STUDY OF DYNAMIC BEHAVIOUR OF TRUCK CHASSIS

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A dissertation submitted in partial fulfillment of the
requirement for the award of the degree of
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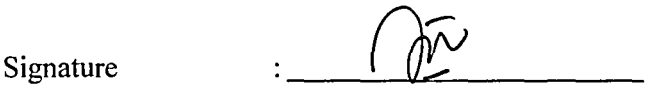
"I hereby declared that this dissertation is the result of my own research except those cited in reference."

Signature : 

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Specially

To my beloved family members and girlfriend for motivation

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ABSTRACT

Truck chassis is a major component in a vehicle system. It integrates the main component systems such as the suspension, engine, cab and trailer. Thus it often identified for refinement in order to develop vehicles with reduced cost and weight. Nowadays with the capabilities of advanced computer aided design and engineering tools, the process of chassis 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 describes the application of dynamic correlation techniques for verification of the FEA models of truck chassis. The dynamic characteristic of truck chassis such as the natural frequency and mode shape will be determined using finite element method. Experimental measurement has been carried out to validate the analytically derived dynamic models. Modal testing is one of the methods that apply the experimental technique in determining the modes of vibration. Initial results from both analysis show that the truck chassis experienced 1st torsion mode for 1st natural frequency, 1st bending mode for 2nd natural frequency, 2nd torsion mode for 3rd natural frequency and 2nd bending mode for 4th natural frequency. However there is a small discrepancy in terms of frequency. Thus, the model updating of truck chassis model has been carried by adjusting the selective properties such as Modulus Young and Poisson ratio in order to get better agreement in the natural frequency between both analysis. Finally, the modifications of the updated FE truck chassis model has been suggested such as by consider adding the stiffener. The purpose is to reduce the vibration as well as to improve the strength of the truck chassis.

ABSTRAK

Casis trak adalah komponen penting dalam sesebuah sistem kenderaan. Ia digunakan untuk menyokong komponen utama sistem trak seperti suspensi, enjin dan treler. Oleh itu pembaikian sering dilakukan ke atasnya untuk mendapatkan sebuah kenderaan yang lebih murah dan ringan. 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. Projek tesis ini menerangkan mengenai applikasi teknik korelasi dinamik dalam mengesahkan model unsure terhingga bagi casis trak. Ciri-ciri getaran casis trak seperti frekuensi tabii dan bentuk ragam akan diperolehi dan ditentukan menggunakan kaedah unsur terhingga. Eksperimen ujikaji modal telah dijalankan untuk mengesahkan keputusan yang diperolehi model analisis unsur terhingga. Bentuk ragam bagi casis trak juga dapat ditentukan melalui ujikaji modal. Hasil keputusan awal daripada eksperimen dan simulasi komputer menunjukkan casis trak mengalami bentuk ragam yang sama. Walaubagaimanapun terdapat sedikit perbezaan nilai frekuensi tabii bagi kedua-dua analisis. Maka, kemaskini model unsur terhingga telah dijalankan dengan menukar cirri sifat bahan seperti Modulus Young dan nisbah Poisson bagi mendapatkan keputusan frekuensi tabii yang lebih jitu di antara model unsur terhingga dan model eksperimen. Seterusnya, beberapa ubahsuaian seperti menambah penguat terhadap casis trak telah dilakukan untuk mengurangkan kesan getaran disamping menguatkan lagi kekuatan casis.

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LIST OF SYMBOLS

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

Chassis used in off-road vehicles have almost the same appearance since the models developed in 20 or 30 years ago. This indicates that the evolution of these structures is still slow and stable along the years [1]. Therefore many researchers in automotive industry have taken this opportunity to be involved in the chassis manufacturing technology and development. Malaysia had invested large amount of money in automotive industry. However, the automotive industry in Malaysia especially in truck manufacturing is still in the development phase and much relying on foreign technology.

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. Chassis is one of the parts in the truck that is strongly influenced by these guidelines of weight and cost reduction [2]. The consequence of a lighter chassis 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 holding problems and also to cargo damage or destruction [3]. However, it is worried most if one of the excitation forces coincides with the natural frequencies of truck chassis. It can cause resonance to occur where the chassis will undergo dangerously large oscillation. This can result in excessive deflection and failure.

