Evaluation of Material Failure Model in RADIOSS to Roof Resistance Test (FMVSS 216)

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DECLARATION

I declare that this project entitled " Evaluation Of Material Failure Model in RADIOSS to Roof Resistance Test(FMVSS 216)" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature : ....

Supervisor Name : Ts. Khairul Amri Bin Tofrowaih

Date : 28th January 2022

DEDICATION

This project report is dedicated with humbleness to my parents, Che W Mohd Amil Bin Che W Sulaiman and Sahazilah Binti Saidin for giving their never ending support and always be myside to motivate me during my tough times. Moreover, I would like to include my siblings in the success of this project. Their unlimited support and love show me that I should never give up easily and should try harder in everything I do. Besides, I would like take this opportunity to dedicate this project report to my classmates because of their teamwork for willing to share information related to this project. Not to forget my supervisor, Ts. Khairul Amri Bin Tofrowaih, who play a vital role in the completion of this project. My appreciation to share this success with him as he always supervises me constantly in using the simulation software from the beginning even the simulation software is quite new for me. I always appreciate his generosity in guiding me when I am stuck using the software.

ABSTRACT

Over the past decade, reducing the severity of roof crash impact collisions has been an emerging area of research by a variety of organizations and research communities. The roof crash simulation normally does not use Altair Radioss as the programme medium. This is because a crash test organisations such as the National Highway Traffic Safety Administration (NHTSA) are using an older applications software such as Ls-Dyna to run the simulation and plus, the Altair Radioss was still very new in the crash simulation study. The main purpose of this research study is to find the right material failure model behavior to replace the material failure that has been allocated in roof crash simulation in RADIOSS. This objective include to simulate the material failure model comparable to the actual roof resistance test according to FMVSS 216 within 20% of error. It also to compare strength to weight ratio(SWR) result between current Finite Element model and updated material failure model. In this research in particular, a test and simulation were carried out in order to evaluate the Finite Element Model (FEM) for car roof crash simulation. This simulation is to find the right material failure model for get close result to actual test. This simulation was done by using HYPERCRASH and HYPERMESH software. The material failure that was used was BIQUAD material failure model because using this material failure the result SWR was 4.91, close to actual test which is 19.76% of percentage error. This material failure model just apply to the critical part of the roof such as B-pillar, A-pillar and roof. Using this type of analysis can reduce cost for the industry of automotive because they just used the simulation for the get close to actual test.

ABSTRAK

Sepanjang dekad yang lalu, mengurangkan keterukan perlanggaran hentaman bumbung telah menjadi bidang penyelidikan yang baru muncul oleh pelbagai organisasi dan komuniti penyelidikan. Penyelidikan ini akan mengkaji model kegagalan bahan yang tepat yang digunakan dalam analisis ujian penghancuran bumbung. Simulasi ranap bumbung biasanya tidak menggunakan Altair Radioss sebagai medium program. Ini kerana organisasi ujian ranap seperti National Highway Traffic Safety Administration (NHTSA) menggunakan perisian aplikasi lama seperti Ls-Dyna untuk menjalankan simulasi dan selain itu, Altair Radioss masih sangat baharu dalam kajian simulasi ranap. Tujuan utama kajian penyelidikan ini adalah untuk mencari gelagat model kegagalan bahan yang sesuai untuk menggantikan kegagalan bahan yang telah diperuntukkan dalam simulasi kemalangan bumbung di RADIOSS. Objektif ini termasuk untuk mensimulasikan model kegagalan bahan yang setanding dengan ujian rintangan bumbung sebenar mengikut FMVSS 216 dalam 20% daripada ralat. Ia juga untuk membandingkan hasil nisbah kekuatan kepada berat (SWR) antara model Elemen Terhad semasa dan model kegagalan bahan yang dikemas kini. Dalam penyelidikan ini khususnya, ujian dan simulasi telah dijalankan untuk menilai Model Elemen Terhad (FEM) untuk simulasi kemalangan bumbung kereta. Simulasi ini adalah untuk mencari model kegagalan bahan yang sesuai untuk mendapatkan keputusan yang hampir kepada ujian sebenar. Simulasi ini dilakukan dengan menggunakan perisian HYPERCRASH dan HYPERMESH. Kegagalan bahan yang digunakan adalah model kegagalan bahan BIQUAD kerana menggunakan kegagalan bahan ini keputusan SWR adalah hampir dengan ujian sebenar iaitu 19.76% daripada peratusan ralat. Model kegagalan bahan ini hanya digunakan pada bahagian kritikal bumbung seperti tiang B, tiang A dan bumbung. Menggunakan analisis jenis ini boleh mengurangkan kos untuk industri automotif kerana mereka hanya menggunakan simulasi untuk menghampiri ujian sebenar.

