT

The goal of this work is to reduce the degree of damage to the passenger car caused by automobile collisions. Bumpers are protective parts installed on the front and rear of automobiles. It can be made of steel aluminum or light weight plastic material. The primary aim of the study is to investigate the energy absorption of the bumper beam. European car bumpers made of aluminum and plastic have been tested to determine the energy absorption. Three specimens from each material were cut in the same shape but with different widths of 20mm, 40mm, and 80mm. The investigation was carried out in three different stages, namely, the experiment using the Universal Testing Machine (UTM); a theoretical approach to the shape of the specimen assumes that the specimens were semi-hexagonal and semi-circle using an expression to calculate the deformation and energy absorption. The study has found that aluminum material absorbs more energy with less deformation compared to the plastic material. The study concludes that large width of 80mm absorbs more energy and less deformation than 40mm and 20mm of the same material. The large area of contact with the applied load increases the energy absorption capacity of the material. The theoretical approach shows that the result is more similar to semi-circle shape so that the shape of the test specimen is close to the semi-circle.

ABSTRAK

Tujuan kajian ini ialah mengurangkan tahap kemusnahan kereta penumpang yang disebabkan oleh perlanggaran automobil. Bumper adalah satu bahagian yang dilindungi, yang dipasang kepada bahagian depan dan belakang automobil. Ia boleh dibuat daripada aluminium keluli atau bahan plastik yang ringan. Tujuan utama kajian ini adalah untuk mengkaji tentang serapan tenaga bim bumper. Bumper kereta Eropah yang dibuat daripada aluminium dan plastik telah diuji untuk menentukan serapan tenaga. Tiga spesimen dari setiap bahan dipotong dalam bentuk yang sama tetapi dengan kelebaran berbeza iaitu 20mm, 40mm, and 80mm. Kajian dijalankan mengikut tiga peringkat, iaitu satu eksperimen menggunakan mesin ujian universal (UTM); satu pendekatan teoretikal tentang bentuk spesimen mengandaikan bahawa spesimen berbentuk separa-heksagon dan separa-bulatan, menggunakan satu ekspresi dalam mengira kecacatan dan serapan tenaga. Kajian mendapati bahawa bahan aluminium menyerap lebih tenaga dengan kurang kecacatan berbanding dengan bahan plastik. Kajian menyimpulkan bahawa kelebaran besar 80mm menyerap lebih tenaga dan kurang kecacatan dari 40mm and 20mm pada bahan yang sama. Kawasan hubungan yang luas dengan beban yang diaplikasi meningkatkan lagi kapasiti serapan tenaga bahan tersebut. Pendekatan teoretikal menunjukkan bahawa keputusan adalah lebih kurang sama dengan bentuk separa-bulatan agar bentuk spesimen ujian hampir kepada separa-bulatan.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
DOE	Design of Experiment
EA	Energy Absorber
FE	Finite Element
FEM	Finite Element Method
FEA	Finite Element Analysis
GMT	Glass Mat Thermoplastic
NHTSA	National Highway Traffic Safety Administration
PEP	Plastic Polypropylene
R&D	Research and Development
UTM	Universal Testing Machine

LIST OF SYMBOLS

A	Cross-sectional area of specimen
L	length of specimen
Y	Yield Strength
F	applied load/force
σ_y	Yield stress
Δ	Elongation
σ	stress
θ	angle
M_p	Moment
r	Radius
D	Dimeter
W	Width
T	Thickness
B	Angle
Sec.	Second
mm	Millimeter
MPa	Megapascal

CHAPTER 1

INTRODUCTION

1.1 Introduction

According to Zhang & his co-authors, a combination of components in a vehicle's front and back of the vehicle is designed for the damping of the kinetic energy without any damage to the vehicle in low-speed impact for energy dissipation in high-speed impact conditions other than serving for aesthetic and aerodynamic purposes (Zhang et al., 2009). The worldwide automotive production rate is on the rise and it is estimated to reach 76 million cars per year by 2020 (Davoodi, 2012). The exponential pace of the automotive technology nowadays requires engineers to be more innovative in their product design. The design automotive engineers must be accurate and they have to demonstrate careful attention for the work they produce. Through the time, many car manufacturers have tried new kinds of materials to make good front car bumpers for their customers to avoid human fatality in car accidents. The front car bumpers play an important role to save customers' lives.

