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Structural Analysis of Ladder Chassis Frame for Jeep Using Ansys

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Abstract: *Automotive chassis frame is an important part of an automobile. The automotive chassis frame is the structural backbone of any vehicle. The main function of chassis frame is to support the body, different parts of an automobile and topayload placed upon it.The chassis frame has to withstand the stresses developed as well as deformation occurs in it and to withstand the shock, twist vibration and other stresses. Its principle function is to carry the maximum load for all designed operating condition safelythat should be within a limit. On chassis, frame maximum shear stress and deflection under maximum load are important criteria for design andanalysis. In these projects, we havecalculated the von mises stress and shear stress for the chassis frame and the finite element analysis has been donefor the validation on the chassis frame model of jeep. We have taken certain material as Mild sheet steel, aluminium alloy and titanium alloy for the rectangular hollow box type to design chassis frame of jeep.*

Software used in this project, CATIA V5-[Product 1] for design purpose and ANSYS 14 is used for analysis.

Keywords: *ladder chassis frame, mild steel, aluminium alloy, titanium alloy, Rectangular Box (Hollow) typecross sections.*

I. Introduction

Chassis is a French term and was initially used to denote the frame parts or Basic Structure of the vehicle. It is the backbone of the vehicle. A vehicle without body is called Chassis. The components of the vehicle like Power plant, Transmission System consisting of clutch gearbox, propeller shaft and rear axle, Wheels and Tyres, Suspension, Controlling Systems like Braking, Steering etc.,and electrical system parts are alsomounted on the Chassis frame. It is the main mounting for all the components including the body. So it isalso called as Carrying Unit. Chassis of Automotive helps to keep an automobile rigid, stiff and unbending. Automobile chassis ensures less noise, vibrations and harshness throughout the automobile. The chassis frame consists of side members attached with a series of cross members. Along with the strength, an important consideration in the chassis design is to increase the stiffness (bending and torsion) characteristics. Adequate torsional stiffness is required to have good handling characteristics. Normally the chassis are designed on the basis of strength and stiffness. In the conventional design procedure the design is based on the strength and emphasis is then given to increase the stiffness of the chassis, with very little consideration to the weight of the chassis. One such design procedure involves the adding of structural cross member to the existing chassis to increase its torsional stiffness. As a result weight of the chassis increases. This increase in weight reduces the fuel efficiency and increases the cost due to extra material. The design of the Chassis with adequate stiffness and strength is necessary.

The different types of automobile chassis are as follows.

Conventional control chassis:
In which engine is mounted in front of the driver`s cabin. This type of arrangement avoids full utilization of the space.

Semi-forward control chassis:-
In which engine is mounted that half of it is in the driver`s cabin whereas the other half is in front, outside the driver`s cabin.

Full-forward control chassis:-
In which engine is mounted completely insides the driver`s cabin. Obviously maximum utilization of space is achieved in this type of arrangement.
The Different Types Of Automobile Chassis Frame Are As Follows:
Conventional Frame:-
It is non-load carrying frame. The loads of the vehicle are transferred to the suspensions by the frame. This suspension in the main skeleton of the vehicle, which is supported on the axles through springs. The body is made of flexible material like wood and isolated frame by inserting rubber mountings in between. The frame is made of channel section or tubular section of box section.
Ladder Chassis:-
Ladder chassis is one of the oldest forms of automotive chassis these are still used in most of the SUVs today. It is clear from its name that ladder chassis resembles a shape of a ladder having two longitudinal rails inter linked by lateral and cross braces.

Fig. 1 Model of rectangular box (hollow) type of ladder chassis frame.

Types of ladder frame:
Ladder frame are classified as follows.
1. C cross section type of ladder chassis frame
2. I cross-section type of ladder chassis frame.
3. Rectangular Box (Hollow) cross section type of ladder chassis frame.
4. Rectangular Box (Intermediate) cross section type of ladder chassis frame.

II. Literature Review

MohdAzizi Muhammad Nor et al. (2012) This paper aims to model, simulate and perform the stress analysis of an actual low loader structure consisting of I-beams design application of 35 tonne trailer designed in-house by Sumai Engineering Sdn. Bhd, (SESB). The material of structure is LowAlloy Steel A 710 C (Class 3) with 552 MPa of yield strength and 620 MPa of tensile strength. The scope of this study concern on structural design of the I-beams for info and data gathering, which will be used for further design improvement. Finite element modelling (FEM), simulations and analysis are performed using a modelling software i.e. CATIA V5R18.Firstly, a 3-D model of low loader based on design from SESB is created by using CATIA. Stress and displacement contour are later constructed and the maximum deflection and stress are determinedby performing stress analysis. Computed results are then compared to analytical calculation, where it is found that the location of maximum deflection agrees well with theoretical approximation but varies on the magnitude aspect. Safety factor for the low loader structure has also been calculated. In the end, the current study is important for further improvement of the current low loader chassisdesign.

