DEVELOPMENT OF AN ACTIVE BUMPER SYSTEM TO REDUCE VEHICLE CRASH IMPACT

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‘I/We approve that we have read this thesis thoroughly and in my/ our opinion, this thesis is has fulfilled the criteria covering all the aspects of scope and quality and satisfied to be awarded for Bachelor of Mechanical Engineering (Automotive).’

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"I admit that this report is all written by myself except for the summary and the article which I have stated the source for each of them."

Signature :……

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To my beloved family and friends

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First of all, I would like to thank Allah for giving me blessings to finish up this project until it is completed. In this segment, I would like to give my appreciation to all those peoples who were assisted me a lot in order to successfully end up this project.

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ABSTRAK

Rekabentuk terbaru “Aktif Bamper” dalam projek ini ialah satu sistem bamper yang menggunakan peredam magnetorheological (MR) untuk menyerap daya impak ketika perlanggaran. Beberapa pengilang automotif telah pun menggunakan sistem penyerapan kejutan yang menggunakan peredam pasif yang dipasang diantara bamper dan casis kenderaan. Walau bagaimanapun, dengan menggunakan system ini kebanyakan daya akan di serap melalui pemadatan peredam dan daya berlebihan akan dipindahkan ke casis kenderaan. Sistem ini biasanya mempunyai pekali peredam statik yang tinggi dan tidak mampu menyerap daya perlanggaran berkelajuan tinggi. Di dalam projek ini kami cuba menggunakan peredam MR yang membenarkan pekali redaman dinamik untuk meminimakan impak perlanggaran dan mengurangkan pemindahan lebihan daya ke badan kenderaan. Persamaan matematik, permodelan simulink dan kaedah ujian perlanggaran kenderaan berskala kecil direka. Keputusan ujian simulasi akan dianalisis untuk mengkaji potensi sistem aktif bamper.

ABSTRACT

A new Active Bumper that was designed in this project is a bumper system that uses magnetorheological (MR) dampers to absorb impact energy during collision. Some of the automotive manufacturers already use shock absorption system that consist passive damper located between the bumper and the vehicle chassis. However, by using this system most of the force will be dissipate by transmitting all the impact energy through the compression of the damper and the remaining force will be transferred to the vehicle chassis. This system normally has very high static damping coefficient and cannot dissipate higher speed collision force. In this project, MR dampers were used to provide dynamic damping coefficient and reduced the crash impact and lowering the transmission of the remaining force to the vehicle body. Mathematical equations, Simulink model, and a small scale vehicle crash test were designed. The simulation results were analyzed to determine the potential benefits of the active bumper system.

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E	=	Energy, Nm
m	=	Mass, Kg
v	=	Velocity, m/s
e	=	Coefficient of Restitution
I	=	Impulse, kgm/s
F	=	Force, N
μ	=	Coefficient of Friction
g	=	**A**cceleration of Gravity, m/s^2
K	=	Spring Stiffness, N/m
D	=	Damping Coefficient Ns/m
$\vec{j}$	=	Jerk, m/s^3

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CHAPTER 1

INTRODUCTION

A road vehicle normally have bumper to absorb an impact from a low velocity collision. Vehicles bumper are usually designed to withstand an impact of collision at a relative velocity of 5 to 15 km/h without having major damage (Buechele et al. 2004). Many conventional bumpers use a stationary impact absorbing structure that is design to deform permanently in order to prevent collateral damage to vehicle frame and car components.

A new Active Bumper is a system that reduces the crash impact by configuring the magnetorheological (MR) dampers that that have been attached between the car body and the front bumper. The MR dampers are semi-active control devices that use magnetorheorogical fluid to produce controllable dampers. The essential characteristic of controllable fluids is their ability to reversibly change from a free-flowing, linear viscous fluid to a semi-solid with controllable yield strength in milliseconds when exposed to an electric or magnetic field (Spencer et al. 1996).

