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Vibration Analysis Of Heavy-Duty Truck Chassis Frames For Enhanced PerformanceAnd Durability

C Mohan[1], N Nagesh [2], K Ganesh[3]
[1]PG Student, Dept. Of Mechanical Engineering, Kuppam Engineering college, AP, India
[2]Associate Professor, Dept. Of Mechanical Engineering, Kuppam Engineering college, AP, India
[3]Associate Professor & HOD, Dept. Of Mechanical Engineering, Kuppam Engineering college, AP, India

Abstract: Truck chassis is to provide structural integrity and stability to the commercial vehicle. In addition to supporting various components like, transmission system, body frames and payload to be placed upon it. Normally High strength low carbon steel is used as a main chassis material of heavy-duty trucks in our country in which the overall weight of the chassis is increased by 7% for reducing the deflection under load condition, road shocks to increase the stiffness of chassis. Due to this the gross weight of the vehicle is also increased. In this project, Aluminum lithium alloy is used as the alternative chassis material for heavy duty truck. In this Aluminum lithium alloy, 1% percentage of Lithium added to Aluminum reduces the density of material by 3% and increase in elastic modulus up to 7%. For a chassis frame thickness of 6 mm the Aluminum lithium alloy 2090 has the ability to give high strength with low density over high strength low carbon steel alloy. By using this aluminum lithium alloy we can be able to reduce one third of gross weight of vehicle chassis frame while compared to present chassis frame material. The modeling of the heavy duty truck chassis (Ashok Leyland Comet 1616 H) done by using Pro-E and The comparison of stress distribution and dynamic behavior like natural frequency of truck chassis made of high strength low carbon steel alloy and aluminum lithium alloy 2090 is done by using ANSYS software.

Index Terms – Pro/ENGINEER, ANSYS for harmonic analysis, free mesh method, Al-Li Alloy and HSLC steel.

I. INTRODUCTION

Frame chassis have been in use since the start of the motor sport scene. Farer consists of steel or aluminum tubular pipes placed in a triangulated format to support the loads from the vehicle caused by; suspension, engine, driver and aerodynamics. There are two main types of chassis used in race cars, steel frames and composite monologue. Although frames are the traditional style they are still very popular today in amateur motor sport. Their popularity maintains because of their simplicity, the only tools required to construct a space frame is a saw, measuring device and welder. The space frame still has advantages over a monologue as it can easily be repaired and inspected for damage after a collision. The chassis has to contain the various components required for the race car as well as being based around a driver's cockpit. The safety of the chassis is a major aspect in the design, and should be considered through all stages. The design also has to meet strict requirements. Due to limited budgets and time constraints the design of the chassis will need to be geared towards simplicity and strength. Vibration analysis of a heavy-duty truck chassis frame is an important aspect of ensuring the structural integrity and performance of the vehicle. Vibration can affect various components of the truck, including the frame, suspension, and attached equipment. By analyzingand mitigating excessive vibrations, manufacturers can improve the ride comfort, reduce component fatigue, and enhance overall vehicle durability.

II. LITERATURE REVIEW

The various works are carried out in stress analysis, Modal analysis of automobile chassis brackets. Among which few are categorized and discussed below.

Rao SS and Mehmood A, et al. discussed this study analyzed how a half car model responds to vibrations caused by different road conditions. A mathematical model of the car chassis was created to understand its vibration behavior and evaluate the effects of damping. The research aimed to obtain graphs showing vibration amplitude over time for different frequencies and calculate the car's damping properties. [1]

Zaman I, et al. Explained about the this study aimed to analyze the dynamic characteristics of a truck chassis using a 3D finite element model. The goal was to reduce weight and manufacturing costs while ensuring structural integrity. The researchers modified the chassis shape and size and incorporated rubber mounts to minimize vibrations and deflections. By updating the model and manufacturing according to industry standards, they achieved better accuracy and reduced errors. The study aimed to optimize the chassis design, improve performance, and achieve cost savings. [2]

