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FINITE ELEMENT ANALYSIS OF TRUCK CHASSIS FOR STEEL AND CARBON FIBER MATERIALS

Kuldeep Singh[1], Dr. Shanawaj Alam[2]
Department of Mechanical Engineering
[1]Research Scholar, Integral University, Lucknow
[2]Professor, Integral University, Lucknow

***Abstract*— A vehicle frame, also known as its chassis forms the backbone to all vehicles. It is one of the important parts that used in automobile industry. It is a rigid structure which acts a skeleton to hold all the major parts together like the skeleton of an organism. It principally used for safely carrying the maximum load for all designed operating conditions. Chassis frames should be strong enough to withstand the load and shock. Chassis is the foremost component of an automobile that acts as the frame to support the vehicle body. Hence the frame ought to be very rigid and robust enough to resist shocks vibrations and stresses acting on a moving vehicle. Steel in its numerous forms is commonly used material for producing chassis and overtime aluminum has acquired its use. However, in this study traditional materials are replaced with ultra light weight carbon fiber materials. High strength and low weight of carbon fibers makes it ideal for manufacturing automotive chassis. This study depicts the modal and static structural analysis of Ashok Leyland 3118il truck chassis frame for steel as well as carbon fibers. From the analyzed results, stress, strain and total deformation values were compared for both the materials. Since it is easy to analyze structural systems by finite element method, the chassis is modified using SOLIDWORKS 2016 and the Finite Element Analysis and Modal Analysis is performed on A workbench.**

***Index Terms*— Chassis, Composite, Ansys, Modal Analysis, Solid works.**

I. INTRODUCTION

An automobile is made of mainly two parts-The Body and The Chassis. A vehicle arrangement without body is called the chassis. The foundation of the automotive chassis on a different chassis units are mounted and to the axles are attached by the springs and sometimes also by other members serving to transmit or take up the axle thrust and torque. During the early years of the industry, the chassis frames were made of tubular steel, rolled steels sections, wood and "armored wood" that is wood sills reinforced with steel flitch plates. The components of the vehicle like Engines, Transmission System consisting of clutch gearbox, propeller shaft and rear axle, Wheels and Tyres, Suspension, Controlling Systems like Braking, Steering, and electrical system parts are all mounted on the Chassis frame. So it is also called as Carrying Unit. The main functions of a frame in motor vehicles are:-

1. To support the vehicle's mechanical components and body.
2. It gives shape to the vehicle body.
3. To deal with static and dynamic loads conditions without undue deflection or distortion.

These include:

- Weight of the body, passengers, and cargo loads.
- Vertical and torsion twisting transmitted by going over uneven surfaces.
- Transverse lateral forces caused by road conditions, side wind, and steering the vehicle.
- Torque from the engine and transmission.
- Longitudinal tensile forces from starting and acceleration, as well as compression from braking and sudden impacts from collisions.

LADDER FRAME

LADDER CHASSIS

So named for its resemblance to a ladder, the ladder frame is the simplest and oldest of all designs. It consists merely of two symmetrical rails, or beams, and cross member connecting them. Originally seen on almost all vehicles, the ladder frame was gradually phased out on cars around the 1940s in favor of perimeter frames and is now seen mainly on trucks.

II. OVERALL DISCUSSION ON RESEARCH

Composite materials typically have a lower modulus of elasticity. As a result, when torque peaks occur in the driveline, the driveshaft can act as a shock absorber and decrease stress on part of the drive train extending life. Many researchers have been investigated about hybrid drive shafts and joining methods of the hybrid shafts to the yokes of universal joints. But this study provides the analysis of the design in many aspects. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and higher specific strength of composite materials. Composite materials can be tailored to efficiently meet the design requirements of strength, stiffness and composite drive shafts weight less steel or aluminium of similar strength.

A. Advantages of Fiber Reinforced Composites

The advantages of composites over the conventional materials are

- High strength to weight ratio
- High stiffness to weight ratio
- High impact resistance
- Better fatigue resistance
- Improved corrosion resistance
- Good thermal conductivity
- Low Coefficient of thermal expansion.
- As a result, composite structures may exhibit a better dimensional stability over a wide temperature range.
- High damping capacity.

