UNIVERSITI PUTRA MALAYSIA

CRASHWORTHINESS ANALYSIS OF ELLPTICAL AUTOMATIVE SIDE DOOR BEAM FOR LIGHTWEIGHT DESIGN

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia.
In Fulfillment of the Requirements for the Degree of Master of Science
January 2014

ABSTRACT

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chairman: Assoc. Prof. Rizal.Bin.Zahari, PhD
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Side door beam (SDB) is one of the most important components in a vehicle to protect the passengers from the side impact. Side impact is the second type of common accident after frontal impact. The limited physical space between the car body and the occupants lead to severe injury due to high deformation of the car body. The weight reduction and crashworthiness improvement of the SDB are two problems that must be solved. In this study, the main objective is to optimize the crashworthiness behavior of different SDBs under impact test. Reducing the weight of SDB as well as the maximum impact load are two significant targets which are investigated simultaneously. In this respect, the specific energy absorption (SEA) and the peak load (PL) are two parameters which play the role key to develop the aforementioned goals. To investigate the crashworthiness of an SDB, two cross-sectional configurations of SDB which are elliptical and rectangular are selected. Three material alloys of magnesium, aluminum and steel as a reference material are assigned to the elliptical and rectangular SDB. In addition, these simulations are conducted with three orientation angles which are 0,45 and 90 degree with respect to the rigid wall impactor. For each case of studies, the elliptical and rectangular cross section of the SDB under each orientation angle is taken into account by considering two variables of geometrical parameters; thickness for both design beam and minor to major radii ratio for elliptical and ratio of sizes for rectangular shape. All the aforementioned steps are performed by LS-DYNA software which are used widely for impact problems. The multi-objective optimization framework is used to find the optimum geometrical characteristics in each series of simulations. Consequently, the optimization process of the SDB is performed using response surface method (RSM) in terms of the weight average method and the geometrical average method. The series of results are presented in a Pareto Frontier graph to show a group of solutions with optimal points and to meet both mentioned objectives at the same time. The optimization steps are performed by MATLAB software. The results show magnesium alloy has good ability to absorb more energy compare with the aluminium and steel alloys. On the other hand, elliptical cross section cause to lower

PL respect to rectangular design. Also, the orientation angle of 90 degrees lead to decrease the PL compare with the 0 and 45 degree. Consequently, elliptical SDB made by magnesium material with the angle of 90 degrees with respect to the rigid wall became the best solution in order to achieve the highest energy absorption (SEA) and the lowest peak load (PL). The selected SDB is optimized to get the optimal design which shows it has 0.5mm thickness and the ratio of radii is 0.284. The SEA and PL of optimized SDB are equal to 1203.74 (J/Kg) and 8.477 (KN) respectively.

ABSTRAK

Abstrak tesis yang dikemukakan kepeda Seant Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

ANALISA KEBOLEH TAHANAN HENTAMAN RASUK PINTU SISI ELIPTIC DENGAN REKAAN RINGAN

Oleh

EHSAN RASOOLIYAZDI

Januari 2014

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SDB adalah salah satu komponen penting dalam kenderaan untuk melindungi penumpang darpada kecedaraan sisi. Kesan sisi la merupakan kecedaraan jenis kedua selepas kecedaraan hadapan. Ruang fizikal terhad antara badan kereta dan penumpang menjurus kearah kecederaan parah disebabkan kecacatan tinggi badan kereta. Pengurangan berat badan dan peningkatan crashworthiness SDB ialah dua masalah yang mesti diselesaikan. Dalam kajian ini, objektif utama ialah untuk mengoptimumkan tingkah lack crashworthiness SDBs berbeza di bawah ujian hentaman. Mengurangkan berat SDB serta beban kesan maksimum ialah dua sasaran penting yang mana disiasat serentak. Dalam hubungan ini, penyerapan tenaga (SEA) tertentu dan beban puncak (PL) ialah dua parameter yang memainkan peranan utama menghasilkan matlamat-matlamat tersebut sebelumnya. Untuk menyiasat crashworthiness SDB, dua konfigurasi berkereta rentas SDB yang mana bujur dan segi empat tepat lelak dipilih. Tiga pancalogam bahan magnesium, aluminum dan keluli sebagai satu bahan rujukan ditugaskan kepada SDB yang bujur dan segi empat tepat. Sebagai tambahan, simulasi-simulasi ini dikendalikan dengan tiga setiap iaitu 0, 45 dan 90 darjah seiring dengam dinding tegar. untuk kes kajian, kereta rentas bujur dan segi empat tempat SDB di bawah setiap sudut orientasi diambil kira dengan mengambil kira dua pembolehubah geometri, ketebalan untuk kedua-dua. Reka cipta alur dan nisbah jejari minima ke maksima untuk bujur dan nisbah saiz untuk bentuk segi em empat tepat. Semua langkah-langkah tersebut dilakukan dengan bantuan perisian LS-DYNA yang mana digunakan secara meluas untuk masalah-masalah kesan. Rangka kerjapeng optimuman yang pelbagai objektif digunakan untuk mencari cirri-ciri geometri yar optimum di setiap siri simulasi. Akibatnya, proses pengoptimuman SDB dijalankan menggunakan kaedah permukaan (RSM) gerak balas yang kaedah berat menggunakan purata dan kaedah purata geometri. Siri keputusan dibentangkan menggunakan Pareto graf menujukkan beberapa jalan penyelesaian dengan mata optimum dan untuk mencapai kedua-dua objektif tersebut secara serentak. Langkah-langkah pengoptimuman dilakukan menggunakan perisian MATLAB. Keputusan menujukkan magnesium mempunyai kebolehan yang baik untuk meresap lebih banyak tenaga berbanding aluminium dan keluli. Sebaliknya, keratan rentas bujur. Mengurangkan PL seinig dengan reka

