CRASH ANALYSIS OF A RAINFOREST VEHICLE (RFV) UNDER FRONTAL IMPACT LOADING

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DEDICATION

To my beloved wife, parents and family

To all my lecturers, for their guidance and encouragement

To all my friends, for their support and sincerity

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ABSTRACT

Rainforest Vehicle (RFV) is defined as an outdoor vehicle that can be used in the rural, military area especially in the forest. This vehicle must have the capability to use in uneven terrain and sloping condition. This thesis presents the crash analysis of a (RFV) under frontal impact loading. A Finite Element (FE) nonlinear code, LSDYNA software was comprehensively employed to evaluate the crashworthiness performance of the space frame model of the RFV. Experimental testing was conducted on subcomponents to validate the FE model and the analytical analyses from the previous researchers were conducted to compare the results. In addition, the simplified model of the upper rails also validated throughout the quasi static experiment. The validated model was then used to examine three different crash scenarios; impacting rigid wall, 40% offset and rigid pole. The simulation results were used to identify the load path, deceleration and the energy absorption capacity of the main longitudinal component and available crush zone, thus facilitating crashworthiness requirement for future design improvements. The primary outcome of this research is to generate research and design information on the vehicle that will enable further modification and enhancement of the current design for optimizing crashworthiness performance and increasing the levels of safety.

ABSTAK

Kenderaan Rainforest (RFV) ditakrifkan sebagai kenderaan luar yang boleh digunakan di luar bandar, kawasan tentera terutama di dalam hutan. Kenderaan ini mesti mempunyai keupayaan untuk menggunakan di kawasan tidak sekata dan keadaan cerun. Tesis ini membentangkan analisa pelanggaran sebuah RFV berdasarkan perlanggaran hadapan. Perisian LSDYNA, yang menggunakan kaedah unsur tak terhingga yang tak linear digunakan secara menyeluruh untuk menilai kemampuan pelanggaran rangka kenderaan (RFV). Kaedah eksperimen dilakukan pada sebahagian tempat pada kenderaan untuk mengesahkan kaedah unsur tak terhingga (FE) dan kaedah analisa pengiraan daripada penyelidik yang lalu dilakukan untuk membandingkan hasil yang diperoleh. Di samping itu, sebuah model landasan atas yang dipermudahkan juga disahkan di seluruh eksperimen separa statik Model yang telah disahkan, digunakan untuk menganalisa tiga jenis perlanggaran yang berbeza iaitu; perlanggaran kekal, 40 peratus perubahan perlanggaran kekal dan tiang kekal. Keputusan simulasi digunakan bagi mengenal pasti laluan bebanan, nyah pecutan dan tenaga resapan pada sesetengah bahagian utama yang membujur dan zon kehancuran yang masih diperolehi sekaligus memudahkan keperluan untuk memberikan perlindungan perlanggaran bagi penambah baikkan reka bentuk pada masa akan datang. Hasil yang diharapkan daripada kajian ini adalah untuk menghasilkan penyelidikan dan reka bentuk maklumat mengenai kenderaan yang akan membolehkan pengubahsuaiaan dan peningkatan reka bentuk semasa untuk mengoptimumkan prestasi perlindungan perlanggaran dan meningkatkan tahap keselamatan.

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LIST OF ABBEREVIATIONS

RFV	-	Rain Forest Vehicle
FEM	-	Finite Element Method
SUV	-	Sport Utilities Vehicle
OUV	-	Outdoor Utilities Vehicle
8WD	-	8 Wheel Drive
FEA	-	Finite Element Analysis
NHTSA	-	National Highway Traffic Safety Administration
CG	-	Centre of Gravity
NCAP	-	New Car Assessment Program
KE	-	Kinetic Energy
IE	-	Internal Energy

LIST OF SYMBOLS

L, l	-	Length
E	-	Modulus of Elasticity
A	-	Area
F	-	Force
K	-	Stiffnes
m	-	Mass
g	-	Constant due to Gravity
t	-	Time
σ	-	Stress
J	-	Joule
v	-	Velocity
a	-	acceleration

CHAPTER 1

INTRODUCTION

1.1 Rainforest Vehicle

Peninsular Malaysia consists about 5.87 million hectares or 45% of its total land area of tropical rainforest. The major rain forest types in Malaysia consist of dry inland forest which is the main forest cover, peat swamp forest and mangrove forest. 4.93 million hectares are Permanent Reserved (PRFs), 0.33 million hectares are State/Alienated Land Forest and 0.61 million hectares are National Park/Wildlife and Bird Sanctuary (Council, 2007). Regarding to this statistic, the use of transportation in the forest is very significant.

