Modal and Static Structural Analysis of Backhoe Loader Chassis

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***Abstract*--Backhoe Loader chassis is the skeleton of a commercial vehicles. The main function of the truck chassis is to support the different components like engine, cabin, transmission, front axle and rear axle. This paper presents modal analysis of chassis that include the natural frequency and mode shapes. Also the static analysis, which includes the stress distribution and deformation contours, is carried out when the dead weight of different components like engine, cabin, transmission, front axle and rear axle are placed on it. At the end of paper some modification are suggested to improve the strength of the chassis.**

***Index Terms*-- Backhoe Loader chassis, vibration, torsion stiffness, stress distribution.**

I. INTRODUCTION

IN the era of globalization and tough competition the use of machines is increasing for the earth moving works, considerable attention has been focused on designing of the earthmoving equipments. Thus it is very much necessary for the designers to provide not only a equipment of maximum reliability but also of minimum weight and cost, keeping design safe under all loading conditions by careful stress analysis of the machines.

Backhoe Loaders are used primarily to excavate below the natural surface of the ground on which the machine rests and load it into trucks or tractor pulled wagons or onto conveyor belts. They are capable of excavating all classes of earth, except solid rock, without prior loosing. They are adapted to excavating trenches, pits for the basement, and general grading work, which require precious control of depths.

Chassis of commercial vehicles have almost same appearance since the model was developed. It indicates that there is very slow and stable improvement in the chassis [1].

As a Backhoe Loader travels along the road, the Backhoe Loader chassis is excited by dynamic forces induced by the road roughness, engine, transmission and more. Under such various dynamic excitations, the Backhoe Loader chassis tends to vibrate. If any of the excitation frequencies coincides with the natural frequencies of the Backhoe Loader chassis, then resonance phenomenon occurs. The chassis will undergo dangerously large oscillations, which may lead to excessive deflection and failure. The vibration of the chassis will also cause high stress concentrations at certain locations, fatigue of the structure, loosening of mechanical joints, and creation of noise and vehicle discomfort. To solve these problems, study on the Backhoe Loader chassis dynamic characteristics is thus essential.

II. BACKHOE LOADER CHASSIS

The Backhoe Loader chassis used for the study has a gross weight of 743 Kg. It consists of 2 inside C-plate and has 1 chassis box members along the 2 inside C-plate. There are some additional members like End plate and chassis Front plate. On the rear side of chassis four cabin mounting points are provided as shown in the figure 1. On the front side of chassis four engine mounting points are provided which is shown in figure 2.

The material of the backhoe loader chassis is structural steel alloy. The properties of the material are listed below:

Modulus of Elasticity, E = 200 GPa

Mass Density, ρ = 7850kg/m^3

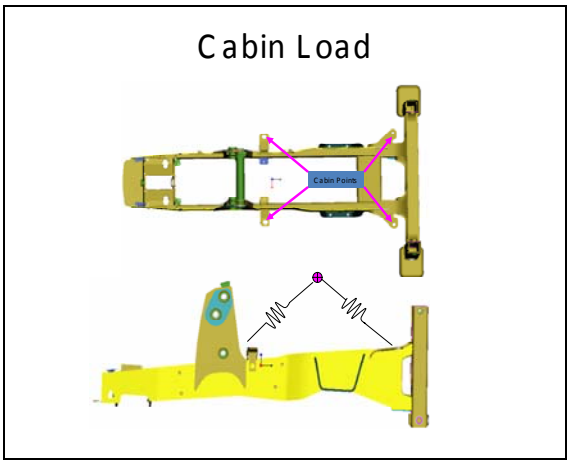


Fig. 1. Cabin Mounting Points

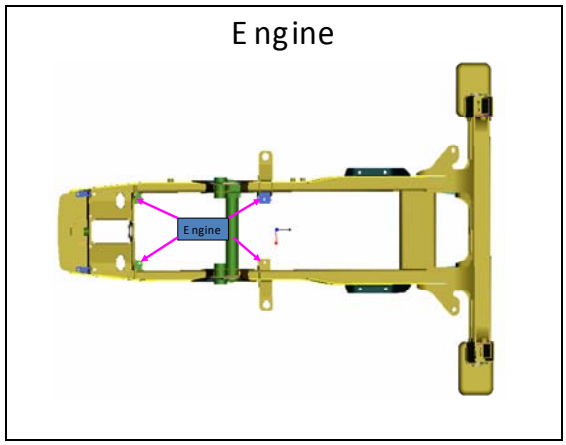


Fig. 2. Engine Mounting Points

III. FINITE ELEMENT MODEL

The Backhoe Loader chassis was modeled by using tetrahedron solid elements. There are two types of analysis carried out; normal mode analysis to determine the natural frequencies and the mode shapes, and the linear static stress analysis to look into the stress distribution and deformation pattern of the chassis under static load. For normal mode analysis and linear static analysis the chassis model was meshed with 109748 tetrahedron elements and 225025 nodes.