bentuk segi empat tepat. Juga, sudut orientasi 90 darjah menjurus pengurangan PL berbanding kesannya pada 0 dan 45 darjah. Akibatnya, SDB bujur yang diperbuat menggunakan magnesium dengan sudut 90 darjah terhadap dinding tegar menjadi penyelesaian terbaik untuk mencapai penyerapan tenaga (SEA) tertinggi dan bedah puncak (PL) terendah. SDB terpilih dioptimumkan untuk mendapat reka bentuk optimum yang menunjukkan ia mempunyai ketebalan 0.5mm dan nisbah jejari 0.284. value untuk SEA dan PL kepada SDB yang optimum adalah 1203.74 (J/kg) dan 8.477 (kN)masing-masing.

ACKNOWLEDGEMENT

"In the name of Allah, Most gracious, Most merciful"

First of all, great thanks and praises are due to Allah, the Lord of all that exist. May Allah's peace and blessing be upon his final prophet and messenger, Muhammad, his family and his companions.

I would like to thank my supervisor, Assoc.Prof.Rizal. Bin. Zahari, for guidance in my master research. I would like to appreciate from my supervisory committee, Prof. Barkawi. Bin.Shari and Assoc.Prof.Faieza.Abdul.Aziz for their suggestion and assistance throughout the years. Also thanks to Mrs.Salwani for help me to learn LS-DYNA software. Special thanks to my parents for their support and blessing during my hardest time in completing this research.

I certify that a Thesis Examination Committee has met on 15th of January to conduct the final examination of Ehsan Rasooliyazdi on his thesis entitled "Crashworthiness Analysis Of Ellptical Automative Side Door Beam For Lightweight Design " in accordance with the University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

SDB	Side Door Beam
SEA	Specific Energy Absorption
PL	Peak Load
LMS	Lumped Mass-Spring model
FE	Finite Element models
CAD	Computer Aided Design
MBD	Multi Bodies Dynamic models
DOE	Design of Experiments
NN	Neural Network
RBF	Radial Basis Fuction
RSM	Response Surface Method
CAE	Computer Aided Engineering

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, the number of accidents has increased in the recent years dramatically. Considering to the last statistical which achieved from the research, more than 1 million people are dead in road accident each year (Murray *et al.*, 2006). Consequently, the safety of passenger requires more focus on the crashworthiness of vehicles.

