STATIC AND DYNAMIC ANALYSIS OF A LADDER FRAME TRUCK CHASSIS

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

SEPTEMBER 2009

Specially

To my beloved family members and friends for motivation

To Prof Dr. Roslan Abdul Rahman and Assoc. Prof Mustaffa Yusof for the guidance

To all technicians from vibration and strength laboratory for their support

To whoever provided help and contributions.

ACKNOWLEDGEMENT

Alhamdulillah, I managed to complete the study after gone through many challenges during the periods. All praise and many-many thanks to Allah S.W.T who gave the strength and confident to me to complete the thesis entitle **Static and Dynamic Analysis of a Ladder Frame Truck Chassis.**

Special thanks to my supervisor, Prof. Dr. Roslan and PM. Mustafa for guidance and support through out the course and not to forget to Mr. Affendi for his assistance and commitment during experimental analysis at the laboratory.

Last but not least, special appreciation to my beloved family for their full support, encourage and understanding in order to complete this study successfully.

ABSTRACT

Truck chassis is a major component in a vehicle system. This work involves static and dynamics analysis to determine the key characteristics of a truck chassis. The static characteristics include identifying location of high stress area and determining the torsion stiffness of the chassis. The dynamic characteristics of truck chassis such as the natural frequency and mode shape were determined by using finite element (FE) method. Experimental modal analysis was carried out to validate the FE models. Modal updating of the truck chassis model was done by adjusting the selective properties such as mass density and Poisson's ratio. Predicted natural frequency and mode shape were validated against the experimental results. Finally, the modification of the updated FE truck chassis model was proposed to reduce the vibration, improve the strength and optimize the weight of the truck chassis. The major area of concern in the truck chassis was structural resonance at 52 Hz, experienced during the torsional and bending modes. Modifications to shift natural frequencies were proposed by increasing the thickness of the chassis center section by 2 mm and additional stiffener members located at the center of the base plate with a thickness of 10 mm. The overall modifications resulted in the natural frequency shifted by 13 % higher than the original value, increased the torsion stiffness by 25 % and reduced the total deflection by 16 %. The overall weight of the new truck chassis was increased by 7%.

ABSTRAK

Struktur chasis trak adalah merupakan komponen utama dalam sesebuah sistem kenderaan. Kajian yang dijalankan melibatkan analisis statik and dinamik bertujuan untuk menentukan ciri utama struktur trak tersebut. Untuk kaedah statik, ia bertujuan untuk menentukan kawasan yang mempunyai tegasan yang paling tinggi dan nilai tegaran daya kilasan. Kaedah kedua adalah kaedah korelasi dinamik yang diaplikasikan dengan menggunakan kaedah unsur terhingga bagi menentukan frekuensi tabii dan juga bentuk ragam struktur tersebut. Analisis ujikaji modal telah dijalankan untuk mengesahkan keputusan yang diperolehi dari analisis unsur terhingga. Seterusnya, kemaskini model telah dijalankan dengan menukarkan ciri dan sifat bahan seperti ketumpatan jisim dan Nisbah Poisson. Keputusan frekuensi tabii dan bentuk ragam yang diperolehi melalui model unsur terhingga ditentusahkan dengan model eksperimen. Seterusnya, beberapa cadangan pengubahsuaian dilakukan terhadap model unsur terhingga tersebut untuk mengurangkan tahap getaran, meningkatkan kekuatan struktur kerangka dan mengoptimumkan berat bagi chasis tersebut. Perkara utama yang perlu di beri perhatian pada struktur chasis tersebut adalah resonan pada frekuensi 52 Hz yang berlaku semasa mod daya kilasan dan lenturan. Justeru itu, beberapa langkah telah diambil untuk menganjak frekuensi tabii tersebut seperti menambahkan ketebalan kerangka pada bahagian tengah sebanyak 2 mm dan menambah sokongan tambahan pada bahagian tengah struktur setebal 10 mm. Secara keseluruhannya, pembaikan dan pengubahsuaian yang dilakukan terhadap struktur kerangka tersebut telah berjaya menganjakkan frekuensi sebanyak 13% lebih tinggi daripada yang asal, tegaran daya kilasan meningkat sebanyak 25% dan mengurangkan terikan sebanyak 16%. Berat keseluruhan meningkat sebanyak 7% daripada nilai asal.

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c	–	Damping coefficient
E	–	Young's Modulus
f	–	Natural frequency
F	–	Force
k	–	Spring stiffness
x	–	Displacement
m	–	Mass
t	–	Time
ν	–	Poisson's ratio
ρ	–	Mass density
{u}	–	Displacement matrix
{ii}	–	Acceleration matrix
{f}	–	Vector of applied forces
{Ø}	–	Eigenvector or mode shape
[M]	–	Mass matrix to represent inertial properties of a model
[K]	–	Stiffness matrix to represent elastic properties of a model
λ	–	Eigen values (the natural or characteristic frequency)

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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 this truck for their transportations such as the logistics, agricultures, factories and other industries. However, the development and production of truck industries in Malaysia are currently much relying on foreign technology and sometime not fulfill the market demand in term of costs, driving performances and transportations efficiency.

