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Design and Analysis of Chassis in 2214 Truck

S. A. Karthikeyan(1) ,R. Pavendan(2)

[1]*PG student, Mechanical Engineering, J.J College of Engineering & Technology, Trichy, Tamilnadu.*
[2]*Assistant Professor, Department of Mechanical Engineering, J.J College of Engineering & Technology, Trichy, Tamilnadu*

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%.*

I. INTRODUCTION OF TRUCK CHASSIS

1.1 Overview

The truck industry has experienced a high demand in market as 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.

1.1.1 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 ave 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 arepopular in a variety of forms, two and four wheel drive, single or dual cab integratedtray or flat bed. These kinds of vehicles are also common in New Zealand, wherethey 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 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.

Figure 1.5: Sample of the Truck Chassis

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.

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. below shows an example of the global module concept, which has been implemented by most truck's manufacturer in the world.

1.5 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 25 ton pay load
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.

II. LITERATURE SURVEY

There are two main objectives, which involves on the development of truck chassis. Firstly, the appropriate static and dynamic characteristics of the existing chassis have to be determined. Secondly, structural development process in order to achieve high quality of the product. There are many factors involve and must take into account, which can affect on the vehicle rolling, handling, ride stability and etc. 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

2.1 Truck Chassis Research

Dave Anderson and Greg Schade developed a Multi-Body Dynamic Model of the Tractor-Semi trailer 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. 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

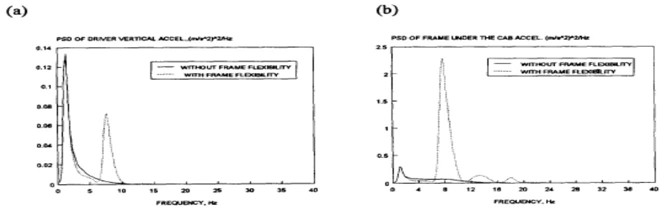


Figure 2.1 – Truck responses spectra [2]

Firstly, the modeling of the chassis used in a commercial off-road vehicle using commercial software based on the finite elements method (FEM). Secondly, a series of testing were conducted to obtain information for modeling and validation. Finally, the validated model allowed the optimization of the structure seeking for higher torsion stiffness and maintenance of the total structure mass.

In the finite element model, the author has developed the chassis by using steel with closed rectangular profile longitudinal rails and tubular section cross- member. The geometry of the chassis was measured directly in the reference vehicle real structure. Then, a modal analysis procedure was accomplished on the real chassis and finite element model structure in order to establish the real structure to the chassis structures. The natural frequencies were extracted. For the frame optimization, the author tried to use groups of numerical and programming techniques to search for the optimum value of mathematical functions. In other words, the purpose of the optimization is to facilitate in finding results that best fills out the needs. Based on the result, the analysis and experimental procedure applied had significantly improved the overall structural stiffness by 75% by maintaining the center of gravity and the total weight was increased by 6%.

2.1.1 Overall Discussion on Truck Chassis Research

It can be concluded that, many of the truck structures found in the research are subjected to internal and external loads, which affected the ride quality of vehicle. These loads and behavior can be determined through a series of processes namely, Modal Analysis, Finite Element and Torsion Analysis. Besides that, the correlation and modal updating technique also important in order to create a good model for further analysis. From the global torsion analysis, it has been found that the torsion load is more severe than bending load. In order to overcome this problem, a cross bar and material selection are very important to consider during design stage. Furthermore, the overall achievement is mainly to reduce the vibration level, so that the life of the structure and performance can be maximized.

2.2 Overview of chassis types

2.2.1 Definition of a Chassis

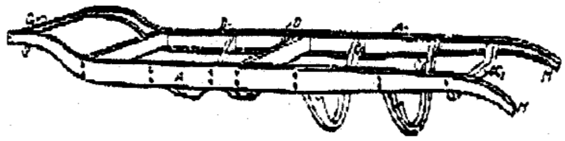
The chassis is the framework that is everything attached to it in a vehicle. In a modern vehicle, it is expected to fulfill the following functions:

i. Provide mounting points for the suspensions, the steering mechanism, the engine and gearbox, the final drive, the fuel tank and the seating for the occupants;
ii. Provide rigidity for accurate handling;
iii. Protect the occupants against external impact.

While fulfilling these functions, the chassis should be light enough to reduce inertia and offer satisfactory performance. It should also be tough enough to resist fatigue loads that are produced due to interaction between the driver, engine, power transmission and road conditions.