B. Disadvantages of Composites

Joining processes are complicated. Poor compressive strength and Creep pose problems to the structure of the ship. Low vibration tolerance is a risk factor. Poor abrasion resistance leads to wear and tear. Quality Control is difficult. Lay-up and Assembly arelaborious.

Composites are highly combustible and vulnerable to heat and fire. Installation of systems proves to be a difficult task. High cost is a major drawback. A number of other technical issues combined with the above drawbacks are constraining the large scale introduction of composites into the large structure marine market. Composite ship joints often have similar design features as welded steel joints even though the joining process is difficult in joining composites, and as a consequence joints made of glass reinforced plastic can have lower strength and fatigue resistance

III. DESCRIPTION OF THE PROBLEM

Stainless steel was mainly used because of its high strength. But this stainless steel shaft has less specific strength and less specific modulus. Stainless steel has less damping capacity. Because of its higher density of molecules of stainless steel, its weight is very high. Because of increase in weight fuel consumption will in increase, the effect of inertia will be more and increase in weight. The steel propeller shaft is replacing with the composite materials, which are very less weight when compared to that of stainless steel. The cost of composite materials is less when compared to that of stainless steel. The E-Glass/Epoxy and Carbon/Epoxy materials are selected for composite drive shaft. Since, composites are highly orthotropic and their fractures were not fully studied.

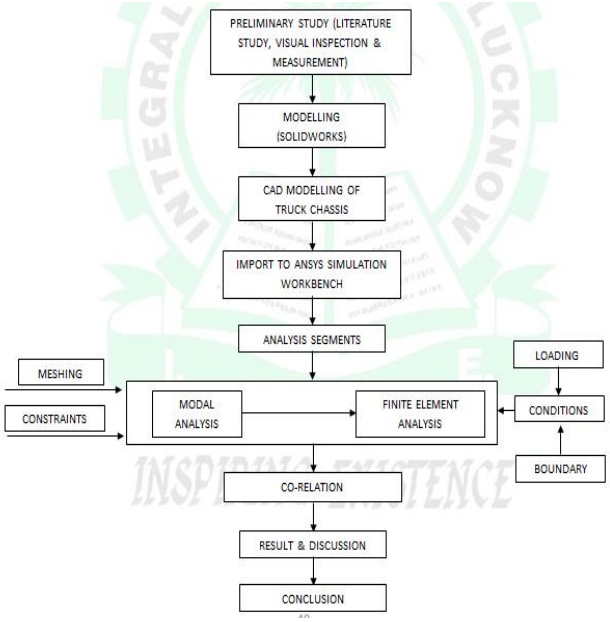
IV. RESEARCH METHODOLOGY

In this project, Modal Analysis and Finite Element analyses were used to determine the characteristics of the Drive shaft. The combination of all the analysis results were used to develop virtual model created using FEM tools and the model was updated based on the correlation process. Further analyses were then executed to the truck chassis design to determine the best suited material for chassis.

For the purpose of this study, the drive shaft was modeled using solidworks software according to the original size of structures. The model was then imported into Simulation software ansys workbench. The purpose was to determine the natural frequencies and mode shapes. For the meshing analysis, 10 node-tetrahedral elements were chosen to model the solid shaft.

The next step was to undertake Experimental Modal Analysis. This was to determine the natural frequencies, mode shapes and damping ratio from the real structure of the drive shaft. In order to maintain the quality of results, the analysis were done on the Ansys workbench. Then, the result from finite element analysis and experimental modal analyses were then compared in order to find the best suited material for the drive shaft material.

A. RM FLOWCHART



V. COMPUTATIONAL AND MODELLING ANALYSIS

Analysis is being categorizes into modal analysis and finite element analysis. The modal analysis is being performed to compute the frequency of the two materials and afterward, compare the stiffness of each material. And after that, finite element analysis is being performed to check the stress, displacement and strain segment of these materials. For the purpose of analysis meshing is to be done in order to get the desired result.