The boundary conditions are different for each analysis. In normal mode analysis, free-free boundary condition will be applied to the Backhoe Loader chassis model, only constraint applied to the stabilizer legs where all degree of freedom are fixed. In this analysis, no load is applied to the Backhoe Loader chassis model. In static analysis, when the Backhoe Loader is stationary, the loads from the weights of the components like cab, engine, transmission, axles are applied to the mounting brackets of the components.

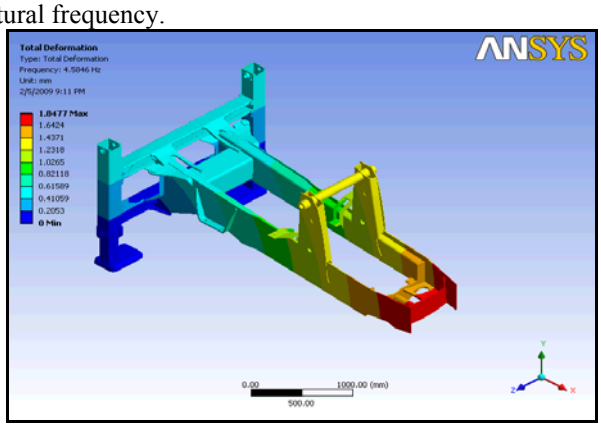
IV. RESULT AND DISCUSSION

1). Modal Analysis

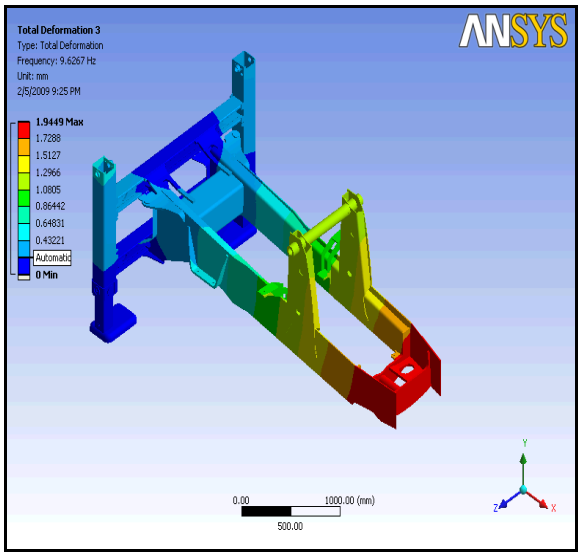
The natural frequencies and the corresponding modes shapes of the first 6 modes are shown in Figure 2. The figure shows the total translation values of the chassis under the vibration mode.

In the operation condition of Backhoe loader, the dynamic characteristic of chassis is very important. When the engine is in running condition, forces from engine, transmission system, exhaust etc. are transferred to the chassis. Also forces from road roughness are transferred to chassis when Backhoe Loader travels along road. Each of the above excitation forces has its excitation frequencies which when it coincidence with the natural frequencies will result in resonance phenomena.

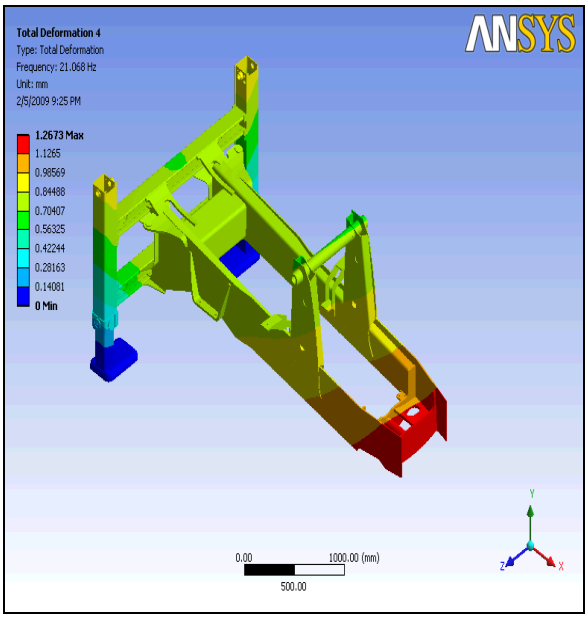
The natural frequency of the Backhoe Loader chassis should not coincide with the frequency range of the axles because this can cause resonance which may give rise to high deflection and stresses and poor ride comfort. Excitation from the road is the main disturbance to the truck chassis when the truck travels along the road. In practice, the road excitation has typical values varying from 0 to 100 Hz [2]. At high speed cruising, the excitation is about 2200 rpm or 36.66 Hz. This value is close to the fourth and the fifth mode natural frequency.