Bumpers are the protective parts installed on the front part of the automobiles that are made of steel aluminium or plastic light weight material. Although they are light, bumpers are made to be tough, flexible, weather resistant and durable. The main aim of a bumper is to prevent the unnecessary destruction of auto parts by absorbing low-level impacts. By statistics, it has been reported that in Malaysia, in 2009 alone more than 23,000 people died due to traffic car accident and low quality safety material used in cars (Davoodi, 2012).

The growing concern and demand that has to be met in the automotive manufacturing industry are to equip the vehicles with high safety features, but at a lower cost. Perhaps, the weight reduction of the car is a feasible idea to lower the energy consumption but the manufacturers must acknowledge the fact that the reduction of the weight might put the safety of the car at stake where safety should be the key feature among passenger cars (Jamail, 2009). The most common impact and crash patterns during vehicle accidents account for about 40.0% with regard to the front bumper (Deng, 2010).

Since the weight reduction is crucial in automobile industries, it is important to design a thin-walled structure which might absorb high energy through deformation in the crash. The vehicle's front part is more vulnerable and can collapse more easily in an accident, where the front can absorb energy more; the higher the energy absorbed the safer the driver and passengers in the vehicle. The frontal bumper of the vehicle is a highly energy-absorbing area and it is connected with the thin wall structure of the vehicle, engine and so on (Jovan, 2010; Lorenzo, 2009).

In the design of the vehicle bumpers system by the application of load conditions the real-time load impact on the bumper has been neglected. The negligence over the real-time load impact on the vehicle bumper spurs us to conduct a further investigative study surrounding real-time collision and energy absorption impact on the bumper beam. In terms of the vehicle safety performance indexing impact, the energy absorption plays a big role and importance. Several studies in the past have taken a closer look at the car's frontal structural energy performance and optimization. Thus, a limited study has been conducted to dwell into the real-time collision energy absorption impact on the vehicle bumper. (Davoodi, 2012).

Bumpers can be made of vinyl ester resin, multilayer fibreglass, and gel coat finish. The polymeric composite material technology boasts off qualities like highly specific stiffness, low weight, corrosion free, and the ability to produce complex shapes, high specific strength, and high impact energy absorption. Polymeric composite materials implementation in the automobile aims to decrease the weight and fuel consumption of the vehicles this is as shown in Figure 1.1. The traditional bumper made of steel and aluminum material is substituted by the newly introduced polymeric composite materials. The parts replaced are a bumper beam, bumper fascia, spoiler, connecting rod, pedal box system, and door inner panel. The bumper system has three main components, namely bumper beam, fascia, and energy absorber (Jamail, 2009).

The external wall structure body of the automobile is a hazardous system and it assumes a different task. As it is, any other automobile structures also play an important role where they hold all components together like one body also makes occupants feel comfortable. Importantly, the tough structure of the car protects the occupants from accidents, therefore, the designer must design with appropriate features in mind (Samantaray, 2009).