The FEM is a common tool for stress analysis. FEM with required boundary conditions was used to determine critical regions in theshaft. Static structural analysis is performed to identify critical regions and based on the results obtained design modification has been done the modal analysis of the shaft is carried out to determine the natural frequency and mode shapes of the system. The rigidity of the system was analysed and their resonance could be avoided.

A. SOLID MODELLING

For our work we used the design specification of Ashok Leyland 3118il

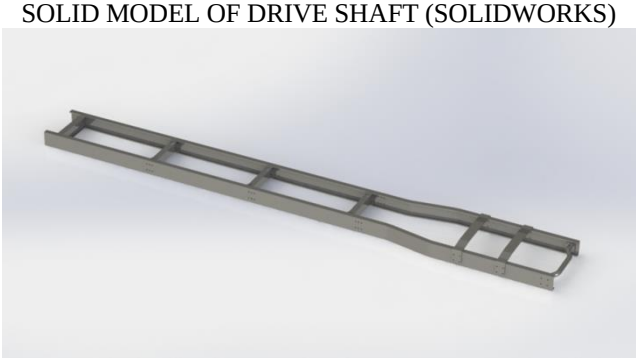
Design of chassis

Truck Model Used	Ashok Leyland 3118il
Suspension Type	Semi Elliptical Spring @ Front & Rear
No. of Gears	6 Forward, 1 Reverse
Max Engine Output	180 BHP @ 2400 RPM
Max Engine Torque	660 Nm @ 1500 RPM
Kerb Weight	10000 Kg
Max Speed	78 km/hr
Overall Length (chassis)	9000 mm
Overall Width (chassis)	1125/860mm
Wheel Base	5200mm
Front Overhang	1500mm
Rear Overhang	2300mm

PROPERTIES OF MATERIAL APPLIED

Material Properties	**Steel**	**Carbon Fiber**
Density (kg/m^3)	7850	1570
Young's Modulus (MPa)	200	190000
Poisson's Ratio	0.3	0.25
Yield Stress (MPa)	250	220

SOLID MODEL OF DRIVE SHAFT (SOLIDWORKS)



B. MESHING OF DRIVE SHAFT

The meshing is done on the model with 76399 No. of nodes and 40378 No. of Tetrahedral elements. In order to get a better result, locally finer meshing applied in the region which is suspected to have the highest stress.

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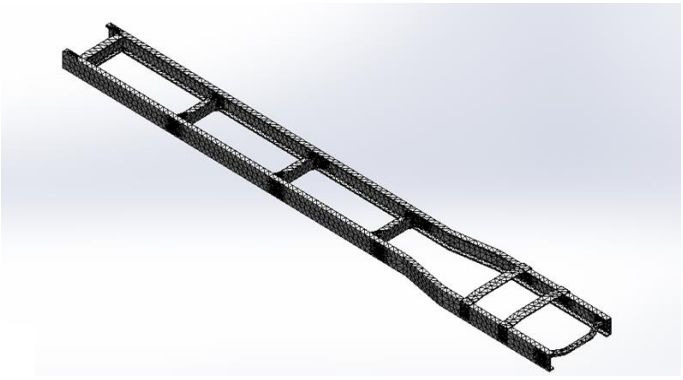
MESHING OF CHASSIS MODEL



C. LOADING AND BOUNDARY CONDITION

The load application is the major part in the analysis of a component. There may be different types of loads like Uniformly Distributed Load, Uniformly Varying Load and Point Load. The present frame carries the UDL throughout its length. The truck chassis model is loaded by static forces from the truck body and cargo.

