TRUCK CRASHWORTHINESS SIMULATION USING ANSYS

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "Truck Crashworthiness Simulation Using ANSYS" is the result of my work except as cited in the references

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report, and in my opinion, this report is sufficient in terms of scope and quality for the award of Bachelor of Mechanical Engineering.

Signature : ....

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Date : 07-02-2022

DEDICATION

My dissertation is dedicated to my family and lots of friends. An extraordinary sense of thanks goes out to my devoted parents, Sakka bin Matta and Raminah binti Kybe. Their words of support and prodding for persistence still ring in my ears. My siblings and friends have never left me and are exceptional.

ABSTRACT

Hundreds of people die in collisions between vehicles and large trucks each year. The greatest danger in the event of a collision between a car and a heavy vehicle is the invasion of the passengers' compartment under the heavy truck's rear underride, which might result in a fatal injury to passengers. The purpose of this paper is to examine, simulate, and analyse a Rear Under Run Protection (RUPD) system in a crashing state. The primary goal of creating the RUPD is to increase the vehicle's safety and occupants. This research aims to improve crashworthiness by creating a new rear underride protection device (RUPD) following FMVSS 223/224 rules. The material selection and structural design are the two primary determinants of impact energy absorption during a crash. This research focuses on the RUPD and the three factors that influence it: type of beam, angle of support, and material. Finite element simulation is utilised for performance analysis of the RUPD in ANSYS by static structural analysis and explicit dynamic analysis with different load distributions at various locations on the RUPD. The legal requirements for an RUPD are specified in regulation FMVSS 223/224 in the United States of America, CMVSS 223 in Canada, and ECE R 58 in Europe, which establishes stringent requirements for the device's design and behaviour under load that the device must meet in order to be approved for commercial vehicles. The results showed that the new RUPD design enhanced the energy absorption and was able to fulfil the standard requirement of crashworthiness.

ABSTRAK

Beratus-ratus orang maut dalam perlanggaran antara kenderaan dan trak besar setiap tahun. Implikasi sekiranya berlaku perlanggaran antara kereta dan kenderaan berat ialah pencerobohan ruang penumpang di bawah bahagian bawah belakang trak berat, yang mungkin mengakibatkan kecederaan maut kepada penumpang. Tujuan kajian ini adalah untuk meneliti, mensimulasikan dan menganalisis sistem Rear Underrun Protection Device (RUPD) berdasarkan situasi pelanggaran. Matlamat utama mewujudkan RUPD adalah untuk meningkatkan keselamatan dan penghuni kenderaan. Penyelidikan ini bertujuan untuk mencipta peranti perlindungan (RUPD) baharu mengikut peraturan FMVSS 223/224 untuk meningkatkan kelayakan kemalangan. Pemilihan bahan dan reka bentuk struktur ialah dua penentu utama penyerapan tenaga hentaman semasa kemalangan. Penyelidikan ini memberi tumpuan kepada tiga faktor yang mempengaruhinya: jenis rasuk, sudut sokongan dan bahan. Simulasi digunakan untuk analisis prestasi RUPD dalam ANSYS oleh analisis struktur statik dan analisis dinamik eksplisit dengan beban yang berbeza-beza di pelbagai lokasi pada RUPD. Keperluan undang-undang untuk RUPD dinyatakan dalam peraturan FMVSS 223/224 di Amerika Syarikat, CMVSS 223 di Kanada dan ECE R 58 di Eropah, yang menetapkan keperluan ketat untuk reka bentuk dan tindak balas RUPD terhadap hentakan yang mesti dipenuhi oleh peranti untuk diluluskan bagi kenderaan komersial. Keputusan menunjukkan bahawa reka bentuk RUPD baharu telah meningkatkan penyerapan tenaga dan mampu memenuhi keperluan piawai pelanggaran.