2.2.2 Ladder frame

The history of the ladder frame chassis dates back to the times of the horse drawn carriage. It was used for the construction of 'body on chassis' vehicles, which meant a separately constructed body was mounted on a rolling chassis. The chassis consisted of two parallel beams mounted down each side of the car where the front and rear axles were leaf sprung beam axles. The beams were mainly channeled sections with lateral cross members, hence the name. The main factor influencing the design was resistance to bending but there was no consideration of torsion stiffness.



A ladder frame acts as a grillage structure with the beams resisting the shear forces and bending loads. To increase the torsion stiffness of the ladder chassis cruciform bracing was added in the 1930's. The torque in the chassis was retrained by placing the cruciform members in bending, although the connections between the beams and the cruciform must be rigid. Ladder frames were used in car construction until the 1950's but in racing only until the mid 1930's. A typical ladder frame shown as below in Figure 2.1

2.2.3 Twin tube

The ladder frame chassis became obsolete in the mid 1930's with the advent of all-round independent suspension, pioneered by Mercedes Benz and Auto Union. The suspension was unable to operate effectively due to the lack of torsion stiffness. The ladder frame was modified to overcome these failings by making the side rails deeper and boxing them. A closed section has approximately one thousand times the torsion stiffness of an open section. Mercedes initially chose rectangular section, later switching to oval section, which has high torsion stiffness and high bending stiffness due to increased section depth, while Auto Union used tubular section. The original Mercedes design was further improved by mounting the cross members through the side rails and welding on both sides. The efficiency of twin tube chassis' is usually low due to the weight of the large tubes. They were still in use into the 1950's,

1958 Lister-Jaguar being an example of this type. A typical twin-tube chassis is shown in Figure 2.2.

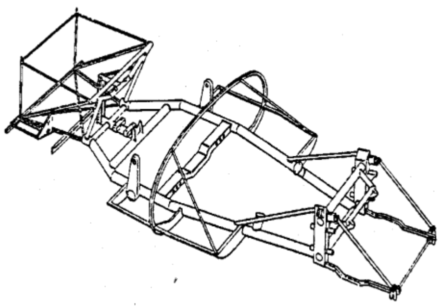


Figure 2.2: Twin-tube chassis

2.2.4 Space frame

Although the space frame (Figure 2.3) demonstrated a logical development of the four-tube chassis, the space frame differs in several key areas and offers enormous advantages over its predecessors. A space frame is one in which many straight tubes are arranged so that the loads experienced all act in either tension or compression. This is a major advantage, since none of the tubes are subject to a bending load. Since space frames are inherently stiff in torsion, very little material is needed so they can be lightweight. The growing realization of the need for increased chassis torsion stiffness in the years following World War II led to the space frame, or a variation of it, becoming universal among European road race cars following its appearance on both the Lotus Mk IV and the Mercedes 300 SL in 1952.
While these cars were not strictly the first to use space frames, they were widely successful, and the attention they received popularized the idea.

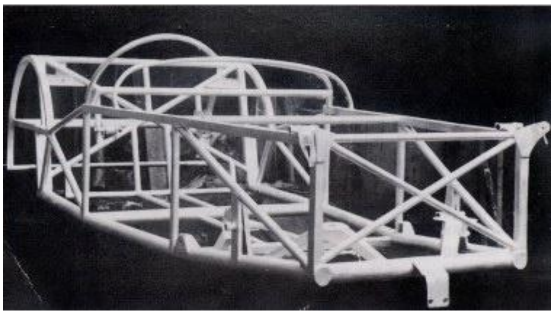


Figure 2.3: 1952 Lotus Mk.IV space frame

III. RESEARCH METHODOLOGY

3.1 Identification of Problem

The chassis frame forms the backbone of the truck and its chief function is to safely carry the maximum load wherever the operation demands. Basically, it must absorb engine and axle torque and absorb shock loads over twisting, pounding and uneven roadbeds when the vehicle moving along the road.