Swami K.I. et al.(Jan. 2014) The Automotive chassis is considered as the backbone of the vehicle. On chassis, different parts are provided with strength, an important consideration in chassis design is to have adequate bending stiffness for better handling characteristics. So, strength and stiffness are two important criteria for the design of the chassis. This paper related with work performed towards the static structural analysis of the truck chassis. Structural systems like the chassis can be easily analysed using the finite element techniques. So a proper finite element model of the chassis is to be developed. The chassis is modelled in ANSYS. Analysis is done using the same software.

RoslanAbd Rahman:does stress analysis on heavy duty truck chassis by finite element package ABAQUS. To improve the fatigue life of components at critical point by design modifications the stresses can be reduces. He uses ASTM low alloy steel a 710 C (Class 3) with 552 MPa of yield strength and 620 MPa of tensile strength for chassis founds the maximum stress 386.9 MPa at critical point occurred at opening of chassis. This critical point is located at element 86104 and node 16045, which was in contacted with the bolt from it he concludes, that this critical point is an initial to probable failure

III. Methodology

Finite element analysis is performed to find the von mises stress and shear stress using ansys workbench 14.Three dimensional model of frame was designed using catia software). The design verification can be achieved without elaborate need for prototypes at each phase saving time and effort. A final prototype for the final design review can be employed for verifying the analytical results.

Specification of Ladder chassis:

Wheel Base (WB) = 2380 mm.
Rear Overhang (ROH) = 1020 mm.
Front Overhang (FOH) = 450/470 mm.
Gross Vehicle Weight (GVW) = 3000 kg = 3 ton.
Length =3860mm.
Width =900mm.

Basic Calculation for Chassis:-

Weight of passengers = Weight per passenger × No. of passengers
= 75kg × 8
= 600kg =0.6 ton Total load acting on chassis = Gross vehicle weight + Weight of passengers
= 3000 kg +600 kg =3600 kg
= 3ton + 0.6 ton
= 3.6 ton

Chassis has two longitudinal members so load will be acted upon these two longitudinal members. Therefore, load acting on each member will be half of the total load acting on chassis.
Load acting on one longitudinal member = 3.6 ton ÷ 2
= 1.8 ton.

Specification of Material

A. Mild Sheet Steel:-
Mass density =7.85 g/cm3
Yield strength = 225 MPa
Ultimate Tensile Strength = 450-500 MPa
Young’s Modulus = 200 GPa
Poisson’s ratio = 0.28
Share modulus=78.125 GPa

B. Aluminium alloy:-
Mass density = 2.64-2.8 g/cm3
Yield strength = 35-500 MPa
Ultimate Tensile Strength = 100-550 MPa
Young’s Modulus = 70-79 (70) GPa
Poisson’s ratio = 0.33
Share modulus=26.32 GPa

C. Titanium alloy:-
Mass density = 4.51 g/cm3
Yield strength = 40-450 MPa.
Ultimate Tensile Strength =900-970 MPa
Young’s Modulus = 110-120 (120) GPa
Poisson’s ratio = 0.33
Share modulus=45.13 GPa

Design of chassis frame through CATIA

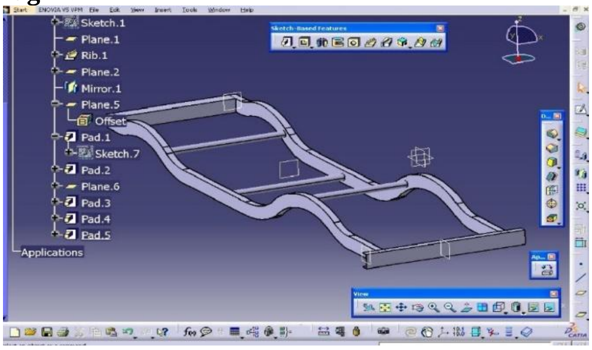

Fig. 2 ladder type chassis frame.

IV. Finite Element Analysis

There are three main steps, namely: pre-processing, solution and post processing. In pre-processing (model definition) includes: define the geometric domain of the problem, the element type(s) to be used, the material properties of the elements, the geometric properties of the elements (length, area, and the like), the element connectivity (mesh the model), the physical constraints (boundary conditions) and the loadings.

In solution includes: the governing algebraic equations in matrix form and computes the unknown values of the primary field variable(s) are assembled. The computed results are then used by back substitution to determine additional, derived variables, such as reaction forces, element stresses and heat flow. Actually, the features in this step such as matrix manipulation, numerical integration and equation solving are carried out automatically by commercial software.