Athikesavan D, et al.
This study focused on the design and vibration analysis of a ladder type chassis with riveted cross members and welded joints. The researchers used finite element analysis to evaluate stress distribution, deformation, mode shapes, and natural frequencies of the chassis. The main goal was to assess the chassis's structural integrity and dynamic behavior under different loads. The analysis provided insights into stress distribution, deformation patterns, and critical areas, enabling design optimization. [3]

Raju AB, et al.
In this discussion, we explored the impact of vibrations on the suspension system and mounts in an automotive chassis. We used both a full model chassis and an equation-based model to study the effects. Simulations were conducted using Finite Element Method (FEM) software to replicate real-world conditions, including dynamic loads and road scenarios. The simulations provided results such as frequencies and mode shapes, which were validated through experimental methods. [4]

Renuke P, et al. We provided a description of this study focused on analyzing the vibration characteristics of a car chassis under dynamic conditions, including road roughness. Modal analysis using finite element analysis was conducted to examine these vibrations. The results revealed that the chassis's behavior is nonlinear, meaning its response is not directly proportional to applied forces. This nonlinearity can be influenced by factors like material properties, geometric complexities, and contact interactions. [5]

III. METHODOLOGY

- The model is imported to ANSYS for harmonic analysis
- The chassis model is combined with all cross bar using VOLUME ADD.
- MESH the model by using free mesh method.
- Change the analysis type to harmonic from static conditions.
- Giving the minimum and maximum frequency values under the subsets of 100.
- Load conditions are given to chassis model and solve the problem.
- The model is tested for amplitude between Al-Li Alloy and HSLC steel.
- Comparative study on performance and weight of the chassis of Al-Li Alloy and HSLC steel is to be done.

IV. PROBLEM IDENTIFICATION AND MATERIAL PROPERTIES

- The automotive industry is one of the industries which Malaysia has made large investment and development. The industry is still in the development phase compared to the sophisticated technology used in some foreign countries like US and Japan Further research and development in the automotive industry is crucial, especially when it comes to truck chassis used in off-road vehicles. These chassis have maintained a nearly identical appearance for over 30 years, suggesting that their evolution has been gradual and consistent over time. However, this also highlights the need for innovation and progress in the field.
- Numerous researchers within the automotive industry have recognized this opportunity and have become engaged in advancing chassis manufacturing technology and development. By doing so, they aim to bring about transformative changes in truck chassis design.
- Therefore, conducting research on truck chassis is of paramount importance to drive progress and achieve the desired advancements in the industry. During the operation of trucks on roads, the truck chassis experiences dynamic forces generated by factors such as road roughness, engine operations, and transmission activities.
- These dynamic excitations result in vibrations within the truck chassis. When the frequencies of these excitations align with the natural frequencies of the truck chassis, resonance can occur, leading to potentially hazardous large oscillations. These oscillations can cause excessive deflection and even structural failure.
- Moreover, chassis vibrations create localized stress concentrations, contribute to structural fatigue, induce mechanical joint loosening, and generate noise and discomfort for vehicle occupants. In order to overcome these challenges, it becomes imperative to conduct in-depth research on the dynamic characteristics of truck chassis.
- The primary purpose of the truck chassis is to provide support for the various components and payload placed on it. As the truck travels on the road, the chassis experiences vibrations caused by road roughness as well as excitations from vibrating components mounted on it.
- One important aspect of the truck chassis vibration is its natural frequencies and mode shapes. These characteristics describe how the chassis vibrates and the corresponding patterns of motion.
- Additionally, the responses of the truck chassis, including stress distribution and displacement, are observed under different loading conditions. To analyze and study these characteristics, the finite element technique is employed as a numerical analysis method.