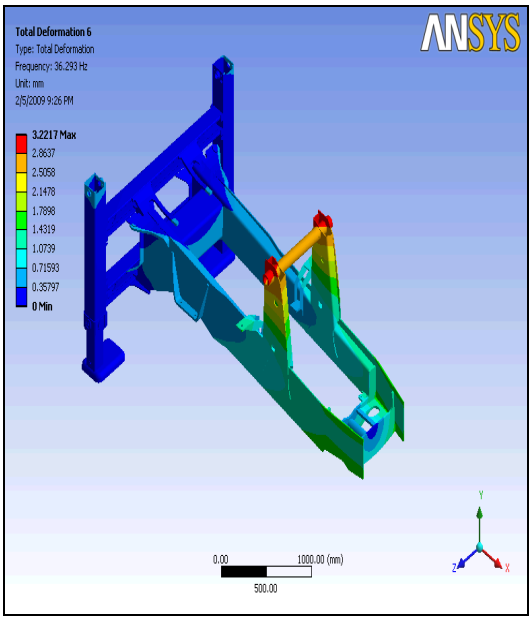
Mode 1: 4.58 Hz



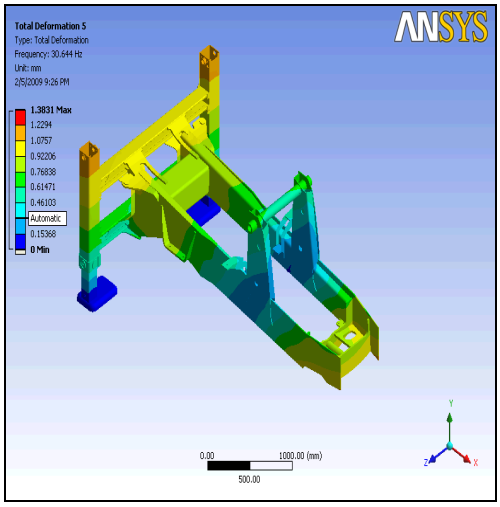
Mode 2: 9.62 Hz



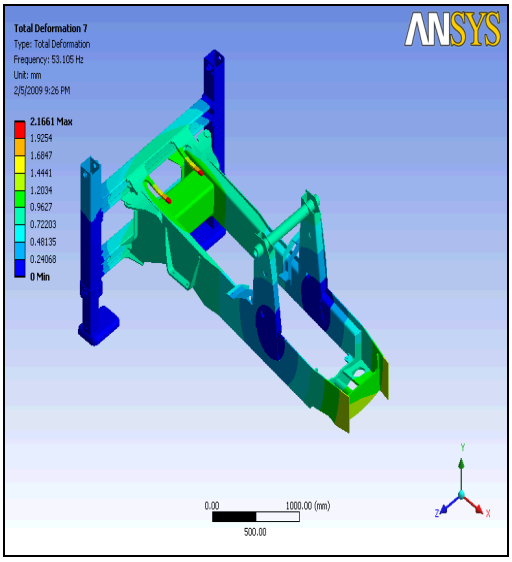
Mode 3: 21.06 Hz



Mode 5: 36.29 Hz



Mode 4: 30.64 Hz



Mode 6: 53.10 Hz

2). Static Analysis

Backhoe Loader Components Loading

This simulation is based on the condition of the Backhoe loader being stationary. Forces as shown in the table 1 are applied to the chassis. For practical calculation, it is recommended that the load on the chassis is concentrated at a small number of points [3].