Based on the necessity in transportation, people need to travel and explore new areas, especially in the new rural areas. This demands the need of a vehicle that is equipped with relevant capabilities and able to restrain with the jungle road condition. In this era, automotive historians will remember 1990s as the Renaissance decade of automotive safety. During this decade, occupant safety has been established as a leading marketing characteristic of motor vehicles. In Malaysia, one company, Innopeak Sdn. Bhd with the association with scholars are developing a vehicle called Rainforest Vehicle (RFV).

RFV is defined as an outdoor vehicle that can be used in the rural, military area especially in the forest. This vehicle must have the capability to be driven in uneven terrain and sloping condition as well as on any paved or gravel surface.

Furthermore, ground clearance aspect has to be in account so that it will not get hung up on obstacles. Since the body is heavy, it needs to keep their wheels or tracks on the ground so as not to lose traction. As it goes through the sloping terrain, the centre of gravity must be maintained so will minimise the probability to turn over. This all are the advantages of this vehicle compared to normal transportation. Figure 1.1 shows the example of the RFV that is available in the market.

Figure 1.1: Example of RFV
(www.virtualmalaysia.com)

In the market, the well-established brand name like Toyota, Mitsubishi, Land Rover and Suzuki are multinational companies. However, this vehicle needs to be modified in order to have a great handling capability, especially while going through the Malaysian rainforest. Besides, it is a good opportunity to produce our own vehicle. In Australia, the use of 8 Wheel Drive (8WD) has been used in the Daintree rainforest as a means of transportation. This means, the utilisation of special vehicle in the forest is very significant throughout other country. Furthermore, the All-Terrain Vehicle (ATV) used in the off-road condition might be influential in designing this vehicle. By taking consideration of the rainforest condition, especially in Malaysia, this vehicle must implement the safety testing required by this vehicle during impact. In spite of these vehicles are not subjected to the safety standards of road cars, but it must be expected higher than the other category. The only regulation that is available currently in the forest condition is ATV. However, this vehicle has the minimal regulation as it is only used for one or two people and the minimal weight that is less than 500kg and in fact, the safety regulation of ATVs is minimal compared with those road cars. As a result, the testing standard for the road safety is the best guideline for the safety requirement in testing the impact.

Figure 1.2: 8 WD Vehicle
(www.cairns.com.au)

1.2 Problem Statement

One company namely Innopeak (M) Sdn Bhd is on an upward spiral of increasing mass and stiffness for heavy duty vehicles. This company is developing one prototype vehicle called rainforest vehicle (RFV) which is used for the outdoor transportation. This design must fulfil the safety requirement before proceeding to another step; this RFV must be tested according to the road safety standard. Since the destructive testing is immensely expensive, time consuming and unsuitable for a developing company, another approach has been proposed to solve this issue. To address this, a comprehensive research will be undertaken to investigate the crash response of this vehicle using finite element techniques complimented by experiments.

This crash response must be guided using a world standard that has been used in the crashworthiness area. Validation of the model will be conducted by comparing finite element simulation with experimental result of individual frontal truck components and scale section of frontal parts. The effect of varying impact velocity and mass will be numerically examined using finite element models to manifest the impact and energy absorption response during a crash. Moreover, structural integrity and crashworthiness aspect will also be considered accordingly to optimise the design of the existing truck cabin during such an event. The expected outcome of this project is to generate research and design information on the design that will enable further modification and enhancement of the current design for optimising crashworthiness performance and enhancing level of safety.

Figure 1.3: Prototype of Rainforest Vehicle (RFV)

1.3 Objectives of the study

The objectives of the studies are as follows:

a) To investigate the crashworthiness and energy absorption capability of a space frame rainforest vehicle when subjected to frontal impact.
b) To generate research information and make design recommendation based on the numerical crash analysis performed.

1.4 Scope of the study

The scopes of this research were as follows:

a) Development of preliminary model under impact loading.

b) Crushing a quasi-static of the vehicle component

c) Validation of FE results supplement by experiment

d) Detailed impact cases of RFV; Full frontal, 40 % offset and rigid pole.

e) Investigating energy absorption capability of frontal longitudinal members and the chassis.

f) Recommendation of improvement in the critical vehicle component.

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