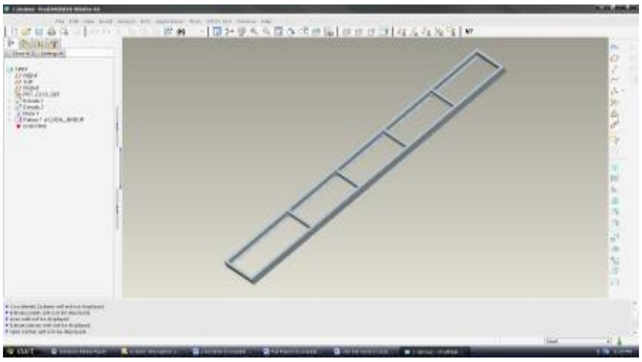

Figure- 1 Models of the Truck Chassis

Chemical Composition byweight,%	0.30 C, 1.0 Cr, 0.90 Mn, 0.20Mo
Modulus of Elasticity	310 Mpa
Mass Density	7850 kg/m^3
Yield Strength	250 Mpa
Tensile Strength	448 Mpa

Table- 1 Material Properties of steel

The primary purpose of the truck chassis is to provide support for the various components and payload placed on it. As the truck travels on the road, the chassis experiences vibrations caused by road roughness as well as excitations from vibrating components mounted on it. One important aspect of the truck chassis vibration is its natural frequencies and mode shapes. These characteristics describe how the chassis vibrates and the corresponding patterns of motion. Additionally, the responses of the truck chassis, including stress distribution and displacement, are observed under different loading conditions. To analyze and study these characteristics, the finite element technique is employed as a numerical analysis method. This approach allows for a detailed examination of the chassis behavior and responses. The results obtained from the analysis reveal that the main disturbance affecting the truck chassis is the road excitation. This is because the natural frequencies of the chassis align with the frequency range of road-induced vibrations. By determining the mode shapes, the appropriate mounting locations for components such as the engine and suspension system can be identified, ensuring optimal performance and minimizing vibrations within the chassis.

V. ANALYSIS OF CHASIS FRAME

All the major components are built using curves, surfaces and volumes. The model is exported to hyper mesh for meshing. The meshed model is taken for application of boundary conditions and material properties. The tool has been analyzed for time-frequency as follows.