TABLE I
WEIGHT AND FORCES OF COMPONENTS

No.	Component	Weight(Kg)	Load(N)
1	Cabin	620	6082
2	Front axle	225	2207
3	Rear axle	410	4022
4	Transmission	215	2109
5	Engine	585	5739
6	Chassis	743	7289

Fig. 4 shows the results of stress distribution and deformation pattern of the chassis under the weight loading of components mounted on it. The stress distribution is almost uniform; with the highest stressed areas are at the front cabin mount bracket, where the maximum stress is about 66.86 MPa. The rest of the chassis structure has very low stress value.
Every member plays a role in strengthening the chassis.

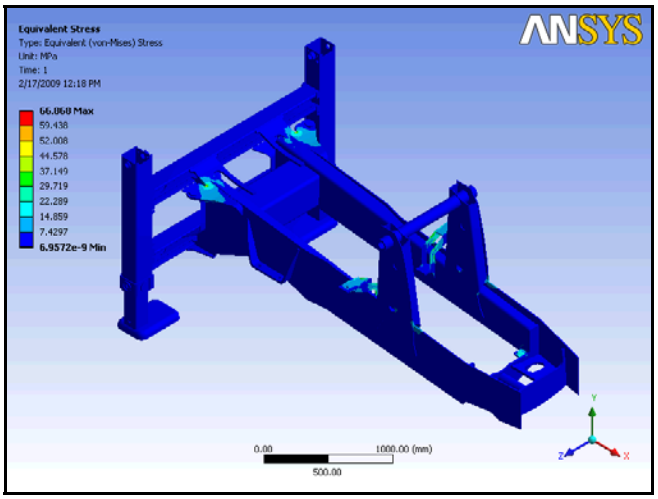


Fig. 4. Stress contour and stress pattern of the chassis under Backhoe Loader components loading

Fig.5 shows the deformation contour and the deformation pattern of the chassis under static case. The highest deformation happens at the cabin mounting plate where the cabin payload is applied. The maximum translation is 0.464 mm. The other components like the axle, engine, transmission, fuel tank and exhaust do not have significant effect to the stress and deformation of the chassis compared to the cabin payload.

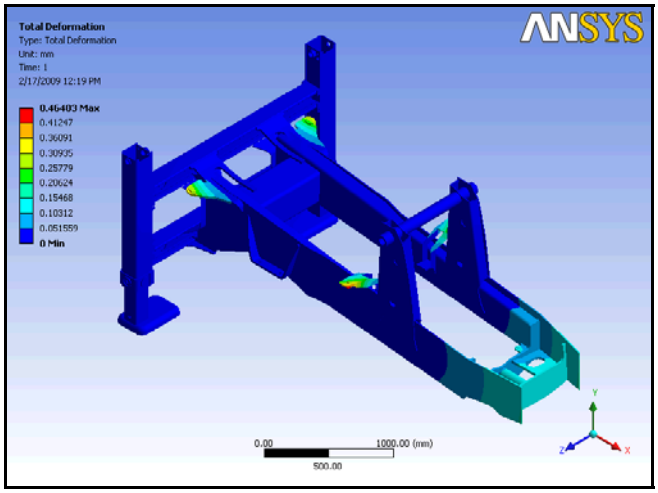


Fig. 5. Deformation contour and the deformation pattern of the chassis under Backhoe loader components loading

3). Modification

The static analysis shows concentration of stress at the sharp edges of the chassis. This concentration of stress can be reduced by smoothening the sharp corner. The sharp corner can be eliminated by introducing fillet in the design. Besides that, the welded joints are also one of the highest stress concentration areas. The imperfect welding during the fabricating process are the weak areas where failure of the chassis is likely to occur due to fatigue.

V. CONCLUSION

The paper has looked into the determination of the dynamic characteristic (the natural frequencies and the mode shapes) of the Backhoe Loader chassis. The first six natural frequencies of the Backhoe Loader chassis are below 100 Hz and vary from 4.58 to 53.10 Hz. For the first four modes, the Backhoe Loader chassis experienced global vibration. The global vibrations of the Backhoe Loader chassis include torsion, lateral bending and vertical bending. The local bending vibration occurs at the loader tower member where the Loader assembly is mounted on it.

In the linear static analysis, the stress distribution and deformation profile of the Backhoe Loader chassis is carried out when subjected to Backhoe Loader components loading. Maximum stress and maximum translation occurred at the mounting brackets of the cabin. The maximum stress of the Backhoe Loader chassis is 66.86 MPa while the maximum translation is 0.464 mm. These values are acceptable as compared to the yield strength of the chassis material and the tolerance allowed for the chassis.

VI. REFERENCES

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