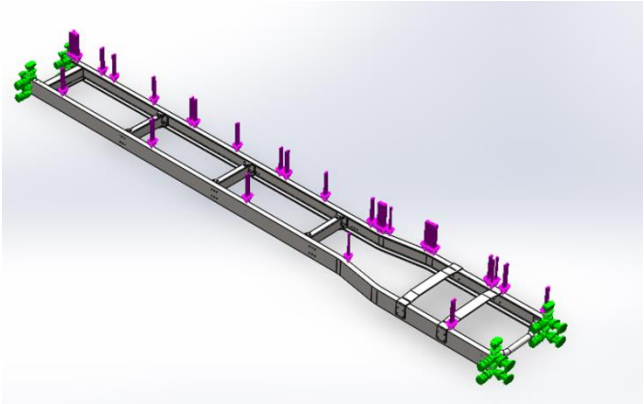
Capacity of Truck = 8 ton = 8000 kg = 78480 N

Capacity of Truck with 1.25% = 98100 N

Weight of body and engine = 2 ton = 2000 kg = 19620 N

Total load acting on chassis = (10000 + 2000) kg = (98100 +19620) N = 117720 N

Chassis has two beams. So load acting on each beam is half of the Total load acting on the chassis. Load acting on the single frame = 117720 / 2 = 58860 N / Beam.

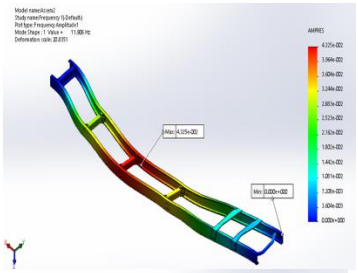


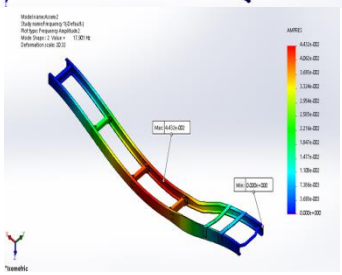
FREQUENCIES AND DEFLECTION FOR THE CHASSIS CONSIDERING THE STEEL MATERIAL

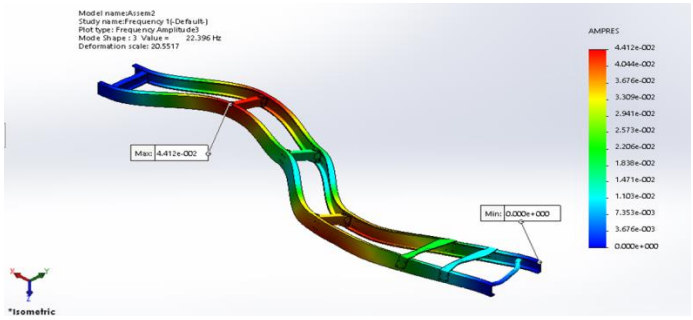
STEEL MATERIAL	FREQUENCY (Hz)	DEFLECTION (m)
DEFORMATION 1	11.906	0.0432479
DEFORMATION 2	17.901	0.0443166
DEFORMATION 3	22.396	0.0441159
DEFORMATION 4	24.996	0.0493883
DEFORMATION 5	36.605	0.0983443

