UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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ENERGY ABSORPTION ANALYSIS OF LOW SPEED FRONTAL IMPACT FOR BUMPER BEAM THROUGH FINITE ELEMENT ANALYSIS

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A thesis submitted
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DECLARATION

I declare that this thesis entitled "Energy Absorption Analysis of Low Speed Frontal Impact for Bumper Beam Through Finite Element Analysis" 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	:	Muhammad Nasiruddin bin Su
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 Science in Manufacturing Engineering.

Signature	:	…………………………………..
Supervisor Name	:	Associate Professor Dr Hambali Arep@Ariff
Date	:	

DEDICATION

I would like to dedicate this thesis especially to my parent (Su Musa and Rosiah Ahmad) and also my whole family who have been source inspiration. Without their prayer, probably impossible for me to complete this study. Thank you very much.

ABSTRACT

Bumper beam is a safety feature of a car where it functions to absorb impact energy during collision. It is important to improve the bumper beam design in order to improve vehicle safety. Natural fiber composite has been introduced to replace the use of conventional materials because it has advantages of low density, high specific strength and stiffness. Natural fibers like kenaf and hemp have low cost and low density which can replace the glass fibers. Bertam leaves composite has not been explored before in automotive bumper beam. This thesis provided information on different bumper beam design structures focusing on energy absorption analysis. The aim of the research is to determine the capability of energy absorption for five conceptual cross section designs for low speed impact of three materials namely low carbon steel, bertam leaves fiber reinforced polyester and sheet moulding compound. Explicit dynamic simulation was adopted using Ansys LS Dyna software to simulate the frontal low speed impact of bumper beam according to Economic Commission for Europe Regulation No 42. Five new cross section designs have been proposed. AHP-TOPSIS method was used to determine best design through identified product design specification of frontal low speed impact low carbon steel bumper beam. Through the seven elements identified in product design specification using AHP-TOPSIS method, cross section 4 (C4) design of bumper beam was the best with Ci value of 0.564. Four parameters namely cross section, wall thickness, materials and ribs influenced the energy absorption and were taken into account for further study. Closed section bumper was slightly better compared to open section bumper beam in energy absorption. C1 closed section bumper beam was capable of absorbing up to 82.79 % of impact energy. Composite material can reduce the bumper beam weight where the bertam leaves fiber reinforced polyester decreased the weight of bumper beam by 87.04 % and sheet moulding compound decreased the weight of bumper beam by 76.75 % compared to low carbon steel. Both composite material with wall thickness of 1.2 mm does not suitable for consideration in automotive bumper beam as the maximum deflection exceed the limit set 30 mm. For wall thickness, as the wall thickness increased, the maximum deflection of bumper beam decreased as well. Two ribs design was added to the C4 bumper beam namely vertical and horizontal rib. A horizontal rib has the highest energy absorption capability which is improved 26.93 % and deflection of bumper beam improved 2 % to 9 %. This thesis can be used as a guideline to design and selecting the best design automotive bumper beam based on the parameters studied and method selection used to determine the best design.