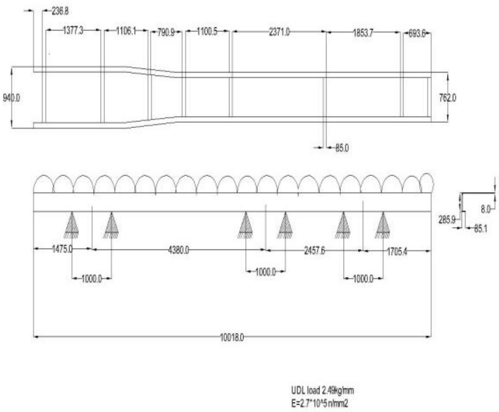
For this project, the truck chassis is categorized under the ladder frame type chassis. Figure 3.1 shows a typical ladder frame chassis for commercial vehicle. A ladder frame can be considered structurally as grillages. It consists of two side members bridged and held apart by a series of cross members. The side members function as a resistance to the shear forces and bending loads while the cross members give torsion rigidity to the frame. Most of the light commercial vehicle chassis have sturdy and box section steel frames, which provide this vertical and lateral strength and resistance to torsion stress.

There are some advantages and disadvantages when using ladder frame chassis. One of the advantages is the ease of mounting and dismounting the body structure. Various body types ranging from flat platform, box vans and tankers to detachable containers can be adapted easily to a standard ladder frame chassis. Besides that, the noise generated by drive train components is isolated from the passenger compartment through the use of rubber chassis design which yields a relatively inexpensive and easy manufacturing process compare to other type of chassis.

While the main disadvantages of the ladder frame is its torsion rigidity. Since it is a two-dimensional structure, its torsion rigidity is very much lower than other chassis, especially when dealing with vertical load or bumps. The weight of the ladder chassis is also high compare to other types of chassis.

Besides that, the overall chassis structure is currently not so good for the actual analysis due to the chassis being old and several portions are badly corroded and therefore, the strength of the structure especially at the welding area may affect the analysis results

Fig no 3.1



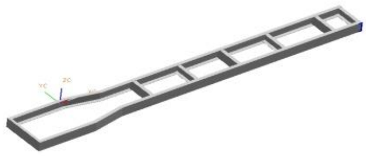


Fig 3.2

3.2 Research Methodology

In this project, Finite Element and analysis is to be used to determine the characteristics of the truck chassis. All methodology principles and theories discussed in Chapter 2 are to be used to achieve the project's objectives. The combination of all the analysis results are to be used to develop virtual model created using FEM tools and the model is updated based on the correlation process. Further analysis and modification are then executed to the existing truck chassis design and proposed for a new truck chassis.

For the purpose of this study, the truck chassis is modeled using Unigraphics software according to the original size of structures. The model is then imported into Finite Element software (ANSYS). The purpose is to determine the natural frequencies and mode shapes. For the meshing analysis, 10 node-tetrahedral elements were chosen to model the solid chassis. Study by previous researches [2] found that 10 node-tetrahedral elements gave a closer dynamic behavior to the experimental results.

Based on overall result, proper modifications on the verified model of truck chassis are carried out to improve the chassis's strength. All the steps required in each of the method used to have a valid FE model representative are described in the following section.

The research methodology flowchart for this project is shown in Figure 3.2. The literature review of the truck chassis was carried out to obtain basic understanding of the project. Information like typical natural frequency values of truck chassis, excitation sources and mode shape of truck chassis were searched and reviewed. Then the dimension of an existing truck chassis was measured. The chassis chosen was a AL2214 truck model of mass approximately 75kg. The type of chassis was known as parallel ladder type frame with box section as shown in Figure 3.1. The next step was the chassis structural preparation and set up for measurement purposes. The measurement of Frequency Response Function (FRF) data was performed and there were 22 measurement points through out the chassis structure. The FRF data were then transformed into ME's Scope software for further analysis on Modal Analysis.

The Computed Aided Design (CAD) modeling was performed on the existing chassis by using Unigraphics Modeling Software. Then, the chassis modeled was completely transformed into the finite element software for further analysis of finite element analysis. Then, the result from both analysis will then be compared and the virtual structural model will be developed using FEM tools. In this stage, the finite element and experimental torsion analysis will also be performed. The objective of these tests is to find the torsion stiffness of the structure and the response of the applied load at different loading condition.

The next steps are the correlation and model updating process to obtain the virtual structure of the chassis. Then, the final stage is the modification of the virtual model to find the optimum chassis condition and suited with current market demand. The final result of the modification of finite element analysis is then proposed for future actual modification.

IV. CONCLUSION

This chapter discusses on the overall results presented in the earlier chapters. Base on the overall results, it can be improved further and include several recommendations for future research especially in structural dynamic behavior to any system.

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