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LIST OF ABBREVIATION

FMVSS	Federal Motor Vehicle Safety Standards
CMVSS	Canada Motor Vehicle Safety Standard
ECE	Economic Commission for Europe of the United Nations
UTeM	Universiti Teknikal Malaysia Melaka
DALYs	Disability-Adjusted Life Years
SDRC	Smart Driving Research Center
HGV	Heavy Good Vehicles
RTA	Roads and Transport Authority
WHO	World Health Organization
DOSM	Department of Statistic, Malaysia
HVNL	Heavy Vehicle National Law
GVM	Gross Vehicle Mass
ATM	Aggregate Trailer Mass
PDRM	Polis Diraja Malaysia
EMR	Eastern Mediterranean Region
RnSUPD	Rear and Side Underride Protection Device
RUPD	Rear Underride Protection Device
UPD	Underride Protection Device
CAD	Computer-Aided Design
HOQ	House Of Quality
FBD	Free Body Diagram
P1	Force at Point 1
P2	Force at Point 2
P3	Force at Pointe 3

LIST OF SYMBOL

σ_x	=	Stress x-direction (Pa)
σ_y	=	Stress y-direction (Pa)
σ_{ave}	=	Stress Average (Pa)
P	=	Force (N)
A	=	Area (m^2)
M	=	Moment (Nm)
I	=	First Moment of Inertia (m^3)
τ_{xy}	=	Shear stress xy plane (Pa)
τ_{max}	=	Shear stress maximum (Pa)
R	=	Radius Mohr's Circle (Pa)
V	=	Shear Force (Pa)
Q	=	The First Moment of the Portion of the Area (m^2)
t	=	Thickness (m)
F.S.	=	Factor of Safety
S_{ut}	=	Ultimate Tensile Strength (Pa)
C	=	Radius (m)
σ'	=	Maximum Stress Von Mises (Pa)
δ_T	=	Total Deformation (m)
U	=	Strain Energy (J)

CHAPTER 1

INTRODUCTION

1.1 Background

Among all traffic accidents, road traffic accidents take the most lives and are the most severe issue worldwide. The number of people killed in traffic collisions worldwide has increased dramatically (RTA), with 1.24 million deaths predicted each year. Road traffic fatalities are the leading cause of death for young people and the eighth leading cause of death worldwide (Elvik, 2013; Kaygisiz et al., 2015). Developing countries account for roughly 85% of all deaths. Males, especially those between the ages of 15 and 44, are disproportionately affected by traffic accidents. Countries spend 1 to 2 per cent of their gross national product on traffic incidents (Elvik, 2013). Although developing countries account for only 52 per cent of all vehicles on the road, they are responsible for 80% of all traffic fatalities. (WHO, 2013). In reality, as shown in Table 1.1.1, road traffic Disability-Adjusted Life Years (DALYs) loss will change from the ninth essential cause of DALYs in 1999 to the third necessary cause by 2020, as predicted by the WHO (Mohammed et al., 2019).

Table 1.1. 1: Disease burden (DALYs lost) for ten leading causes by (Smart Driving Research Center (SDRC)).

S.No	1998 Disease or Injury	2020 Disease or Injury
1	Lower respiratory contaminations	Ischaemic heart disease
2	HIV/AIDS	Unipolar major depression
3	Perinatal conditions	Road traffic injuries
4	Diarrhoeal diseases	Cerebrovascular disease
5	Unipolar major depression	Chronic obstructive pulmonary disease
6	Ischaemic heart disease	Lower respiratory infections
7	Cerebrovascular disease	Tuberculosis
8	Malaria	War
9	Road traffic injuries	Diarrheal diseases
10	Chronic obstructive pulmonary disease	HIV/AIDS