When a collision occurs, the data acquisition device will send rapid signals to the MR dampers controller. The dampers controller in the vehicle central processor will then analyzing the data before sending appropriate control signal to the bumper MR damper. The input of the MR dampers is in the form of electrical currents which will be traveled through coils around the piston heads. This will cause an electromagnetic field and will effect the MR fluid hence change the damping coefficient suitably. All this will happen instantaneously during the collision to reduce the impact force effect.

1.1 Background Research

Automotive safety is intentionally to avoid vehicle accident or reducing the effect of accident especially to the human body including the driver, passengers and pedestrians. Moreover, some of the safety features are also purposely to reduce vehicle damages in order to minimize the repairing cost.

Active safety in vehicle system uses the information of vehicle external environment and the system will response accordingly to the situation during the phase of pre-crash or during the crash event. This is will either avoid the crash from happen or increase the safety of the vehicle by reducing the crash effect. Passive safety in the other hand is a system that only works to prevent injury but not change the vehicle action in response to crash scenario. The examples of the passive safety are like airbag, crumple zone, seat belt and passive automotive bumper.

A metal or plastic shell that is filled with a foam energy absorbing block of polypropylene or foam normally used in an automotive low-impact absorbing bumper construction, and is mounted to the vehicle on a relatively rigid beam (DePottey et al. 2004). The kinetic energy from the collision will be absorbed by the foam energy absorbing material through the deformation of the bumper structure. Many researches have been made regarding to the bumper deformation characteristic and absorption capability. Usually the research is concentrating on the selection of the bumper material like aluminum and composites.

In this project, the active bumper system is design to reduce the collision impact to through the compression of the MR damper that have dynamic damping coefficient. A vehicle frontal collision test rig was designed and a study on the collision characteristic is conducted during this project. The test rig was designed to conduct imitation of heavy, medium and light collision. A control structure was developed for the active bumper to minimize the jerk on the vehicle chassis. This is very important in order to avoid huge amount of impact force from transferring to the passenger compartment hence will probably cause serious injury or fatality to the vehicle occupants.

1.2 Problem Statement

Vehicle accidents have become a serious problem in Malaysia and all other country around the world. Every one of us has the probabilities to be involved in road accident including the pedestrian. Statistic shows that the numbers of road accident cases in Malaysia were increased every year in the last 11 years (refer Table 1.1 and Figure 1.2).

Table 1.1: General road accident statistics and fatality index in Malaysia.

(Source: www.miros.gov.my)

Year	Vehicles Registered	Road Length (km)	Number of		Fatality Index		
			Accidents	Death	Per 10,000 Vehicles	Per 100,000 Population	Per Billion VKT
1997	8,550,469	63,382	215,632	6,302	7.37	29.1	33.57
1998	9,141,357	63,382	211,037	5,740	6.28	25.3	28.75
1999	9,929,951	64,981	223,166	5,794	5.83	25.5	26.79
2000	10,589,804	64,981	250,417	6,035	5.7	26	26.25
2001	11,302,545	64,981	265,175	5,849	5.17	25.1	23.93
2002	12,068,144	64,981	279,237	5,887	4.88	25.3	22.71
2003	12,868,934	71,814	298,651	6,282	4.88	25.1	22.77
2004	13,801,297	71,814	326,815	6,228	4.51	24.3	21.1
2005	14,816,407	72,400	328,268	6,200	4.18	23.7	19.58
2006	15,790,732	72,400	341,252	6,287	3.98	23.6	18.69
2007	16,825,150	72,400	363,314	6,282	3.73	22.8	17.6