VI. RESULTS

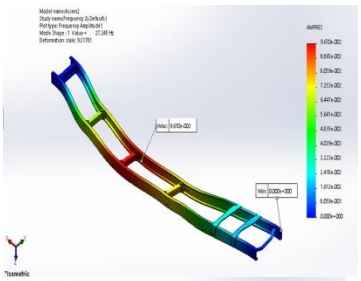
A. MODAL ANALYSIS OF THE CHASSIS WITH MATERIAL AS STRUCTURAL STEEL

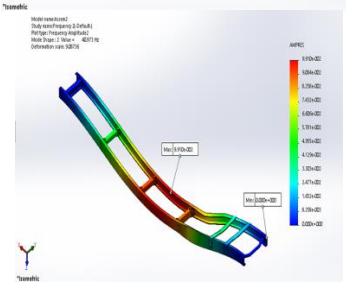


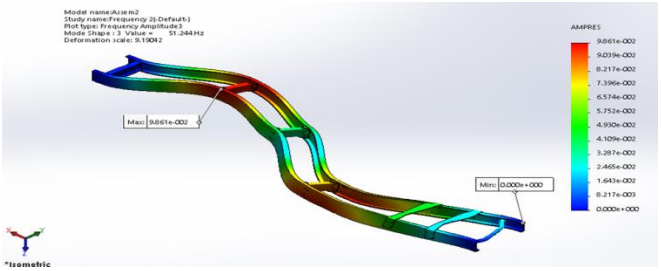




B. MODAL ANALYSIS OF THE CHASSIS WITH MATERIAL AS CARBON FIBER



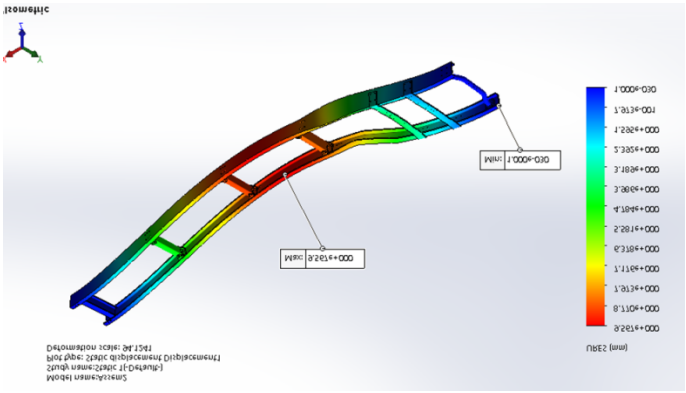




FREQUENCY AND DEFLECTION FOR THE CHASSIS CONSIDERING THE CARBON FIBER MATERIAL

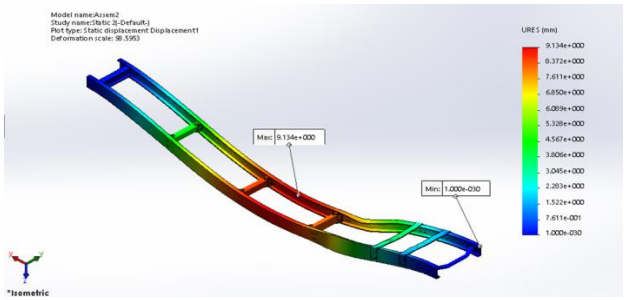
STEEL MATERIAL	FREQUENCY (Hz)	DEFLECTION (m)
DEFORMATION 1	27.245	0.0967046
DEFORMATION 2	40.973	0.0990952
DEFORMATION 3	51.244	0.0986067
DEFORMATION 4	57.457	0.110459
DEFORMATION 5	83.69	0.233941

C. STATIC STRUCTURAL ANALYSIS BY USING STEEL



TOTAL DEFORMATION STEEL

D. STATIC STRUCTURAL ANALYSIS BY USING CARBON FIBER



TOTAL DEFORMATION CARBON FIBER

ANALYZED STATIC STRUCTURAL RESULTS

PARAMETER	STEEL	CARBON FIBER
EQUIVALENT STRESS (MPa)	207.1	207.2
EQUIVALENT STRAIN	0.0007118	0.0006324
TOTAL DEFORMATION (m)	0.009567	0.009134

VII. CONCLUSIONS

The modal analysis and static structural analysis on the ladder chassis of Ashok Leyland 3118il truck was carried out. From the above results of steel and carbon fibers, it can be seen that von equivalent stress for carbon fibers has increased and the total deformation has reduced. Thus the stress values for carbon fibers are under acceptable limit. So it is ideal to use the carbon fiber as a chassis material for vehicles because of its high strength and low weight. Also for the same load carrying capacity, carbon fibers are preferable instead of steel for the manufacturing of ladder frame because it (mass of steel frame 170.45 Kg and carbon fibers = 54.28 kg) reduces the weight by 60-68% and increase the stiffness of the chassis frame. But on the economic point of view, the cost of the carbon fiber is relatively higher than that of the steel materials.

the variation of frequency at different mode number during the modal analysis of truck chassis, therefore it is concluded that the carbon fiber are having more stiffness as compared to the steel material.

Therefore, from this study it is concluded that for the same load carrying capacity the efficiency of the carbon fibers materials are more as compared to the steel materials.

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