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LIST OF SYMBOLS AND ABBREVIATIONS

ABS	-	Acrylonitrile utadiene Styrene
BH	-	Bake Hardning
BIW	-	Body-in-white
CAD	-	Computer Aided Design
CEM	-	Crash Energy Management
ESP	-	Electronic Stability Program
FE	-	Finite Element
FEA	-	Finite Element Analysis
FMVSS	-	Federal Motor Vehicle Safety Standart
GFRP	-	Glass Fiber Reinforced Plastic
HF	-	Hot Formed
HSLA	-	High Strong Low Alloy
IIHS	-	Insurance Institute For Highway Safety
MPV	-	Multi-Purpose Vehicle
MS	-	Martensitic Steel
NHTSA	-	National Highway Traffic Safety Admistration
QBAT	-	Quasi-Brewster Angle Technique
QEPH	-	Quadrilateral Elastoplastic Physical Hourglass Control
SAE	-	Society of Automotive Engineers
SUV	-	Sport Utility Vehicle
SWR	-	Strength to weight ration
WHO	-	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 Background

There were over 15,000 single vehicle traffic accident deaths in the 1,990 deadly reported in automotive system. Hence, more than half of them were from rollover accidents. The Federal Motor Vehicle Safety Standard (FMVSS) 216 defines the specifications for the roof crush resistance of a car. The structural components use a broad variety of materials and need to be modelled on stress analysing challenges. A range of constitutive laws is available to define material behaviour by means of a mathematical approach for all types of material. The choice of constitutional legislation for a specific material is mostly based on the desired model quality. In ordinary steel, for example, plasticity, anisotropical hardening, stress rate, and dependency on temperature can be considered in the constitutive law (Simulia, 2015). Other than that, models of failure define failure rates, frequencies, and further statistically observed details of real systems, which are mainly used to recreate failures in simulation and prediction systems (Poola et al., 2017). This research only studies several type of material failure model that was used in the roof crush simulation test.

The roof crush test was simulated using HyperWorks to see how this 3-material failure model affects the roof crush test. Roof crush is when the roof of the vehicle fails and falls into the passenger compartment during a roll-over collision. In this research, we want to see how many percentages that can be the same if we use HyperWorks simulation compared to the actual test. The advantage of this simulation roof crush test compared to the real test are, it can avoid danger and loss of life. It will also save the cost of the vehicle model (BBC, 2021).

A specific effort has been put into the development of two special libraries by RADIOSS Solver for predictive solutions, which are the material law library and rapture criterion library. Both libraries are entirely interoperable, and the user is able to combine the legislation and the criteria for rupture. Although many commercial solver software does not provide the whole yet expandable material and failure models necessary to represent RADIOSS reality correctly, it is distinct and combines the requisite libraries, extendability, and customization. RADIOSS enables users to blend the parts of the two libraries, providing additional possibilities for precisely modeling the structural material to be analyzed. If necessary, the breach of any material law can also be taken into consideration, and the RADIOSS is special since the criteria of damage or failure are included in some material laws. Any criterion in the rupture library may also be applied with material legislation, even damaged ones. Finally, every substantive legislation can be linked to numerous conditions for rupture (Terrier, 2011).