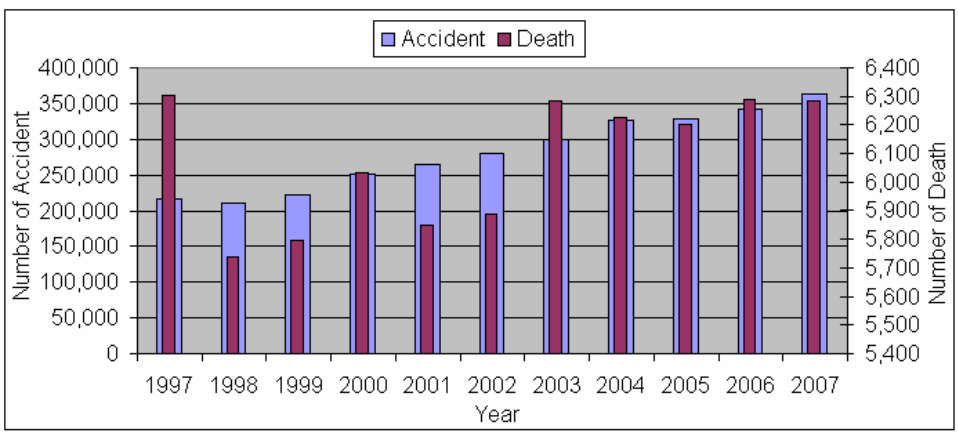

Figure 1.1: Road accident and death cases in Malaysia.

(Source: www.miros.gov.my)

In order to reduce the vehicle crash impact that will prevent injury and fatality, a lot of researches have been made to increase the crashworthiness of a vehicle structures and bumper. Active bumper is design to assist the absorption of impact energy through the compression of the MR damper that will reduce the transmission of the impact energy to vehicle body hence reducing jerk. The use of MR damper will allow the system to continuously vary the damping mode through a specific range. This will overcome the disadvantages of the conventional passive bumper damper.

1.3 Objectives and Scopes

The objectives of this project are as follows:

- To develop the equation of motion for front to front crash of vehicle.
- To develop the mechanism of an "Active Bumper System" using MR damper.

The scopes of this project are as follows:

- Simulation study on the potential benefits of an "Active Bumper System".
- Development of a small scale vehicle crash test methodology.
- To design a frontal collision test rig.

CHAPTER 2

LITERATURE REVIEW

Automotive safety has become major concern to the car manufacturers and will always be a subject of interest to the research and development (R&D) centers. Besides the improvement of drive train performance, safety is also plays an important role in order to convince customers that the vehicles are safe enough to be ride. This chapter consists of brief discussions regarding to current automotive safety technology including any existing technology or on going research that related to active safety system, energy management of frontal collision, active bumper system and magnetorheological (MR) damper.

2.1 Active Safety System

There are many factors that affecting the automotive safety. Vehicle safety can be categories into three main areas as follows (Seiffert and Wech 2007):

a) Accident avoidance – All measures that serve to prevent accident.
b) Mitigation of Injuries – All measures that help to reduce injury during accident.
c) Pre-Crash measures – All measures to reduce the severity of an accident after the sensor detect that that severe accident is unavoidable.

Active safety is more on preventive action to avoid accident (Bosch 2006). The examples of active vehicle safety system include ABS (Antilock Braking System), TCS (Traction Control System) and ESP (Electronic Stability Program).

In the field of accident avoidance three main influences are found (Seiffert and Wech 2007):

