UNIVERSITI TEKNIKAL MALAYSIA MELAKA

COMPARISON BETWEEN MULTIBODY DYNAMICS (MBD) ROLLOVER MODEL AND FINITE ELEMENT (FE) ROLLOVER MODEL

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

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A thesis submitted
in fullfilment of the requirements for the degree
Bachelor in Mechanical Engineering Technology (Automotive Technology) with Honours

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2021

DECLARATION

I declare that this thesis entitled "Comparison between Multibody Dynamics (MBD) Rollover Model and Finite Element (FE) Rollover Model" 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 : Amin Irfan Bin Masri

Date : 14/1/2022

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. MOHD HAFIZI BIN ABDUL RAHMAN

Date : 18/1/2022

DEDICATION

To my precious family, who always gave me advice and helped me throughout this journey. I had be nothing without the love and support of my family.

ABSTRACT

At the moment, the number of vehicle ownership was relatively high, and social progress and development were increasing fast. Vehicles were one of the most significant transports in people's daily lives. In recent years, safety of vehicles has received significant attention. There are various types of traffic accidents, including a frontal crash, a side crash, etc. In all types of traffic accidents, the vehicle roll-over has the lowest risk of serious injuries and the majority result of these incidents are fatal. Even if there are fewer than 10% of incidents involving vehicles in Malaysia in single vehicle and roll-over accidents, there have been roughly one-third of the deaths of light-vehicle occupants. This reserach aims to establish a way of predicting the chance of rolling over. Static Stability Factor (SSF), which may be connected with a rollover likelihood using NHTSA statistic data, is one of the essential geometric variables to estimate the vehicle's rollover risk. The SSF is the ratio of one-half the width of the track to the height of the center of gravity. The rollover rates are predicted in relation to current rates. The approach to rollover crash includes investigations, the method for finite elements and models on a rigid body basis. In this research in particular, a test and simulation were carried out in order to evaluate the Finite Element Model (FEM) for car rollover collision. This research study also used to forecast the likelihood of rollover in Malaysia for SUV. This technique may be used as a way of reducing the amount of rollover incidents that can lower occupants' fatality for manufacturers, users and regulators. The outcome can also be a tool to evaluate the ASEAN region's roll-over risk trend and will benefit ASEAN NCAP in determining safety rates for SUVs.

ABSTRAK

Pada masa kini, jumlah pemilikan kenderaan agak tinggi, dan kemajuan dan perkembangan sosial meningkat dengan cepat. Kenderaan adalah salah satu pengangkutan paling penting dalam kehidupan seharian manusia. Dalam beberapa tahun kebelakangan ini, keselamatan kenderaan mendapat lebih perhatian. Terdapat pelbagai jenis kemalangan jalan raya, termasuk pelanggaran hadapan, pelanggaran sisi, dan lain-lain. Dalam semua jenis kemalangan jalan raya, penggulingan kenderaan mempunyai risiko kecederaan serius yang paling rendah dan kebanyakan kejadian ini boleh membawa maut. Walaupun terdapat kurang daripada 10% insiden yang melibatkan kenderaan di Malaysia dalam kemalangan kenderaan tunggal dan kemalangan penggulingan, terdapat kira-kira satu pertiga kematian yang melibatkan penumpang kenderaan ringan. Penyelidikan ini bertujuan untuk mewujudkan kaedah untuk meramalkan kadar peluang penggulingan kenderaan. Faktor Keselamatan Statik (SSF) yang mungkin dihubungkan dengan kemungkinan peralihan menggunakan data statistik NHTSA, adalah merupakan salah satu pemboleh ubah geometri penting untuk menganggarkan risiko peralihan kenderaan. Faktor Keselamatan Statik adalah nisbah satu setengah lebar lintasan sehingga ketinggian pusat graviti. Kadar penggulingan diramalkan berkaitan dengan kadar semasa. Pendekatan untuk kemalangan penggulingan kenderaan merangkumi penyiasatan, kaedah untuk elemen dan model sehingga asas badan yang kaku. Dalam penyelidikan ini khususnya, ujian dan simulasi dilakukan untuk menilai Kaedah Unsur Terhingga (FEM) untuk perlanggaran penggulingan kereta. Kajian penyelidikan ini juga digunakan untuk meramalkan kemungkinan penggulingan kenderaan di Malaysia untuk kereta SUV. Teknik ini dapat digunakan sebagai cara untuk mengurangkan jumlah insiden penggulingan kenderaan yang dapat mengurangkan kes kematian penumpang untuk pengeluar, pengguna dan pengawal selia. Hasilnya juga boleh menjadi alat untuk menilai trend risiko penggulingan kenderaan di rantau ASEAN dan akan memberi manfaat kepada NCAP ASEAN dalam menentukan kadar keselamatan untuk kenderaan SUV.