ABSTRAK

Rasuk bamper adalah ciri keselamatan kereta di mana ia berfungsi untuk menyerap tenaga hentaman semasa perlanggaran. Adalah penting untuk meningkatkan reka bentuk rasuk bamper untuk meningkatkan keselamatan kenderaan. Komposit gentian semulajadi telah diperkenalkan untuk menggantikan penggunaan bahan konvensional kerana ia mempunyai kelebihan kepadatan rendah, kekuatan khusus yang tinggi dan kekakuan. Serat semulajadi seperti kenaf dan rami mempunyai kos yang rendah dan ketumpatan yang rendah boleh menggantikan gentian kaca. Daun bertam komposit belum dikaji sebelum ini dalam penggunaan rasuk bamper automotif. Tesis ini memberikan maklumat mengenai struktur reka bentuk rasuk bamper yang berbeza yang memberi tumpuan kepada analisis penyerapan tenaga. Tujuan penyelidikan ini adalah untuk menentukan keupayaan penyerapan tenaga untuk lima reka bentuk konsep keratan rentas untuk hentaman berkelajuan rendah untuk tiga bahan iaitu keluli karbon rendah, serat daun bertam poliester dan sebatian acuan lembaran. Simulasi dinamik telah diguna pakai menggunakan perisian Ansys LS Dyna untuk mensimulasikan hentaman hadapan berkelajuan rendah rasuk bamper mengikut Peraturan Suruhanjaya Ekonomi Eropah Nombor 42. Lima reka bentuk keratan rentas baru telah dicadangkan. Kaedah AHP-TOPSIS digunakan untuk menentukan reka bentuk terbaik melalui spesifikasi reka bentuk produk yang dikenalpasti hentaman hadapan berkelajuan rendah rasuk bamper keluli karbon rendah. Melalui tujuh elemen yang dikenalpasti dalam spesifikasi reka bentuk produk menggunakan kaedah AHP-TOPSIS, keratan rentas rasuk 4 (C4) adalah reka bentuk rasuk bamper yang terbaik dengan nilai Ci 0.564. Empat parameter iaitu keratan rentas, ketebalan dinding, bahan dan tulang rusuk mempengaruhi penyerapan tenaga diambil kira untuk kajian lanjut. Rasuk bamper tertutup agak lebih baik berbanding dengan rasuk bamper bahagian terbuka dalam penyerapan tenaga. C1 rasuk bamper tertutup mampu menyerap sehingga 82.79% tenaga hentaman. Bahan komposit boleh mengurangkan berat rasuk bamper di mana serat bertam polimer menurunkan berat rasuk bamper sebanyak 87.04 % dan sebatian acuan lembaran menurunkan berat rasuk bamper sebanyak 76.75 % berbanding keluli karbon rendah. Kedua-dua bahan komposit dengan ketebalan dinding 1.2 mm tidak sesuai untuk dipertimbangkan dalam rasuk bamper automotif kerana pesongan maksimum melebihi had ditetapkan iaitu 30 mm. Untuk ketebalan dinding, semakin meningkat ketebalan dinding, pesongan maksimum rasuk bamper akan menurun. Reka bentuk dua tulang rusuk telah ditambahkan ke rasuk bamper C4 iaitu tulang rusuk menegak dan mendatar. Rusuk mendatar mempunyai keupayaan penyerapan tenaga tertinggi iaitu meningkat sebanyak 26.93 % dan pesongan rasuk bamper meningkat 2 % hingga 9 %. Tesis ini boleh digunakan sebagai panduan untuk merekabentuk dan memilih reka bentuk terbaik bamper automotif berdasarkan parameter yang dipelajari dan pemilihan kaedah yang digunakan untuk menentukan reka bentuk terbaik.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AHP	-	Analytical Hierarchy Process
CMVSR	-	Canadian Motor Vehicle Safety Regulation
CI	-	Consistency Index
CR	-	Consistency Ratio
COR	-	Coefficient of Restitution
EA	-	Energy Absorption
ECE	-	Economic Commission for Europe
FEA	-	Finite Element Analysis
IIHS	-	Insurance Institute for Highway Safety
MCDM	-	Multi Criteria Decision Method
NHTSA	-	National Highway Traffic Safety Administration
OEM	-	Original Equipment Manufacturer
PDS	-	Product Design Specification
RCAR	-	Research Council for Automobile Repair
SEA	-	Specific Energy Absorption
SMC	-	Sheet Moulding Compound
TOPSIS	-	Technique for Order of Preference by Similarity to Ideal Solution

LIST OF SYMBOLS

J	-	Joule
J/kg	-	Joule per kilogram
Kg	-	Kilogram
m_A	-	Mass of the impactor
m_B	-	Mass of vehicle
mm	-	Millimeter
ms	-	Millisecond
v_0	-	Final velocity of the impactor and vehicle at maximum deflection point
v_A	-	Velocity of the impactor before impact
v_{A2}	-	Final velocity of vehicle
v_{B2}	-	Final velocity of the impactor after separation point

LIST OF PUBLICATIONS

Journal

1. Muhammad Nasiruddin S., Hambali A., Rosidah J., Widodo W.S., and Ahmad M.N., 2017. A Review of Energy Absorption of Automotive Bumper Beam. International Journal of Applied Engineering Research, Volume 12, Number 2 pp. 238-245 (ISSN:0973-4562)

Proceeding

1. Nasiruddin S.M., Hambali A., and Rosidah J., 2017. Energy Absorption Analysis of Different Cross Section Bumper Beam using Finite Element Analysis. Proceeding of Innovative Research and Industrial Dialogue'16 (IRID'16) pp. 97-98 May 2017

CHAPTER 1

INTRODUCTION

1.1 Backgrounds

The bumper system is mainly to protect the body of the car and passengers against collision. A front bumper system consists of three main components namely fascia, absorber and bumper beam (Sapuan et al., 2005). The fascia is often used to serve aesthetics purpose and decrease aerodynamic drag force, but it cannot tolerate impact energy. Hence, it is considered a non-structural component. The absorber is designed to dampen a portion of the kinetic energy from a collision. The bumper beam is a key structure that helps to absorb the kinetic energy from a high-impact collision and provide bending resistance in a low-impact collision (Davoodi et al., 2008).

There are many types of bumper beam structures which can be categorized as open and closed section. Modern automotive industry has two basic types which are close and open section. The close section is also known as “B” or “D” shape and open section is often known as “C” shape or “hat” sections (Heatherington et al., 2005). These different types of structures have different impact performances.

Energy absorption ability is very important. Bumper beam absorbs most of the kinetic energy during collision. Designers and engineers are facing huge challenges in identifying optimum design, material and process during the development of the bumper beam. Cross section structure of bumper beam affects the performance of bumper beam in