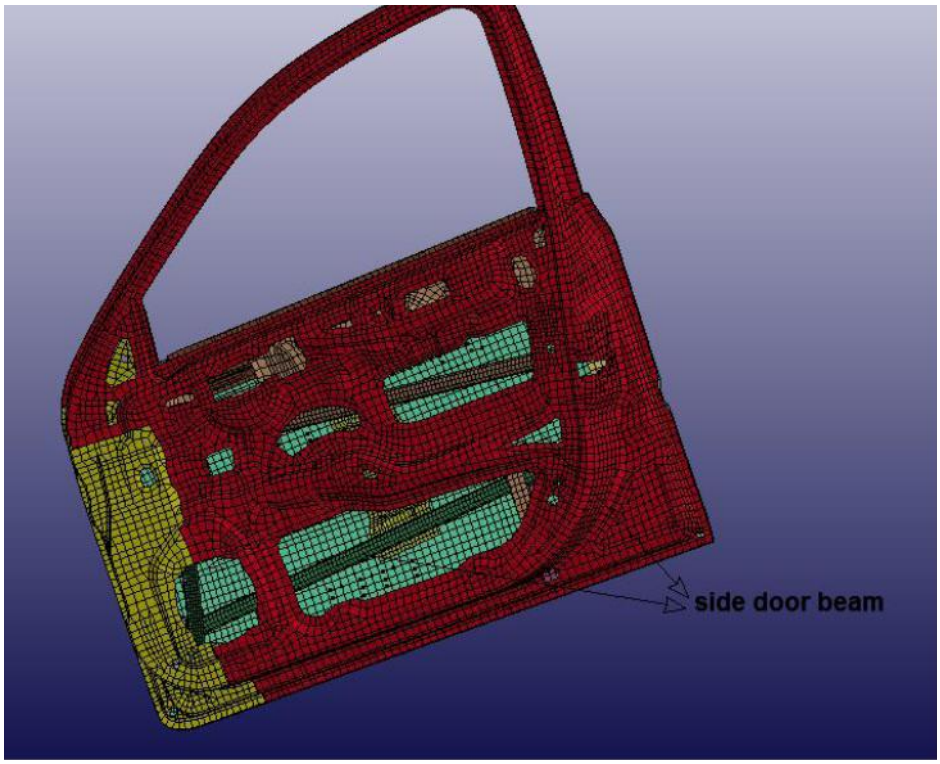
Currently, most of companies in the world spend more money to improve the safety of cars because it is an essential parameter for customers and an important factor for competitions between companies productions. Companies perform the impact test on vehicles to find the best design for improving the crashworthiness. Side impact is one kind of test to assess the crashworthiness of vehicles. In the side impact, the crumple zone by accident is limited and occupants are very close to the car body. Side impact is the second type of common accident after frontal impact. Accordingly, development of safety for side impact is important. General Motors was the first company that evaluated the side impact with barrier in 1934 in Michigan (Raja, 2008).

In the past decades, the companies used a real car for experimental test and then, they had been analyzed the results which obtained from the test. These tests are too expensive and time consuming. This problem was solved by researcher when they used the nonlinear finite element method. Nonlinear finite element method is a tool to simulate the crash test with high accuracy. This method helps to designers to analyze the crash test relatively easily with high reliability.

Thin walled structures have more application in industry. In vehicles, thin walled structures are used because of their lightweight. These structures have a good ability to absorb the impact energy and resistance against the folding and bending. In this study, the elliptical and rectangular beams are examined in the impact test. This beam uses inside the car doors to protect the passengers subjected to the side impact.

In the automotive industry, several kinds of materials are used: steel, magnesium and aluminum. Due to their properties, steel is stiffer than others, but is heavier. On the other hand, magnesium is very interesting material, because it is so light. It is three times lighter than steel, so it is suitable in some part of structures which needs lighter material.

Response surface method (RSM) is one of the approximate methods that is widely used for impact problems. In impact problems, maximizing the specific energy absorption (SEA) and minimizing the peak load (PL) are two targets which have to obtain simultaneously. In this work, the multi - objective optimization is used to optimize the size of the beam. The results of multi-objective optimization are presented by the Pareto Frontier graph. All points in the graph are optimal points. It depends on designer that which parameter between SEA and PL is more important.


side door beam

1- To investigate the effect of material and the orientation angle of impact loading on the structural behavior of elliptical and rectangular SDB subject to the side impact.
2- To obtain the optimal design of both the elliptical and rectangular section beams subjected to side impact loading using multi-objective optimization.

Based on the previous studied which are mentioned in chapter 2, changing the materials and the cross section of the beams can lead to the improvement of the SEA and have a positive effect to decrease the PL. Moreover, the position of the beam while it collides with the rigid wall can cause to change the PL. So, these are the research hypothesis which are investigated to be proved.

1.4 Research Scope

As it is mentioned, the goal of this research is improving the crashworthiness of SDB. To achieve this goal, elliptical and rectangular configuration of the SDBs are selected for impact analysis. The materials which are used for the SDBs are alloy steel AISI1006, alloy aluminum 3105-H18 and alloy smagnesium AZ31B. These materials are selected because they are widely used in the automotive industry. The orientation angle of SDB to rigid wall is another item which investigated for all SDBs that have different materials. Three angles of 0,45 and 90 degrees are selected for investigation. To evaluate the impact tests, The CAD data of the SDBs are modelled, meshed and simulated in Ls-Dyna 3.1 Beta software. After that, multi-objective optimization is applied to achieve the optimal design. In this research, the results optimized by MATLAB software.

1.5 Thesis Structures

This thesis consists of five chapters. First chapter consists of problem statement, objectives, research scope and thesis organization. In the second chapter, literature review is written that it shows what works have been done with other researchers till yet. The third chapter is methodology which explains the way of working on this study. Chapter 4 consists of the results and discussion that shows the results of impact test on beam and also Optimization of the results is done for getting the optimal design. Finally the last chapter shows the recommendations and conclusions of this research.

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