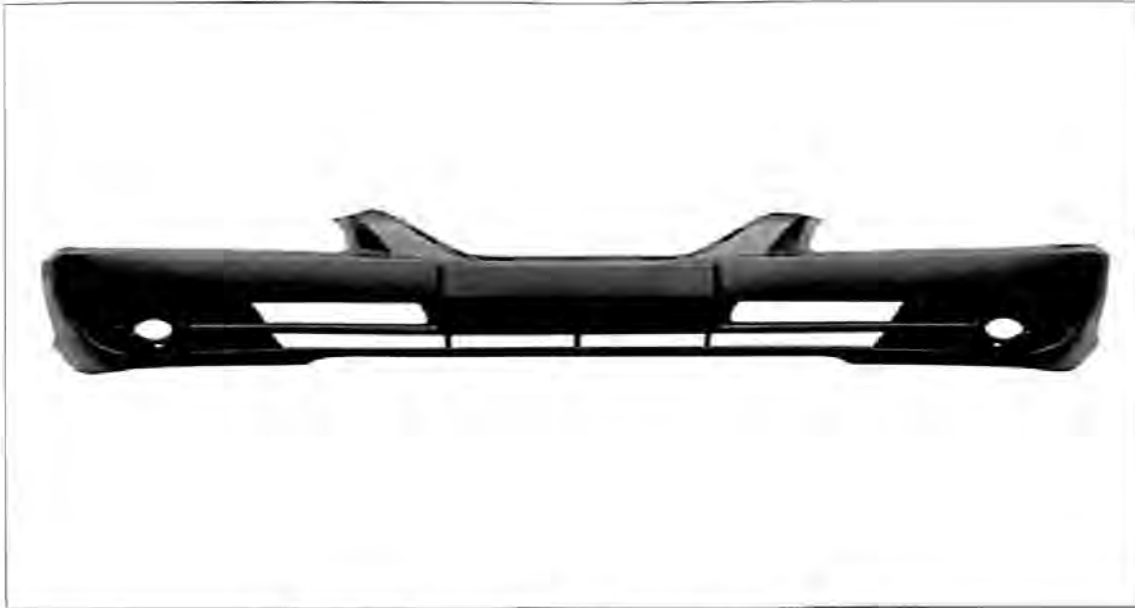


Figure 1.1: A sample of car bumper (Jamail, 2009)

There has been an increasing rate of fatality because of the speedy collision of cars because of the less durable vehicle bumpers. The lightweight bumpers in the modern vehicle technologies need to be improved further to increase the performance efficiency during the crash. The crash impact and energy absorption on bumper could be addressed if the vehicle front bumper can extend the pressure during a collision and divert it onto the structure. For several years, the bumper has always been getting the attention from the designers and researchers where work is always in progress to determine new materials and design to ensure safer and better energy absorption of the vehicles, (Liu, 2008).

The use of plastic in auto bumpers and fascia tends to liberate the designers when it comes to styling a prototype vehicle, or improving an existing model. Plastic can be styled for both aesthetic and functional reasons without so much leaving an impact to the cost of production. Plastic bumpers contain reinforcements that allow them to be as impact-resistant as metals although they are less expensive to replace than their metal equivalents.

Plastic car bumpers under most circumstances expand at the same rate as metal bumpers under normal driving temperatures and do not usually necessitate special fixtures to keep them in order. Energy absorber is a device which transforms the kinematic energy of impact into another form of energy and its main purpose is to mitigate the destructive force that is transferred to the structure. Energy absorbers such as thin-walled tubes, honeycombs also foams are frequently used in the industry and among them; thin-walled sections are used extensively in vehicles, rail transportation, and air industries. A good car bumper design must provide safety for passengers and it should have a low weight. Different countries have different bumpers' performance standards. The best bumper always caters for the need of the automobile industry where they can protect users in car accidents, so this study sheds light on the impact of energy absorbed by the bumpers (Bois, 2004).

1.2 Problem Statement

An investigation into energy absorption necessitates an understanding of materials engineering, structural mechanics and impact dynamics. It is done by looking into the deforming mode as well as the load-displacement characteristics. Thus, the data of the applied load and energy absorption can be determined and saved to help the manufacturer create the most suitable impact of energy absorption of bumpers.

1.3 Objective

The objectives of the study are;

- i. To observe the mode of deformation.
- ii. To examine the load-displacement characteristics.
- iii. To compare the experimental results with theoretical results.