In post processing, the analysis and evaluation of the result is conducted in this step. Examples of operations that can be accomplished include sort element stresses in order of magnitude, check equilibrium, calculate factors of safety, plot deformed structural shape, animate dynamic model behaviour and produce color-coded temperature plots. The large software has a pre-processor and postprocessor to accompany the analysis portion and the both processor can communicate with the other large programs. Specific procedures of pre and post are different dependent upon the program.

The model of existing chassis as per the dimension is as shown in Figure2.The model is then saved in IGES format which can be directly imported into ANSYS workbench. Figure 3 shows the imported model in ANSYS workbench.

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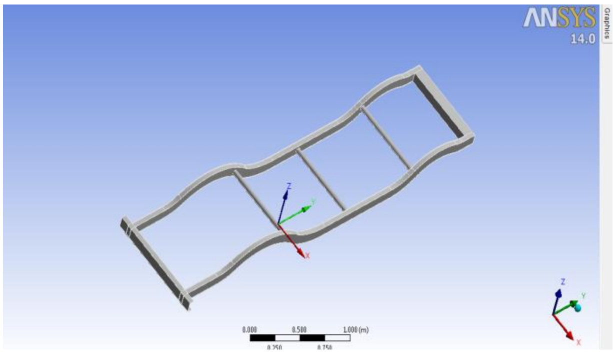

Fig.3Imported Model in ANSYS Workbench

Meshing of Chassis Frame

The meshing is done on the model with 22996 No. of nodes and 11385 No. of Tetrahedral elements. Figures 3.4 show meshing of model.

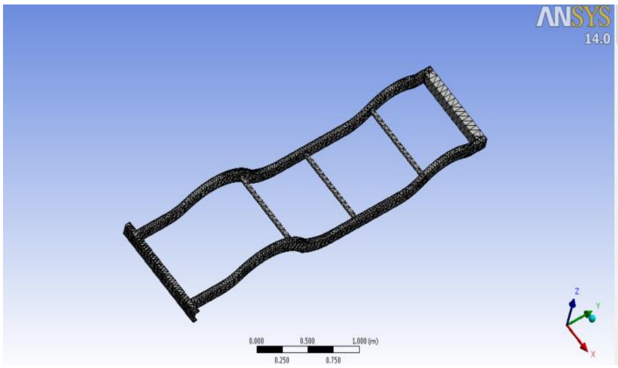

Fig.4 after generating mash

Loading Condition of Chassis Frame

The jeep chassis model is loaded by static forces from the jeep body and load. For this model, the maximum loaded weight of jeep and body is 3,600 kg. The load is assumed as a uniform distributed obtained from the maximum loaded weight divided by the total length of chassis frame. Detail loading of model is shown in Figure 4.1and 4.2. The magnitude of force on the upper side of chassis is 35316 N, which is carried by two side bars so load on one side bar is 17658 N.

The formula of design stress is defined by,

$$\text{Design Stress} = \frac{\text{Yield Stress}}{\text{Factor of Safety}}$$

considering factor of safety = 3 for design.

Stress analysis of ladder type chassis frame

1) **Mild sheet steel**

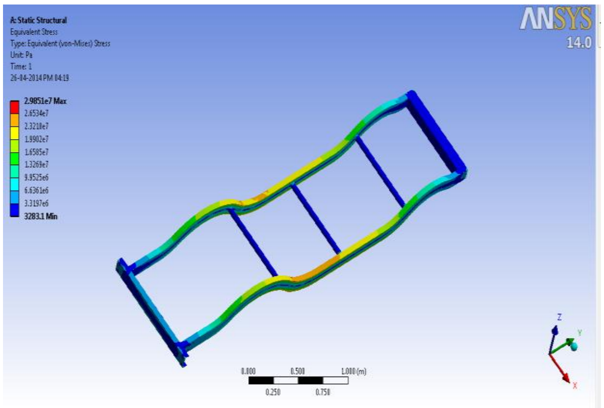

Fig. 5 Von misses stress on chassis frame

Von mises stress maximum value is 29.8 MPa.
Von mises stress minimum value is 0.032 MPa.