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LIST OF SYMBOLS AND ABBREVIATIONS

T	-	Track Width
H	-	The Car's Centre of Gravity Height
CG	-	Centre of Gravity
Fy	-	Lateral Force
N	-	Normal Force
W	-	Weight of Vehicle
G	-	Gravity
mm	-	Millimetre
lbf	-	A Pounds-Force
ms	-	Milliseconds
km/h	-	Kilometre per hours
mm/s	-	Milliseconds per seconds
°	-	Degree
SUV	-	Sport Utility Vehicle
FEM	-	Finite Element Model
SWR	-	Strength Weight Ratio
CCSA	-	Center for Collision Safety and Analysis
ASEAN	-	Association of Southest Asian Nations
NCAP	-	New Car Assessment Program
NHTSA	-	National Highway Traffic Safety Administration
ATD	-	Anthropometric Test Device
SSF	-	Static Stability Factor
SRT	-	Static Rollover Threshold
FMVSS	-	Federal Motor Vehicle Safety Standard
MPV	-	Multi-purpose Vehicle
IIHS	-	Insurance Institute of Highway Safety
CAE	-	Computer Aided Engineering
CAD	-	Computer Aided Design
GUI	-	Graphic User Interface

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CHAPTER 1

INTRODUCTION

1.1 Introduction

These days, the vehicle ownership has become a rather big figure, and increasing rapidly with the societal expansion and transformation. Vehicle has been among the relevant transportation in people's lives. Consequently, there are a huge number of deaths and severe injuries in road collision every year. Vehicle safety has been given ever more attentions in recent years.

In every automobile model, occupational safety is the main criteria. Crashworthiness is the term that emphasizes on occupant safety to minimize the amount of serious and severe incidents. Crashworthiness is a research method to establish and upgrade test protocols for assessing protection of motor vehicles. Crashworthiness research includes latest and modified body model, safety countermeasures and passenger safety features. The primary principle of occupational safety in cars is accomplished by ensuring that automotive deformation during collisions happens in such a manner that the passenger has enough room to escape the decelerating loads at the period of the collision. (Narayan, 2019).

There are many types of road collisions like frontal crash, side crash, etc., whereas rollover crash is a particular type. The car rollover has the lowest occurrence in the all sorts of road collision but has the greatest percentage of severe injuries, most of which lead to death. Rollover is the main element of fatality in collisions associating with sport utility vehicles (SUVs). Rollover collision events are the unforeseeable and life-threatening for safety of the passenger and an automobile. The occurrence of rollover collision events accounts for just 3% amidst all kinds of collisions, but the fatality rate represents 33% of

deaths in vehicle crash events. Rollover is a very dynamic and volatile occurrence that makes it very hard to design a standard testing procedures. The roll over tendency of vehicles is urgently needed to be predicted and their structure from the perspective of rollover resistance to be improved. (Lin, Zhigui, et al., 2017).

The cause of a rollover event can be clarified by using basic physics. A rollover happens when the centripetal force produced by the friction between car tires and the track is adequate. Generally cars with a large centre of gravity appear to be unsteady and effortlessly to roll over on a narrow road. Consider a moving car taking a turn to rotate the cars wheels that would produce a lateral force called "Centripetal Force" in opposition to Law of Inertia. Due to the friction between car tires and the track, the centripetal force is produced, when enough friction occurs, the force is enough to trigger the rolling scenario.

Consider a car shifting at right, there is a traction between car tires and track and, in the other direction, there is a force called a centrifugal force. Therefore, no centrifugal force but the vehicle that follows Newton's Law is exactly the same as the centripetal force which allows the vehicle to turn on the right. It is fascinating to remember that the driver assumes that he/she has a force on his left side (the Centrifugal Force). In fact, he/she is just the driver who obeys the Newton's Law of him/her attempting to go straight as the car and the seat move to the right.

The technique to analyze rollover collision involves experiment, the finite element approach and rigid-body-based models. The finite element approach offers numerous benefits such as cheap cost, repeatability, comprehensive data and so on, however the restriction is clear. An evaluation and simulation has been fulfil to research the Finite Element Method (FEM) for vehicle rollover collision especially in this thesis. (Lin, Zhigui, et al., 2017).