According to the Department of Statistics, Malaysia (DOSM), in 2018, new registrations of motor vehicles increased by 8.2% to 1,218,662 compared to 1,125,900 in 2017. Public transportation (48.0%), commercial vehicles (15.3%), and motorcycles (15.3%) all contributed to the rise (11.5 per cent). This study will be focused on commercial vehicles crash with a heavy vehicle type. A heavy vehicle is defined by the Heavy Vehicle National Law (HVNL) as one that has a gross vehicle mass (GVM) or aggregate trailer mass (ATM) of greater than 4.5 tonnes. Heavy vehicles include semi-trailers, B-double freight trucks, road trains, commuter buses, vehicle carriers, livestock and agricultural equipment, mobile cranes, and other specialised vehicles. By comparison, heavy goods vehicles (HGVs) are huge trucks used to transport products across the land. In Malaysia, HGVs are classified as trailers (articulated lorries), rigid lorries (two or more axles with a gross weight higher than 2.5 tonnes), and tiny trucks (2 axles small lorry or pick-up with gross weight less than 2.5 tones).

The Malaysian HGV fleet consists of nearly a million units (data from 2016), covering a total of 200 kilometres of travel per day and an average annual VKT (AAKT) of about 70,000 kilometres (Jamaluddin et al., 2021). The distance travelled by HGV is expected to increase with the growth of Malaysia's e-commerce industry. In Malaysia, the evolution of HGV incidents has shown a consistent up-and-down pattern. Figure 1.1.1 (sources of Polis Diraja Malaysia 2016 Royal Malaysia Police Annual Report, 2016 (Kuala Lumpur, Malaysia: PDRM) depicts the five-year way of HGV-related road accidents in Malaysia. Even though HGVs account for a small percentage of traffic, accidents involving HGVs result in over 1000 deaths per year in Malaysia. The involvement of an HGV in an accident is responsible for more than 80% of second-vehicle fatalities. It demonstrates that HGV accidents significantly affect other road users' welfare (Hamidun et al., 2019).

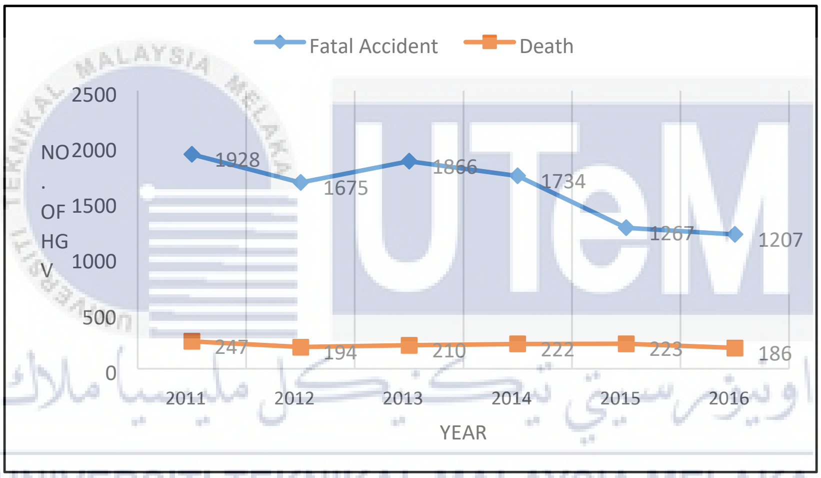

Figure 1.1. 1: Number of fatal road accidents and death involving HGV by Polis Diraja Malaysia 2016 Royal Malaysia Police Annual Report, 2016 (Kuala Lumpur, Malaysia: PDRM.

Over a year, medico-legal autopsies were done on 950 instances of fatal road traffic accidents at the SRN Hospital, MLN Medical College, Allahabad. The male to female ratio was 3:1, and 33.68 per cent of patients were between the ages of 25 and 44 (Kual et al., 2005). The most vulnerable were pedestrians, who accounted for 35.79 per cent of all deaths, followed by motorised two-wheelers, which accounted for 30.53 per cent. Heavy vehicles were found to be involved in 58.52 per cent of incidents, with highways accounting for 83.05 per cent of all collisions. In most cases, multiple injuries were suffered for heavy vehicles.