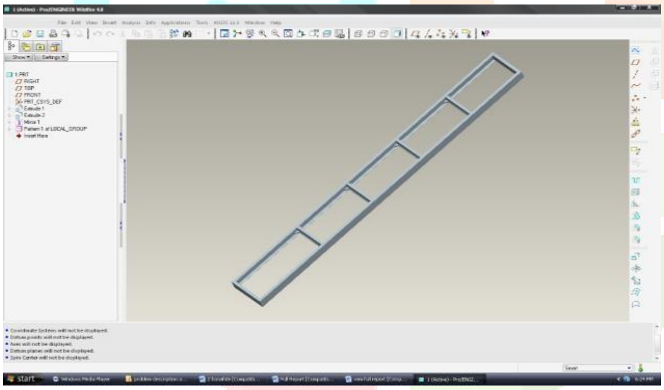

Figure: 2 Design of chassis frame

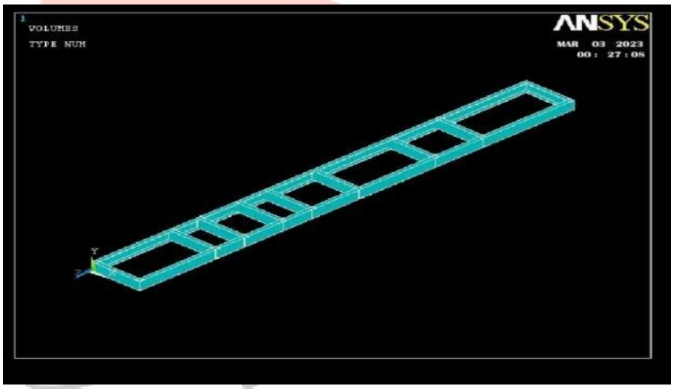

Figure: 3 Chassis Model

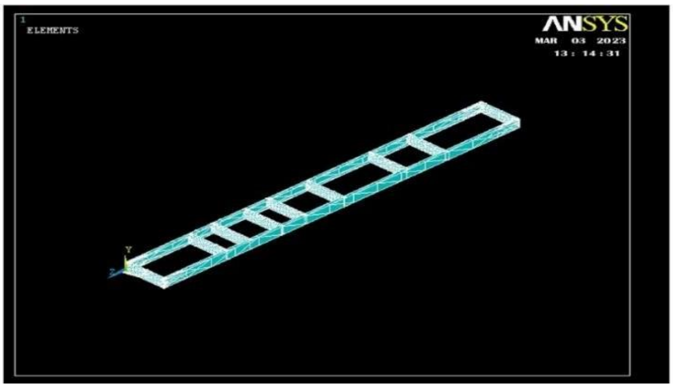

Figure: 4 Chassis Model Mesh Detail

Forces apply along with the x, y, and z direction.

Structural analysis.

Displacement	:	All DOF
Pressure / Force	:	23,26,30Ton
Analysis Type	:	Harmonic analysis
Frequency	:	0.01 – 5Hz
Frequency Substeps	:	100 (Sparce solver)

Figure: 5 Applying The Load Condition

Table-2 Properties of HSLC material

Young’s Modulus	310*10**6 Mpa
Poisson's Ratio	0.3
Density	7860 kg/m³
Type of Chassis material	Al-Li 2090 alloy

Table-3 Proposed material properties of al

Youngs Modulus	483*10**6 Mpa
Poisson's Ratio	0.3
Density	2590 kg/m³

Analytical Calculation of Chassis for Different Load Condition

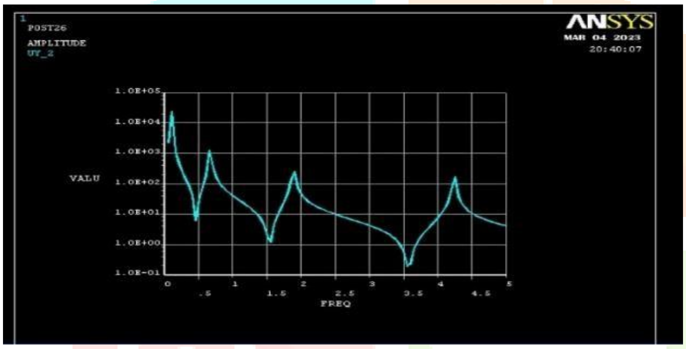

Figure-6 Amplitude of HSLC steel Chassis (5mm)

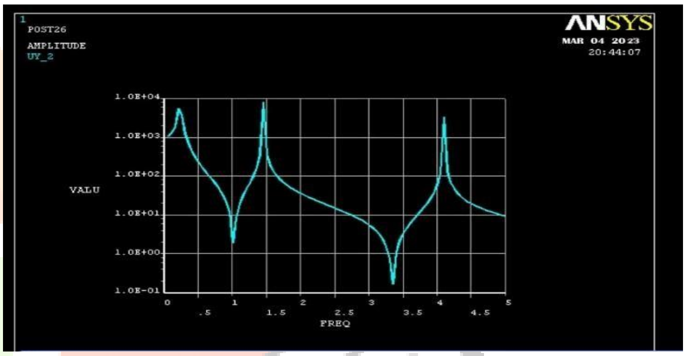

Figure-7 Amplitude of Al-Li Chassis (5mm)

The above fig show Amplitude of HSLC steel Chassis (5mm). The model is exported to hyper mesh for meshing. The meshed model is taken for application of boundary conditions and material properties. The tool has been analyzed for time-frequency.