1.2 Problem Statement

Nowadays, in asia, most of the accidents that occurred on the road involving cars, especially the type of car accident known as rollover. Rollover is a vehicle crash that is very dangerous because this accident mostly tipping the vehicle turns over on its roof. Most of accident in roof crash usually has higher dead ratio. According to national statistics, only 2% of vehicles involved in all traffic crashes from 2014 to 2018, but 24% of all deaths were caused by overhead collisions rollover (Kweon, 2020).

In order to find the right material, this research will be study in RADIOSS simulation. The current FE model has error in strength to weight ratio (SWR = 5.41) compare to the actual test result (SWR = 4.10). This is because RADIOSS and LS-Dyna used different material failure model. The error is cause by during the conversion of FE model from LS-Dyna to RADIOSS Solver. The roof crash simulation normally does not use Altair RADIOSS as the program medium. This is because a FE model provided in Center for Collision Safety and Analysis (CCSA) website is in LS-Dyna, the Altair Radioss was still very new in the crash simulation study. Despite this fact, most of the researches that related to the crashing impact done from Universiti Teknikal Malaysia Melaka (UTeM) are using Altair Radioss. The main purpose of this research study is to find the right material failure model behavior to replace the material failure that has been allocated in roof crash simulation in RADIOSS.

1.3 Research Objective

a) To simulate the material failure model comparable to the actual roof resistance test according to FMVSS 216 within 20% of error.

b) To compare strength to weight ratio (SWR) result between current FE model and updated material failure model.

1.4 Scope of Research

The scope of this research are:

a) Use Altair HYPERWORK as a medium in converting the Finite Element (FE) of Chevrolet Silvarado (SUV) model from LS-Dyna to RADIOS format in order to run a roof resistance simulation.

b) Setting parameter at BIQUAD Material failure model properties.

c) Focus on critical part, such as B-pillar, A-pillar and roof which are surrounding at impactor contact of Roof Resistance Test.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The real roof crush test has been widely used to evaluate the safety integration of vehicle structure, where there are specified standards such as FMVSS 208 and 216. Despite the different road conditions, Europe is trying to accomplish the same safety target. However, complete tests have shown themselves to be very expensive and unrepeatable in many cases. With computer technology advancement, several codes have been crashed, such as LS-DYNA3D, Pamcrash, and RADIOSS, which are used for vehicle impact simulations. These codes were primarily created based on explicit time integration, analysis-specific shell elements, and assumptions about dynamic behavior. Despite enormous experience over the last few years, the quasi-static simulation of roof crush remained the most difficult of these simulations. Just before greater speed is used in the quasi-static simulation, inertia effects are caused, which smooth the solution algorithms' nonlinearities and deficiencies. But even though implicit solvers may address whereas almost static impact scenarios, the large deformation of the roof and pillar areas and the multi-vehicle parts contact makes convergence in implicit solvers extremely difficult and sometimes unstable (Chirwa, 2005).

2.2 Statistic Roll-Over Accidents

Roll-overs are the most serious and fatal kinds of road accidents. This is due to the fact that roll-overs are complex dynamic events that, like other traffic accidents, include the vehicle, human, and environmental factors, as well as their interactions. The car has achieved its unstable equilibrium position during a roll-over, the transition between the precrash and crash phases (tripping phase). The dynamic relationship between the tires and the road results in unexpected vehicle cinematics and a chain of unpredictable occurrences. From 2014 until 2018, according to national data (National Highway Traffic Safety Administration, 2019a), Rollover collisions included just 2% of all cars affected in vehicle accidents, yet they resulted in 24% of all deaths. In 2017, 23,551 passenger vehicle users and 30 percent of them were killed in road crashes (7,170 killed occupants) in roll-over crashes (National Highway Traffic Safety Administration, 2019b). These data show that roll-over collisions represent a substantial risk to occupants of the car.