1.4 Scope of Study

The scope of the study starts with the review of past studies. The material selection includes the purchasing of used car bumper structure fabricating into the design required. The specimens are compressed quasi-statically to get the load-displacement. The linear elastic, plateau and densification zone are identified. The determination of densification is of utmost importance as the energy absorbed can be determined. The load-displacement characteristic is compared with the theory and current road traffic accidents data collections and the major impact on the vehicle body analyzed. The study will establish detailed information concerning the accident load impact on the vehicle bumpers and results. Our current work looks into the deformation that occurs in the bumpers under various load applications.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The vehicle frontal bumpers play a major role in accidents where most accidents took place front to front and durable bumpers make the defensive components of the occupants. This part of the study has overviewed the capabilities of the traditional bumpers. The study has highlighted this aspect. The outcomes and investigation outlined in the past are also discussed in this chapter. Furthermore, the previously adopted method in the improvement of car bumpers design and impact also is also discussed. This is important to comprehend the energy absorbers' implementation that has taken place within the structure body where the kinetic energy is transformed into other forms. Primarily, the energy absorber is designed to reduce the effect of exerted forces on the vehicle's occupants and stimulate the distribution of the impact energy around the passenger cabin.

2.2 Bumper

In the introductory chapter, a vehicle has two bumpers, which are the front bumper and rear bumper. The key function of the car bumper is to protect the passenger or occupant with any object during the occurrence of a collision. The bumper systems also protect the hood, trunk, fuel, exhaust and cooling system as well as safety-related equipment. The front bumper is normally made of aluminum, steel rubber, composite or plastic mounted on the front and rear of an automobile vehicle.

The bumper is capable of absorbing the energy when slow speed collision occurs so during this time the bumper absorb the energy to prevent or reduce the damage to the vehicle. In some bumpers, the energy absorber is strong enough to resist to the high-speed collision and absorb high energy (Hosseinzadeh, 2005).

2.2.1 Front Bumper System

A bumper system consists of three components namely Fascia, an energy absorber and bumper beam as shown in Figure 2.1. Owing to the development and government's new rules to provide safety, the material and designing concepts have changed through the years. Brief descriptions of the components are provided in the following sub-sections.

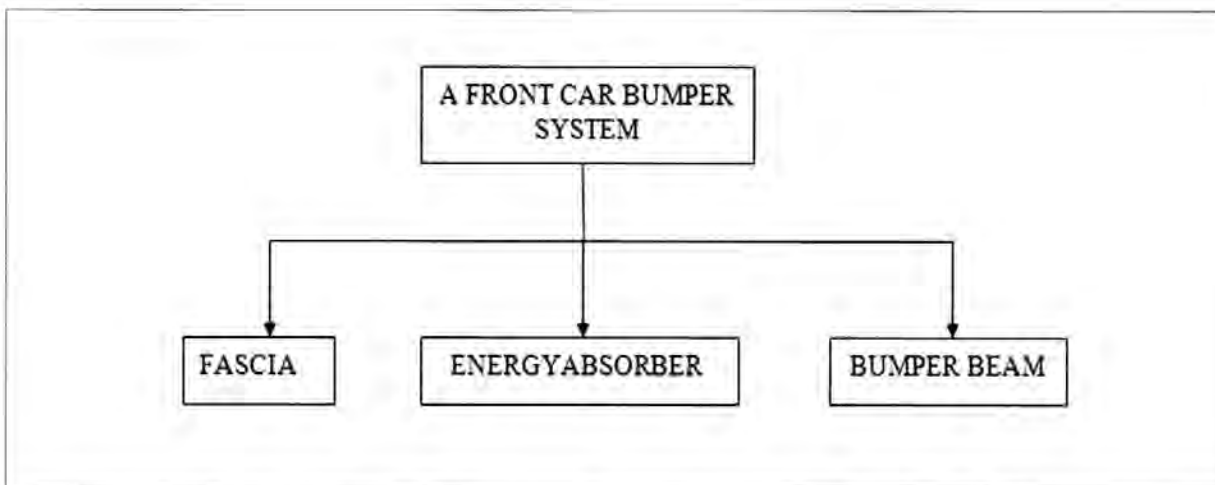


Figure 2.1: Automotive bumper system components (Zhang, 2009)

Bumper fascia is set to meet a few prerequisites. It must be streamlined to control the stream of the air around the auto and the measure of air that goes into the motor compartment. It ought to satisfy the customer. Average sash is styled with numerous bends and edges to give guard measurement and to recognize vehicles from the contending