OPTIMIZATION OF WATER TANK SUPERSTRUCTURES FOR FIRE FIGHTING VEHICLES

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'I admit that had read this thesis and in my opinion this thesis was satisfied from the aspect of scope and quality for the purpose to be awarded Bachelor of Mechanical Engineering (Design and Innovation)'

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Specially

Thank to Allah S.W.T.

To my beloved family members and girlfriend for motivation

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ABSTRACT

Water tank superstructure is use to support fire fighting water tank and other payload integrates with it. It mounts on the vehicle main chassis, thus refinement need to be made in order to reduce the structural weight and manufacturing cost. Nowadays with the capabilities of advanced computer aided design and engineering tools, the process of structural design in the automotive industry has been significantly refined. The application of FEA such as structural modification and optimization is used to reduce component complexity, weight and subsequently cost. Because the level of model complexity can be high, the opportunity for error can also be high. For this reason, some form of model verification is needed before design decisions made in the FEA environment can be implemented in production with high confidence.

This thesis project involved static and dynamics analysis to determine key characteristics of a water tank cladding. The static characteristics include identifying location of high stress area and deflection area. The dynamic characteristics of truck chassis such as the natural frequency and mode shape were determined by using finite element method. Model updating of water tank cladding model was done by alters the structure dimension and added stiffener such as hollow beam or c-channel beam. The purpose of these modifications was proposed to reduce the vibration, improve the strength, and optimize the weight of the tank cladding.

ABSTRAK

Struktur rangka tangki air digunakan untuk menyokong tanki air bersama beban yang terdapat pada struktur tersebut. Ia di pasang pada casis utama lori bomba, justeru itu penambahbaikan pada struktur perlu dijalankan supaya dapat mengurangkan beban dan juga kos pembuatanya. Dengan kecanggihan rekabentuk berbantu komputer yang ada ketika ini, proses rekabentuk casis trak dalam industri automotif dapat dipertingkatkan. Analisis unsur terhingga seperti modifikasi struktur dapat diaplikasikan untuk mengurangkan bentuk komponen yang kompleks dan seterusnya mengurangkan kos. Oleh kerana tahap kompleks model yang tinggi, maka peluang untuk berlakunya ralat juga adalah tinggi. Oleh sebab itu, suatu bentuk pengesahan model diperlukan sebelum sebarang keputusan rekabentuk dibuat dalam analisis unsur terhingga dilaksanakan dalam proses pembuatan. Kajian yang dijalankan adalah melibatkan analisis statik and dinamik bertujuan untuk menentukan ciri-ciri utama sebuah struktur tanki air trak tersebut. Untuk kaedah statik, ia di aplikasikan untuk menentukan kawasan yang mempunyai tegasan yang paling tinggi dan menentukan nilai pesongan. Kaedah kedua adalah kaedah korelasi dinamik yang diaplikasikan dengan menggunakan analisis unsur terhingga bagi menentukan frekuensi tabii dan juga bentuk ragam struktur tersebut. Maka, kemaskini model unsur terhingga telah dijalankan dengan mengubah ukuran struktur dan menambah kekuatan seperti rasuk yang berongga dan rasuk "C-Channel". Seterusnya, beberapa ubahsuaian seperti menambah kekuatan terhadap struktur telah dilakukan untuk mengurangkan kesan getaran di samping menguatkan lagi kekuatan casis.

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f	-	Natural frequency
T	-	Period of harmonic motion
F	-	Force
k	-	Spring stiffness
x	-	Displacement
m	-	Mass
$\ddot{x}$	-	Acceleration
c	-	Damping coefficient
$\dot{x}$	-	Velocity
ω	-	Natural frequency
t	-	Time
[K]	-	Stiffness matrix to represent elastic properties of a model
[M]	-	Mass matrix to represent inertial properties of a model
$\{\ddot{u}\}$	-	Acceleration matrix
$\{u\}$	-	Displacement matrix
$\{\phi\}$	-	Eigenvector or mode shape
λ_i	-	Eigenvalues (the natural or characteristic frequency)
{f}	-	Vector of applied forces
E	-	Young's Modulus
ρ	-	Mass density
υ	-	Poisson ratio

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CHAPTER 1

INTRODUCTION

The truck industry has experienced a high demand in market especially in Malaysia whereby the economic growths are very significantly changed from time to time. There are many industrial sectors using the truck for their transportations such as the logistics, agricultures, factories, fire fighting and other industries. Malaysia had invested large amount of money in automotive industry. However, the development and production of truck industries in Malaysia are currently relies on foreign technology and sometime do not fulfill the local market demand in term of costs, driving performances and transportations efficiency.