1.1 Types of truck

There are many types of truck in all over the world. Majority of truck's manufacturers receiving order from many industries for transportation purposes in various types and specifications in term of size and truck capacity. Based on that, there are three types or categories which are currently available in the market namely, the compact truck, full size truck and mid size truck.

1.1.1 Compact truck

The compact truck is the most widespread form of pickup truck worldwide. It is built like a mini version of a two-axle heavy truck, with a frame providing structure, a conventional cab, a leaf spring suspension on the rear wheels and a small I4 or V6 engine, generally using gasoline.

The compact truck was introduced to North America in the 1960s by Japanese manufacturers. Datsun (Nissan 1959) and Toyota dominated under their own nameplates through the end of the 1970s.

1.1.2 Full size truck

A full size truck is a large truck suitable for hauling heavy loads and performing other functions. Most full-size trucks can carry at lease 450 kg in the rear bed, with some capable of over five times that much.

1.1.3 Mid size truck

In North America, trucks were commonly used as general purpose passenger cars. They were popular not only with construction workers, but also with housewives and office workers. Thus arose the need for a pickup truck that was bigger than a compact and smaller and more fuel-efficient than the full-size pickup.

1.2 The cultural significant of the truck

There are many types of truck that have been developed in the market especially for the cultural needs. The research and development have always found the new technology, which have really contributed to their needs especially for private use as well as organization and country.

1.2.1 The Australian Truck

The Australian utility truck, or more affection ally called "ute", is the mainstay variety of truck in Australia. Since the modern design of the ute first rolled off the assembly line at the Ford factory in Geelong in 1934, which Henry Ford described as the "kangaroo chaser". There were two common types exist, which is the American style truck, commonly popular with farmers. It is usually Japanese or Australian built model, such as the Isuzu Rodeo or the Toyota Hilux. These are popular in a variety of forms, two and four wheel drive, single or dual cab integrated tray or flat bed. These kinds of vehicles are also common in New Zealand, where they are also referred to as "utes". The other type of vehicle commonly referred to as a "ute" is quite different-a two-seater sporty version of typical saloon cars, featuring a "ute"-type integrated tray back.

1.2.2 Truck in Europe

In Europe, pickups truck is considered light commercial vehicles for farmers. Until the 1990s, pickup trucks were preferred mainly as individual vehicles in rural areas, while vans and large trucks were the preferred method of transportation for cargo.

1.2.3 Military use

Pickup trucks have been used as troop carrier in many parts of the world, especially in countries with few civilian roads of very rough terrain. Pickup trucks have also been used as fighting vehicles, often equipped with a machine-gun mounted on the bed.

1.3 Basic Frames

Below is some basic technique in developing the frame commonly used by truck chassis manufacture in the world since it was introduced in 1977. The frame rails start as 1/8'' flat steel. Side rails, boxing plates, top and bottom lips are plasma cut to shape and fully jig welded. (Figure 1.1)

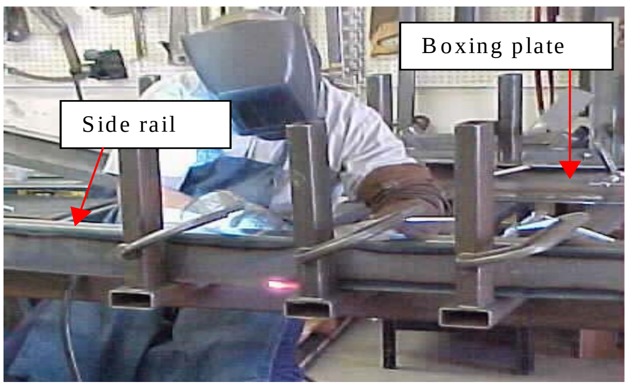

Figure 1.1: Cutting process

The top and bottom lips are then full length welded on the inside as well as the outside as illustrated in Figure 1.2. The reason is to make the rails stronger so that crack will not occur at the weld seams.

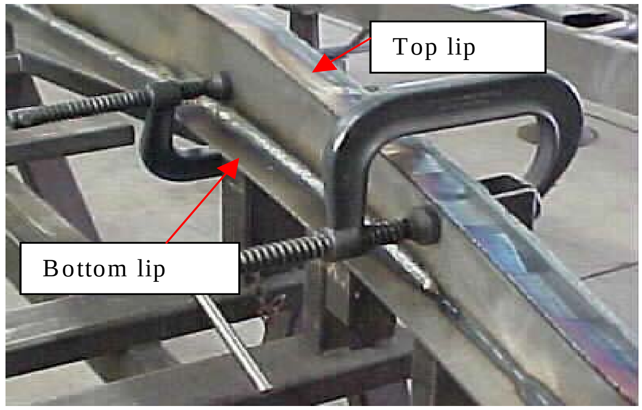

Figure 1.2: Welding process

The rails are fully ground and smoothed as shown in Figure 1.3.