a) The human being
b) The technical features of a car
c) The environment

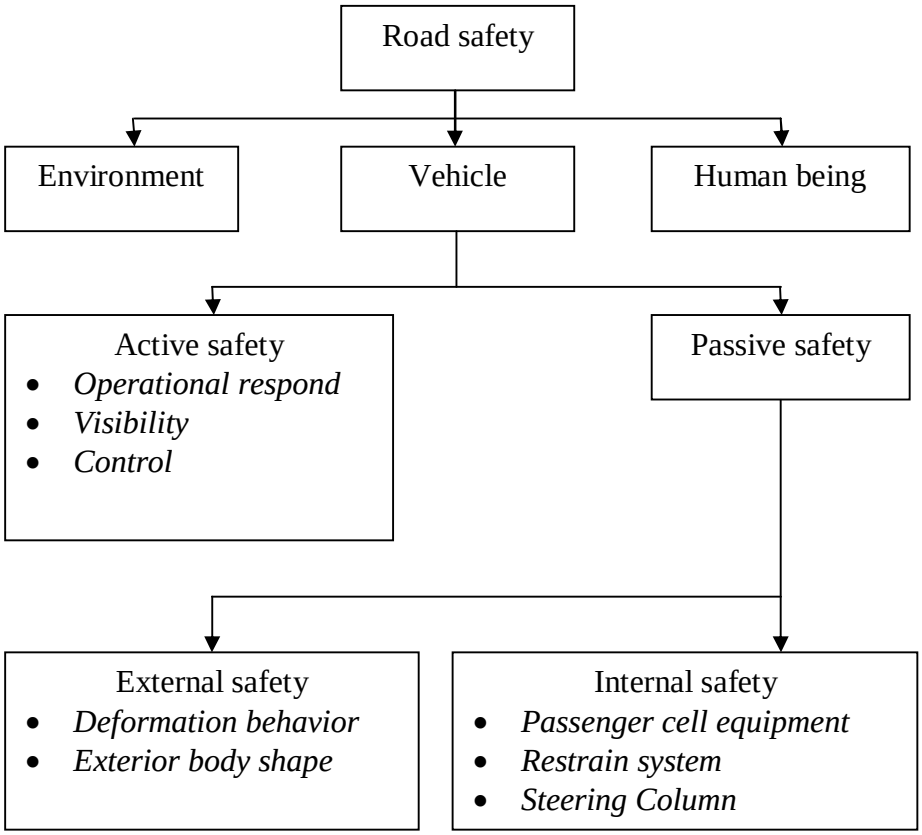

Figure 2.1: Safety when driving on roads

(Source: Bosch, 2006)

Active bumper system is also considered as an active system since it can respond due to the vehicle external environment condition and can prevent excessive damage to the vehicle frontal structure. The bumper is also has controller that capable to receive data and send control signal to configure the bumper MR dampers.

2.2 Energy Management of Frontal Collisions

The study on the energy management during frontal collision is very important. In order to prevent serious injuries, many vehicles are using structural features like crumple zone to absorb energy from an impact during head on collision through the compression of the vehicle structures. However, excessive compression and deformation of the vehicle body will probably affecting the passenger compartment. Any compression or deformation that involving passenger compartment may lead to serious injury to the vehicle occupant.

2.2.1 Crash Box

Many car manufacturers use crash box or thin wall as its front rail that can absorb impact energy through the collapse of the crash box. The materials that used as crash box are such as strength steel, aluminum alloy or composites.

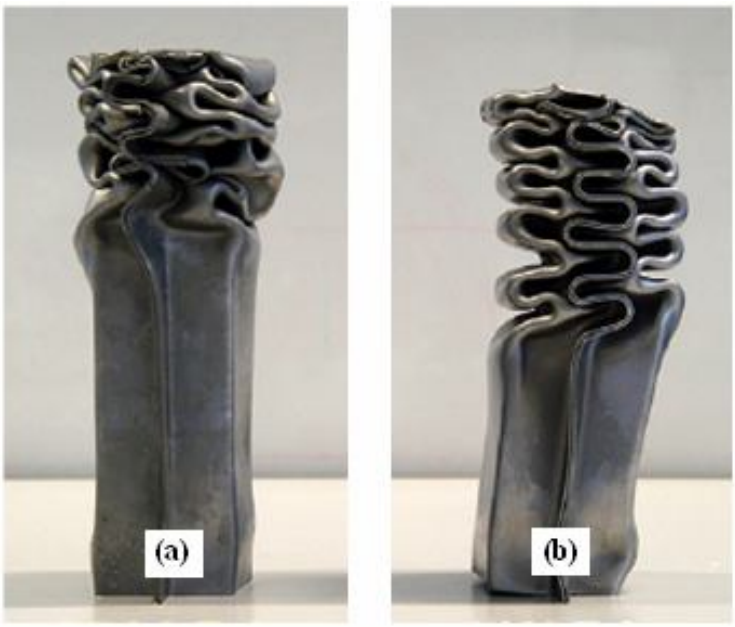

Figure 2.2: Folding pattern in quasi static test on (a) bonded crash box (b) laser welded columns

(Source: Peroni et al., 2008)