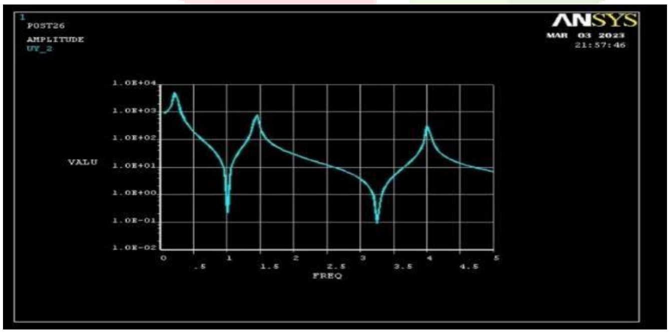

Figure-8 Amplitude of Al-Li Chassis (6mm)

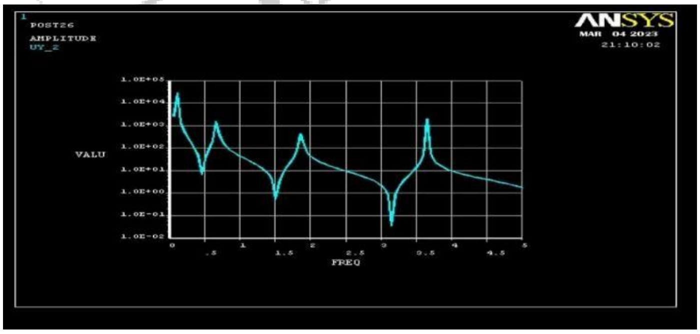

Figure-9 Amplitude of HSLC steel Chassis (5mm)

Harmonic analyses are used to determine the steady state response of a structure to loads that vary sinusoidally (harmonically) with time. • This enables the verification of a design, providing insight such as; - Will resonance occur, which could result in excessive motion, stress, noise and vibration. - Will the cyclically repeating load result in repetitive stress, resulting in fatigue damage and potential failure. An important property of a harmonic analysis is when the system has a steady state sinusoidal input or excitation, the output is also sinusoidal, but with varying amplitude and phase angle.

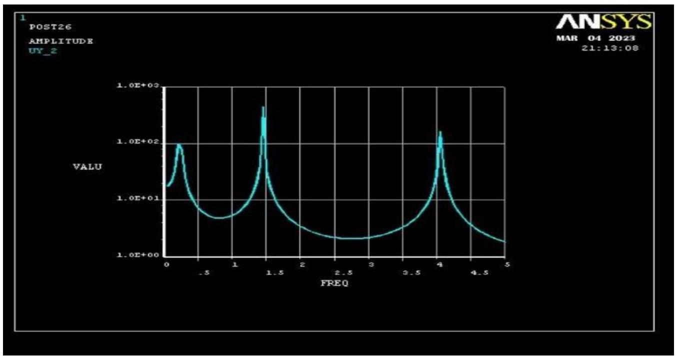

Figure-10 Amplitude of Al-Li Chassis (5mm)

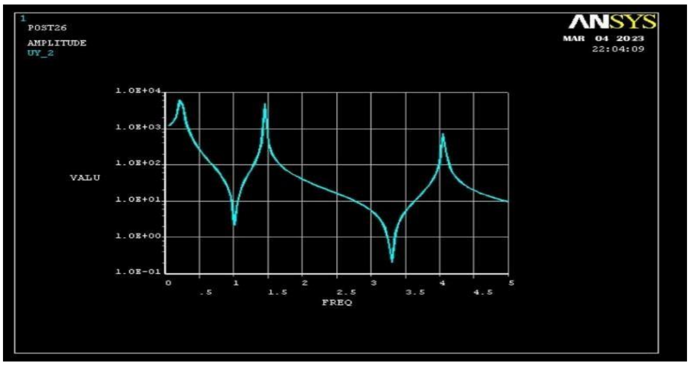

Figure-11 Amplitude of Al-Li Chassis (6mm)

We explore the development of high-strength low-alloy (HSLC) magnesium alloys intended for use as biodegradable implant materials. These alloys have limited amounts of Zn and Ca as alloying elements. Our study tracks the progression from the ZX50 alloy, which contains higher levels of Zn (MgZn5Ca0.25) and has conventional purity, to an ultrahigh-purity modification of ZX50, and further to the ultrahigh-purity Zn-lean alloy ZX10 (MgZn1Ca0.3). Our findings indicate that alloys with high Zn content are susceptible to biocorrosion in various environments, likely due to the presence of the intermetallic phase Mg6Zn3Ca2. However, by reducing the Zn content, we observed the formation of the (Mg,Zn)2Ca phase. This phase transformation suggests improved corrosion

Comparison with analytical results validation.