In the last two decades, Figure 2.1 shows that in the 1980s and 1990s, critically injured occupants had larger roll-over rates than their earlier counterparts. In recent years, it means that enhancing rolling safety through the prevention of a car and

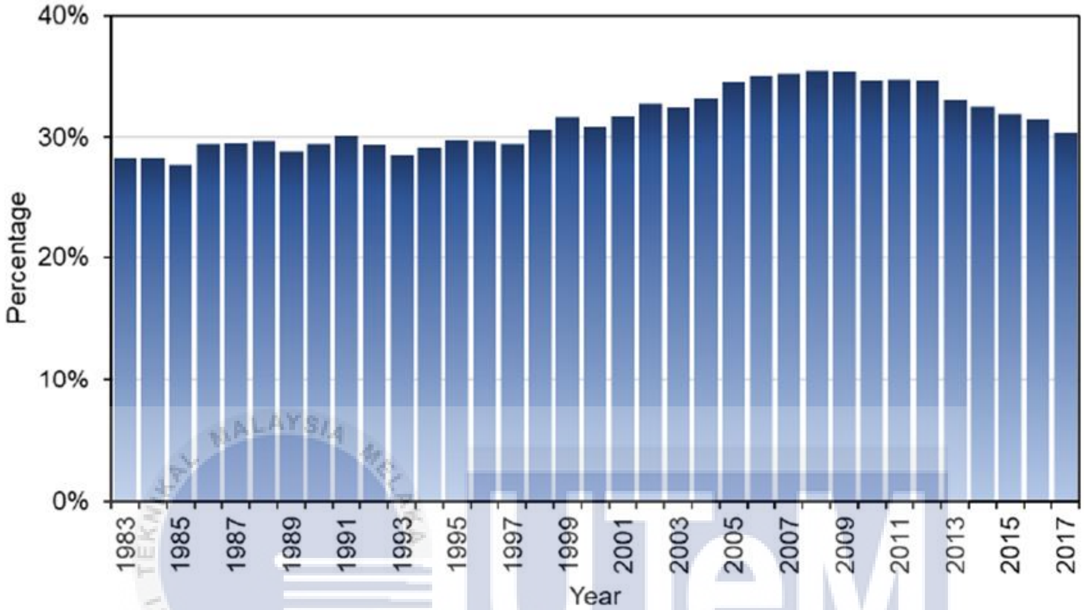

Figure 2.1 Rollover percentages in killed occupants of passenger cars and light trucks (1983-2017) (Kweon, 2020).

reduction of an occupant's injury severity when rolling over might play a major part in lowering rolling fatality.

A crash involves a pivoting vehicle about its longitudinal axis in at least two quarters (≥180◦). While roll-over crashes are less common than the frontal, side, or rear impact crashes, they are more likely than any other type of crash to cause injury and fatality. Compared with planar crashes (front, back, and side), rotary components are included in occupant cinematics, which leads to a variety of types of injuries. The most vulnerable to roll-over crashes are head and neck injuries. The main issue arises whether the degree of vehicle roof crush, vertical penetration into the passenger’s car roof or the ceiling constitutes a danger of head-and-neck damage.

The connection between roof crush, head, neck and back injuries in a rollover accident was added to NASS-CDS data in a number of ways via the use of population-based data, but contributed numerous ways to the existing literature. First of all, the only injuries included in our analysis were those determined by an NHTSA accident investigator to occur because of the contact with the overhead vehicle component at the location of an occupant (Chikazawa et al., 2012).

2.3 RolloverCrash Characteristics

Identifying the core criteria that define the majority of real-world rollover accidents is a crucial steps in rollover prevention. This sections presents criteria that relate to the vehicle reaction during a rollover accident. According to the research, the main criteria are vehicles and road characteristics, initial contact status, and accident end product (Rho, 2016). Vehicle and road characteristics involve the shape and inertial properties of the vehicle, tyre and suspension properties, structural resistance, road friction, and geometry. These two variables will affect the initial effect (pneumatic) and hence the rollover performance. The quarter rolls, deceleration velocity, roll depth, complete of the centre of gravity height and the roof crush all lead to a crash (Yin et al., 2020).