Figure 1.3: Finishing process

Finally, the rails are clamped back into fixture, ready for the cross members to be welded into place. (Figure 1.4)

Figure 1.4: Final assembly

Figure 1.5 is a set of 1933 Chevy Master Rails, completed and ready.

Figure 1.5: Chevy Master Rail [12]

1.4 Problem Statement

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 structures 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. Since the truck chassis is a major component in the vehicle system, therefore, it is often identified for refinement and improvement for better handling and comfortably.

The frame of the truck chassis is a backbone of the vehicle and integrates the main truck component systems such as the axles, suspension, power train, cab and trailer. The typical chassis is a ladder structure consisting of two C channel rails connected by cross-members as illustrated in Figure 1.6. Almost all the chassis development is varying in design, weight, complexity and cost. However, the effects of changes to the frame and cross-members are not well understood in term of vehicle response during riding especially on bumpy and off road conditions. For example, if the torsion stiffness of a suspension cross-member is lowered, what is the effect on the vehicle's roll stability, handling, ride and durability? Therefore, the main criteria in the analysis are the behavior of truck chassis, how to improve the current design for better riding quality and suitably to customer needs.

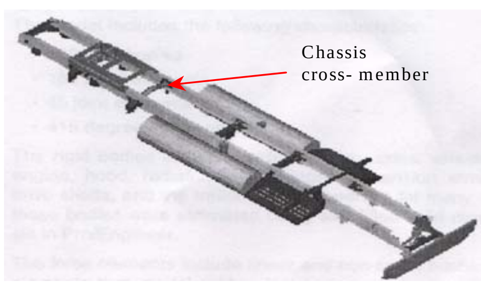

Figure 1.6: Sample of the Truck Chassis [1]

On overall, this research study is really requiring attention to improve the existing condition for betterment of riding quality and comfortably. There are major areas need to be established in the study to come out with proper investigation on truck chassis especially research methodology on experimental and computational analysis. The ultimate result would be improvement of vehicle quality, reliability, flexibility, efficiency and low production cost. Figure 1.7 below shows an example of the global module concept, which has been implemented by most truck's manufacturer in the world.

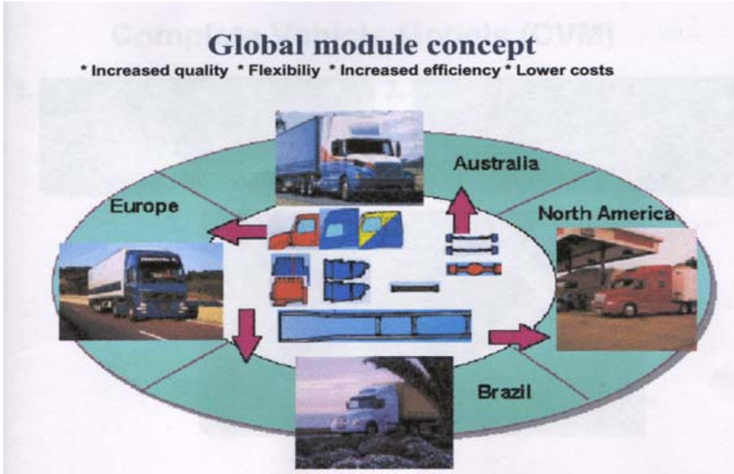

Figure 1.7 Global Module Concepts [2]

1.5 Objective

The objectives of this study are:

i) To determine the torsion stiffness and static and dynamic mode shape of the truck chassis by using torsion testing, modal analysis and finite element method.

ii) To improve the static and dynamic behavior of the truck chassis by changing the geometrical dimension and structural properties.

iii) To develop a new truck chassis.

1.6 Scope of work

The scope of work includes:

i. Literature review associated with truck chassis development, design and analysis to the commercial truck chassis.
ii. This study will concentrate on truck chassis of not more than 2 ton
iii. Simulation and experimental work on the existing truck chassis
iv. Correlation of simulation and experimental results.
v. Model updating process, which include parameters adjustment in order to obtain a good model of truck chassis
vi. Improvement of truck chassis characteristic by changing the geometry, material and structure to the existing model.
vii. Development of new truck chassis.

1.7 Expected result.

Base on the research and development planning, it is expected to achieve a better performance of truck chassis and the main focuses of the analysis are listed below:

i. To improve the existing chassis performance such as the torsion stiffness, strength and dynamic behavior due to dynamic load. The result shall be able to present the static and dynamics motion of the truck chassis which include the natural frequency, mode shapes and damping value.
ii. The experimental data will be used to validate a finite element model and the updated model shall represent the real structure of the chassis.
iii. The improvement of structures and supports shall be done to the existing chassis in order to fulfill the customer’s requirement such as cost, reliability, conformability and better performance.