Table-4 Theoretical Calculation of Chassis table 1

Theoretical Calculation Of Chassis For 23 Ton Load Condition Natural frequency of High strength low carbon steel for 5mm frame:	Theoretical Calculation Of Chassis For 23 Ton Load Condition Natural frequency of 2090 Aluminium lithium alloy for 5mm frame:	Theoretical Calculation Of Chassis For 23 Ton Load Condition Natural frequency of 2090 Aluminum Lithium alloy for 6mm frame:
Length of the channel = 9.12 m	Length of the channel = 9.12 m	Length of the channel = 9.12 m
Thickness of the channel = 0.005 m	Thickness of the channel = 0.005 m	Thickness of the channel = 0.006 m
Height of the channel = 0.235 m	Height of the channel = 0.235 m	Height of the channel = 0.235 m
Moment of inertia, I = 1.19988 * 10**-5	Moment of inertia, I = 1.19988 * 10**-5	Moment of inertia, I = 1.41511 * 10**-5
Deflection, $\partial = WL^3 / 3E\,I$= 15.634 mm	Deflection, $\partial = WL^3 / 3EI$= 12.48 mm	Deflection, $\partial = WL^3 / 3EI$ = 10.58 mm
Stiffness, S= F / ∂= 14.71 N/ m	Stiffness, S= F / ∂= 18.41 N/ m	Stiffness, S= F / ∂= 14.71 N/ m
Natural frequency, fn = 0.52 Hz	Natural frequency, fn = 0.22 Hz	Natural frequency, fn = 0.12 Hz

Table-5 Theoretical Calculation of Chassis table 2

Theoretical Calculation Of Chassis For 26 Ton Load Condition Natural frequency of High strength low carbon steel for 5mm frame:	Theoretical Calculation Of Chassis For 26 Ton Load Condition Natural frequency of Aluminium Lithium alloy for 5mmframe:	Theoretical Calculation Of Chassis For 26 Ton Load Condition Natural frequency of 2090 Aluminium Lithium alloy for 6mm frame**:**
Length of the channel = 9.12 m	Length of the channel = 9.12 m	Length of the channel = 9.12 m
Thickness of the channel = 0.005 m	Thickness of the channel = 0.005 m	Thickness of the channel = 0.006 m
Height of the channel = 0.235 m	Height of the channel = 0.235 m	Height of the channel = 0.235 m
Moment of inertia, I = 1.19988 * 10**-5	Moment of inertia, I = 1.19988 * 10**-5	Moment of inertia, I = 1.41511 * 10**-5
Deflection, $\partial = WL^3 / 3EI$= 18.6 mm	Deflection, $\partial = WL^3 / 3EI$= 15.234 mm	Deflection, $\partial = WL^3 / 3EI$= 13.45 mm
Stiffness, S= F / ∂= 14 N/ m	Stiffness, S= F / ∂= 18 N/ m	Stiffness, S= F / ∂= 21 N/ m
Natural frequency, fn = 1.12 Hz	Natural frequency, fn = 0.34 Hz	Natural frequency, fn = 0.30 Hz

VI. CONCLUSION

- The new material shows minimum amplitude variations while changing the dimensions under same loading condition. Also the weight of the chassis gets reduced.
- Shape optimization of the chassis is done to Chassis weight optimization. Same material is maintained and the quantity of the material is added. Excess material in the area where is minimum stress acts is reduced. The properties of the material are not changed by shape optimization.
- Thus the resonance condition is avoided by keeping the excited frequency less than the natural frequency by changing the chassis frame thickness.
- The Al-Li chassis frame exhibits a significant weight reduction, being merely one-third of the weight of the HSLC steel counterpart.

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