Nowadays, the current trend in truck design involves the reduction of costs and increase in transportation efficiency. The pursuit of both these objectives results in lighter truck, which uses less material and carries less dead weight. At the same time, the comfort of the driver cannot be neglected as the driver has to operate safely and comfortably for many hours. Water tank cladding is one part in use in water tender that is strongly being influenced by these guidelines of weight and cost reduction. The consequence of a lighter structure is a vehicle that has structural resonance within the range of typical rigid body vibrations of the truck subsystems. On the other hand, the vibration also can be formed due to dynamic forces induced by the road irregularities, engine, transmission and more. Thus under these various dynamic excitation, the chassis will tend to vibrate and can lead to ride discomfort, ride safety problems, road.

1.1 Objectives

The objectives of this project are:

i) To determine the maximum weight saving for the water tank structures.

ii) To optimize the existing water tank structure base from the structural analysis.

iii) To develop new water tank cladding.

1.2 Scopes

The scopes of study for this project are:

a) Study on the water tank superstructure of the Fire Fighting Vehicle.
b) To do static analysis base computational on the existing superstructures.
c) Optimize the existing superstructures design to fully utilize it structural strength
d) To conduct and demonstrate a 3D modeling and simulation analysis using appropriate tool to collect data analysis

1.3 Problem Statement

In Malaysia, the vehicle models that have been developed almost the same appearance since the models developed in 20 or 30 years ago. This indicates that the evolutions of these truck components are still behind from other countries and research and development technology is not fully utilized in our country. This is a major challenge to truck manufactures to improve and optimize their vehicle designs in order to meet the market demand and at the same time improve the vehicles durability and performance.

The water tank superstructure basically consists of frame structure, c-channel beam, and bracket such as mounting bracket. The frame structure is the main component in the structure. However, the effects of changes to the frame and beam are not well understood in term of vehicle response during riding especially on the effect of water tank with it maximum load on bumpy and off road conditions. For example, if the torsion stiffness of a support beam is lowered, what is the effect on the vehicle's roll stability, handling, ride and durability? Therefore, the main criteria in the analysis is the behavior of water tank cladding structure, how to improve the current design for better riding quality and support stability.

On overall, this research study is really requiring attention to improve the existing condition for betterment of riding quality and stability. There are major areas need to be established in the study to come out with proper investigation on water tank cladding structure especially research methodology on computational analysis. The ultimate result would be improvement of vehicle quality, reliability, flexibility, efficiency and low production cost.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the related research involving truck structure component. The review of the available information related to the study area will help to get more ideas on the project. It's also discussed the basic theory of the components that are used in the research such as the fire fighting vehicle, water tank cladding structure, theory and mechanics of vibration, basic concept of finite elements method, modal analysis and structural analysis. All the information was gathered mostly from text books, journals and internet.

There are two main objectives of the development of water tank structure. Firstly, the appropriate static and dynamic characteristics of the existing structure have to be determined. Secondly, structural development process in order to achieve high quality of the product. There are many factors such as excitation from engine and road that involve which can affect on the vehicle rolling, handling, ride stability and etc.

2.1 Related Research

Today, there are many researches and development program available in the market especially by the international truck manufacturers, which are very much related to this study. Therefore, there are several technical papers from the

'Engineering Society for Advancing Mobility Land Sea Air & Space' (SAE) and some other sources which are reviewed and discussed in this chapter.