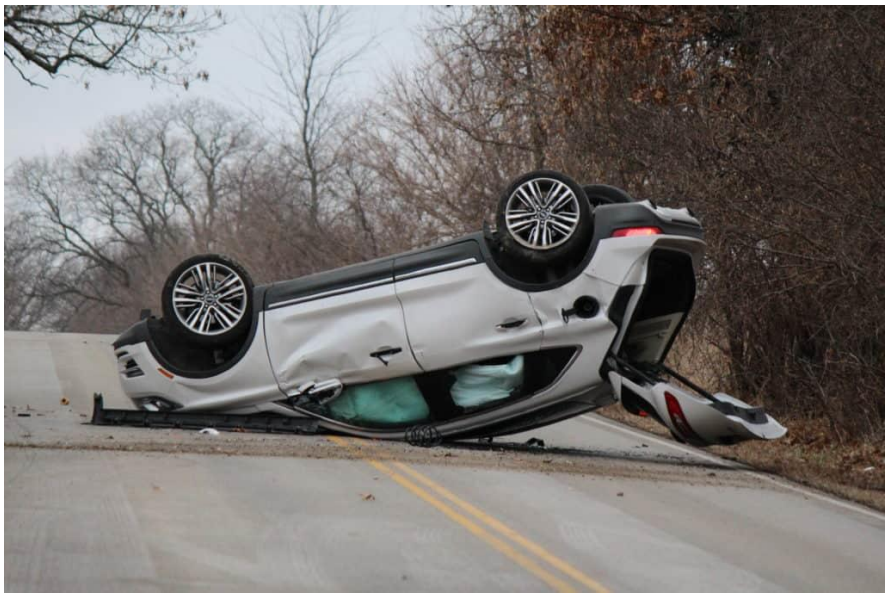

Figure 1.1: Vehicle Rollover (Sam Borcia, 2020)

1.2 Problem Statement

Although all ASEAN countries have concentrated on the growth of the automobile sector, the customer bases and specific economic sectors vary substantially amongst these countries. In 2010, the market share in Malaysia for SUV vehicle fell below 3%. Due to recent trends, SUV vehicles now account for roughly 23% of all new automobile sales in Malaysia. For these purposes, it is really important to research the SUV vehicles rollover accident as there are no specific standards for vehicle rollover test in Malaysia. However, there were only roof crush test that being tested on SUV vehicles to see the strength of roof structure because in order to run rollover test, it required higher cost to run the test compared to roof crush test and it's very challenging that there are only a little quantity of literatures in investigating rollover due to its diversity, huge degree of flexibility, and complexity to repeat and manage.

The purpose of this research project is to correlate the SUV rollover motion between Multibody Dynamics (MBD) model and Finite Element (FE) Model. The workflow of the vehicle rollover system is generally divided in two phases. The first phase involves estimating the possibility of a vehicle rollover, often by measuring the driving parameters of the vehicle (roll over angle, folding angle, lateral acceleration, yaw rate and angular folding velocity, etc.). The second phase is during the estimate results surpass the predetermined side of the door, shifting on the roll over control mechanism by adjusting the driving status of the vehicle to stop the vehicle from rolling. The main innovation for vehicle roll over safety is therefore primarily to assess the risk of vehicle roll-over and to minimize the potential for safe driving through a roll-over control system.

Static and dynamic models are available to predict the likely of vehicle to rollover. The initial determine a static overview of the rollover possibility. The second utilizes complicated equations of strong dynamics to forecast the roll over almost simultaneously

with the vehicle rollover. The first has the benefit that the geometric design can be used to measure the rollover potential. The latter is well suited for estimating the probability of rollover driving if the car has a proper sensor system.

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1.3 Objective of Research

The objective of this research are:

a) To fine tune damping (C) and stiffness (K) parameter of contact between all tires and platform through Altair Hyperstudy (Optimization software).

b) To fine tune compliant of joints between tires and vehicle body through Altair Hyperstudy.

c) To correlate the SUV rollover motion between Multibody Dynamics (MBD) model and Finite Element (FE) Model.

1.4 Scope of Research

The scope of this research are:

i. Setup FE model for roll over analysis. FE model obtain from Center for Collision Safety and Analysis (CCSA) and type of SUV vehicle is 2014 Chevrolet Silverado.

ii. Setup roll over analysis using Federal Motor Vehicle Safety Standards.

iii. Run the roll over analysis using RADIOSS. Setup initial velocity parameters using HyperCrash.

iv. Setup Multibody Dynamics (MBD) model in Motion View.

v. Run the roll over MBD model and obtain base result. Optimize tune damping (C) and stiffness (K) parameter.

vi. Run optimize roll over MBD model.

vii. Correlate the result of base model, FE model and optimize model.