To solve this problem, the study of dynamic characteristics of truck chassis is essential by determining the natural frequency and mode shape of the system. The truck chassis can be avoided from vibrating at dangerous level by making sure that the excitation forces frequency does not coincide with the natural frequency of truck chassis. Besides that by understanding the dynamic characteristics; mode shape of truck chassis, the suitable mounting location of the components such as engine, suspension, cab and transmission can be determined. Modification of chassis structure has also become one of the important stages in a truck chassis development. This can be done by modifying the dynamic behavior of the chassis which result in enhancing the structure fatigue characteristic, reduce the vibration effect and improve the strength of truck chassis. Adding stiffener is the most common method used in structural modification [4].

1.1 Objective

The objectives of this project are:

i. To determine the natural frequency and mode shape of the truck chassis by using finite element method and modal analysis.
ii. To improve the dynamic behavior of the truck chassis.

1.2 Scope of Project

The scopes of this project are:

i. Literature review and critical analysis of dynamic characteristic of truck chassis.
ii. Analysis of 1 tonne loading truck chassis
iii. Simulation work by using finite element method.
iv. Experimental work by modal analysis.
v. Correlation of finite element analysis and modal analysis.
vi. Modal updating analysis on FE model by adjusts the selective properties.
vii. Proper modification and improvement of truck chassis to suit desired requirement.

1.3 Outline

Chapter 2 discusses on the literature study of truck chassis based on recent papers and journals that have been carried out lately. The entire literature searches are basically related to the recent structural dynamic analysis, modal analysis testing, finite element analysis and model updating on the truck chassis.

The theory and mechanics of vibration as they are used in this study are explained in Chapter 3. An explanation of truck chassis such as the ladder frame chassis, fundamentals of finite element methods and modal analysis testing are also discussed.

Chapter 4 provides an outline of the truck chassis setup at the Structural Dynamic Laboratory for vibration testing. It includes the chassis installation for free-free vibration test and the data acquisition system for modal testing. Meanwhile the steps and work procedure for finite element analysis are also been clarified in Chapter 4. The correlation and updating process are also defined in this chapter.

Chapter 5 discusses on the experimental results and the analytical predictions by finite element analysis of the truck chassis vibration. All the discussion related to this study such as the correlation analysis, model updating and the structural modification of truck chassis are also discussed in this part.

Finally, Chapter 6 summarizes and concludes the results of the study and provides recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

An extensive literature search in the area of vehicle vibration prediction especially for truck and method of testing was conducted. It has been done to get some idea for the project. The databases such as Society Automotive Engineers (SAE) Technical Papers and Science Direct, which are a leading source literature for automotive, vibration and engineering research, were used to complete the search. Mostly the literature reviews that have been found are based on a previous researcher's technical papers from Society Automotive Engineers. The literature search is basically related on recent structural dynamic analysis, modal analysis testing, finite element analysis and model updating on the truck chassis. In this section, there are 5 papers that related to the studies will be discussed.

R.Rossi Pinto Filho et al. [1] have carried out a research for a commercial off-road vehicle chassis. The work consists in obtaining an optimized chassis design for an off-road vehicle with the appropriate dynamic and structural behavior, taking into account the aspects relative to the economical viability of an initial small scale production. In this paper, the authors have divided the work into three main parts, first are the experimental test done to the chassis to find the torsional stiffness and modal parameters, second are the validation of the finite element model of the chassis using experimental data, and third are the optimization of the chassis based on the validated finite element model to increase in the structural stiffness but with

maintenance of the center of gravity of height and total weight of the structure. Because of the scope of the thesis, only the modal analysis, the validation of finite element model and the optimization of the chassis will be discussed. In a modal testing analysis, the real structure of chassis was sustained by strings to represent a free-free boundary condition. In this experimental test, 6 accelerometers, an inertial hammer, 7 signal conditioners and an acquisition board attach to a Laptop was used for data acquisition. This experimental setup is shown in Figure 2.1.

Figure 2.1: Experimental modal analysis setup for truck chassis [1]

While in the finite element analysis, the chassis model was built using the ANSYS program. A combination of several elements such as a quadrilateral shell elements and triangular shell element were used in the meshing analysis. The results of the modal testing and finite element analysis are shown in Table 2.1. The natural frequencies for the first 7 modes are shown in this table. The authors also found that the first mode of the chassis is torsion, the second mode is bending in y axis and the third mode is bending in z axis. Besides that, the author had discovered the optimized structure presented increase in torsional stiffness, increase of height of center gravity and increase in total mass.