Dave Anderson and Greg Schade (2001) developed a Multi-Body Dynamic Model of the Tractor-Semitrailer for ride quality prediction. The studies involved representing the distributed mass and elasticity of the vehicle structures e.g. frame ladder, the non-linear behavior of shock absorbers, reproduce the fundamental system dynamics that influence ride and provide output of the acceleration, velocity and displacement measures needed to compute ride quality. There were three main factors contributed in this study. Firstly, the author had come out with the development of an ADAMS multi-body dynamics model for use as a predictive tool in evaluating ride quality design improvement. The model includes frame, cab and model generated from finite element component mode synthesis. Second, the construction and correlation of the model has been developed and followed a multi-step process in which each of the major sub-systems were developed and validated to test results prior to corporation in the full vehicle model. Finally, after a series of refinements to the model, the next steps were implemented to obtain an acceptable degree of correlation. The author had managed to evaluate the model's ability to predict ride quality by using accelerations measured in the component, which were then processed through an algorithm to compute an overall ride comfort rating.

I.M. Ibrahim, et.al. (1994) had conducted a study on the effect of frame flexibility on the ride vibration of trucks. The aim of the study was to analyze the vehicle dynamic responses to external factors. The spectral analysis technique was used in the problem study. Other than that, the driver acceleration response has been weighted according to the ISO ride comfort techniques. From the author point of view, the excessive levels of vibration in commercial vehicles were due to excitation from the road irregularities which led to ride discomfort, ride safety problems, road holding problems and to cargo damage or destruction. Also, it has been found that the frame structure vibrations due to flexibility have a similar deleterious effect on the vehicle dynamic behavior. In order to study the frame flexibility, the author had came out with the truck frame modeled using the Finite Element Method (FEM) and its modal properties have been calculated. Numerical results were presented for the truck, including power spectral densities and root mean square values of the vehicle dynamic response variables. The results show that there was good agreement with the experimental analysis and that modeling technique was a very powerful and economical for the analysis of complex vehicle structures. From the comparison of the responses of the rigid and flexible body models it has been found that the frame flexibility strongly affects the accelerations of both driver and truck body. Therefore, the author suggested that the frame flexibility effects were taken into account in the design of primary, cab and engine suspension systems.

As a comparison, Figure 2.1 is shown the response of the rigid and flexible body model of the parameters that has been tested.

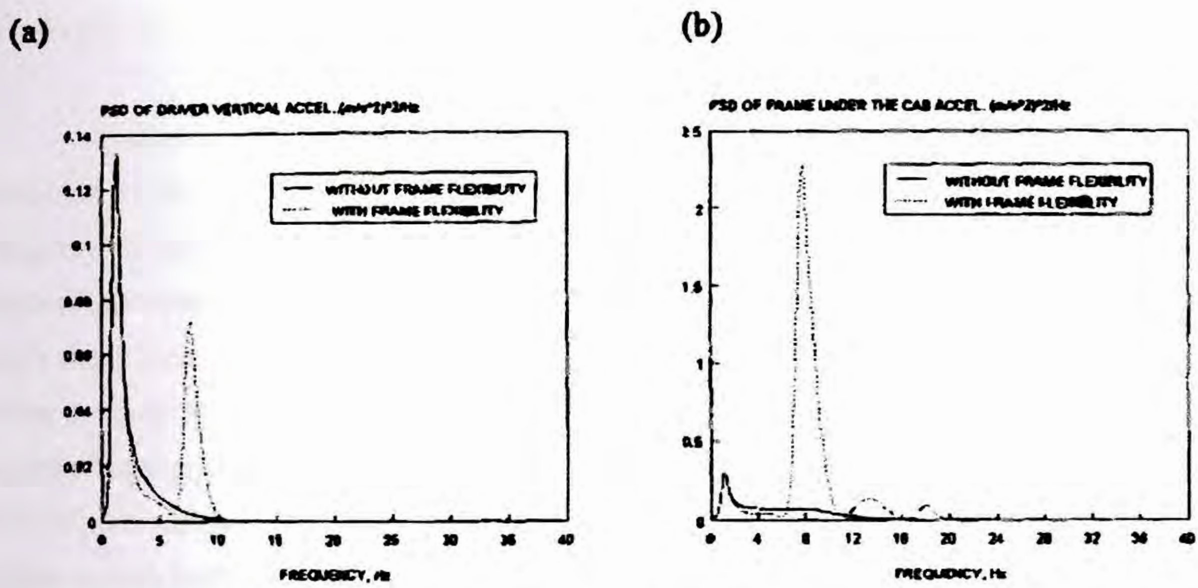

Figure 2.1 – Truck responses spectra (I.M. Ibrahim, et.al. 1994)