1.5 Summary

There are a huge number of deaths and severe injuries in road collision every year. Crashworthiness is the term that emphasizes on occupant safety to minimize the amount of serious and severe incidents. Rollover is the main element of fatality in collisions associating with sport utility vehicles (SUVs). The occurrence of rollover collision events accounts for just 3% amidst all kinds of collisions, but the fatality rate represents 33% of deaths in vehicle crash events. The cause of a rollover event can be clarified by using basic physics. A rollover happens when the centripetal force produced by the friction between car tires and the track is adequate.

Generally cars with a large centre of gravity appear to be unsteady and effortlessly to roll over on a narrow road. Newton's Law is exactly the same as the centripetal force which allows the vehicle to turn on the right. The technique to analyze rollover collision involves experiment, the finite element approach and rigid-body-based models. An evaluation and simulation has been fulfil to research the FEM for vehicle rollover collisions.

This research will be carried out by modifying the current roof structure, minimize injuries suffered by the passengers and reducing car body damages. Several regions of complex space impact collisions have to be considered to enhance the crash-resistant structure of the vehicle roof and analyze the energy absorption properties of metals and composites. The aim of the project would be concern, material evaluation, component testing, FE-guidelines for the vehicle roll over. The crash worthiness criteria, which use finite element techniques to demand both statistical and simulation models, will be accomplished through the crashworthiness criteria. The priority is to study the behaviour of the roll over under crash simulation is studied and improvisation is carried out in vehicle roll over.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Vehicle rollovers is a severe accident which leads to loss of life and property. The passengers will severely injured, causing abdominal, pelvic and spine fractures. Therefore, it is necessary to protect passengers from severe injuries and crashes in the car. Although seat belts and airbags are secured in rollover collisions, passengers need some space to escape from their vehicles. (Prajwal et al., 2018).

The most frequent cause of rollovers is a drastic shift in cornering forces, which causes the car to become unstable. When a car turns around in the corner, three forces are at work: tyre forces, inertial effect and gravity. The tyre's cornering forces drive the automobile into the centre of the swerve. This force runs at the bottom level, under the centre of gravity. The inertia force acts horizontally around the centre of the car's load from the centre of the rotate. This two forces cause the car to roll away from the curve. The vehicle's weight works in the reverse direction, backward into the centre of mass. The car starts to roll over as the pneumatic and fictitious forces are sufficient to balance the influence of gravity. (Parit & Shinde, 2015).

Despite considerable gains on passenger protection due to frontal, side effects as well as pedestrian automobile collisions to a certain degree, the same cannot be done with regard to preventing or mitigating fatalities and serious head and spinal injuries caused by the events of the rollover. Rollover collisions are low level incidents associated with front and side injuries, since the energy of impact dissipates in seconds instead of milliseconds. Consequently, the source of the possibility of serious injuries and overrepresented is not the

crash itself, but rather the lack of protection for passenger in a vehicle. (Vangi, D. et al., 2019).

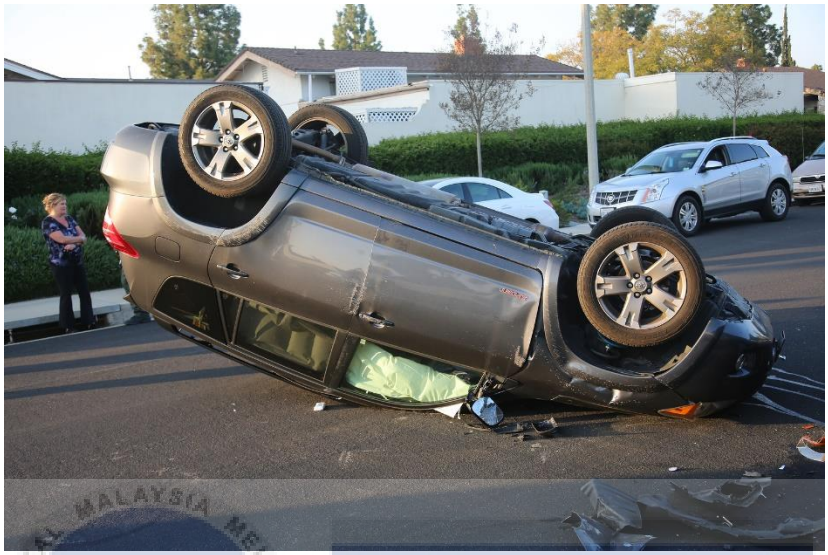

Figure 2.1: Vehicle Rollover Collisions (Boohoff Law, 2019)