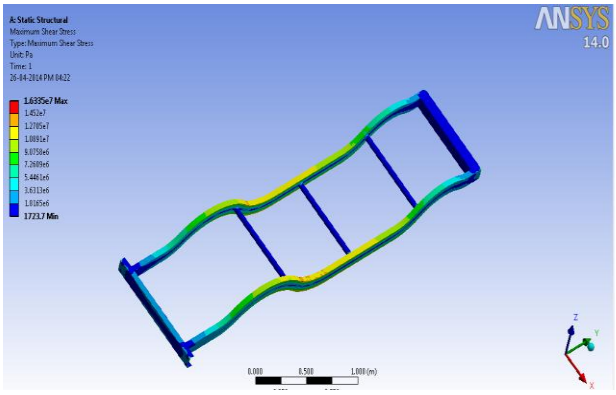

Fig. 6 Shear stress on chassis frame

Shear stress maximum value is 16.33 MPa.
Shear stress minimum value is 0.00173 MPa.

$$\text{Design Stress} = \frac{225}{3}$$

$$\text{Design Stress} = 75 \text{ MPa.}$$

2) **Aluminium alloy**

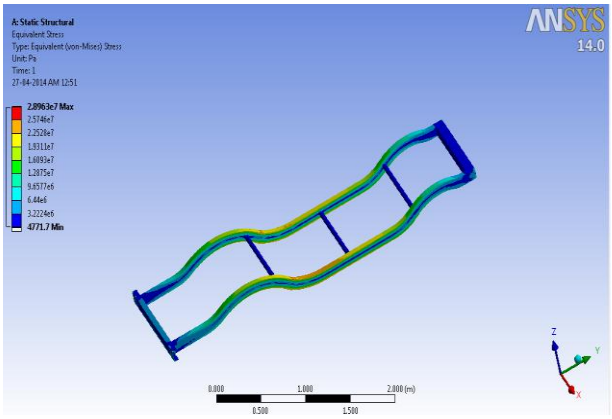

Fig. 7 Von misses stress on chassis frame

Von mises stress maximum value is 28.96 MPa.
Von mises stress minimum value is 0.0047 MPa.

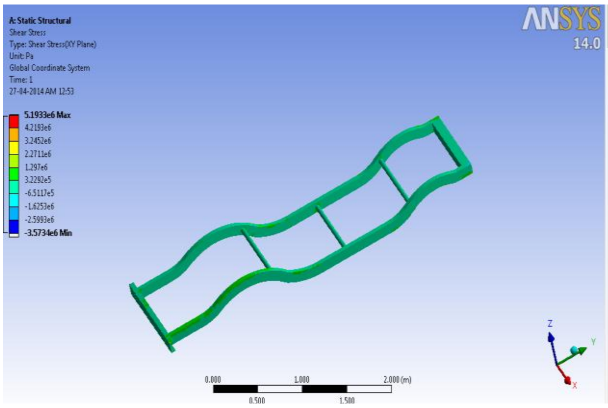

Fig. 8 Shear stress on chassis frame

Shear stress maximum value is 5.19 MPa.
Shear stress minimum value is -3.57 MPa.

$$\text{Design Stress} = \frac{35}{3}$$

$$\text{Design Stress} = 11.67 \text{ MPa.}$$

3) Titanium alloy

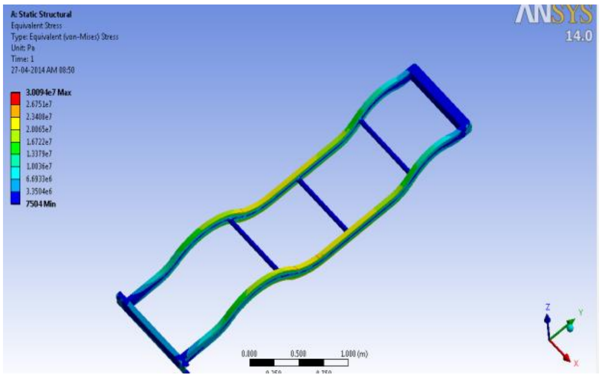

Fig. 9 Von misses stress on chassis frame

Von mises stress maximum value is 30.09MPa.
Von mises stress minimum value is 0.0075 MPa.

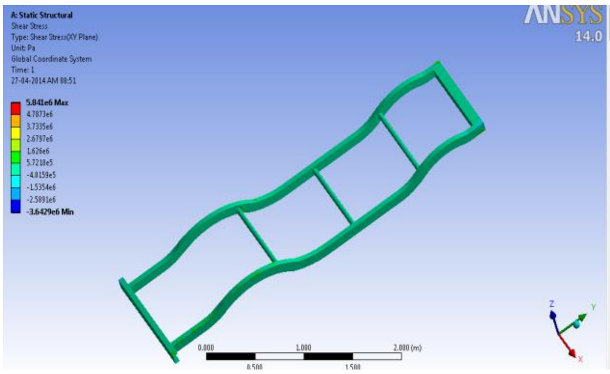

Fig. 10 Shear stress on chassis frame.

Shear stress maximum value is 5.84 MPa.
Shear stress minimum value is -3.64 MPa

$$\text{Design Stress} = \frac{55}{3}$$

$$\text{Design Stress} = 18.33 \text{ MPa.}$$

stresses	**Mild sheet steel**		**Aluminium alloy**		**Titanium alloy**	
	Max. MPa	Min. MPa	Max MPa	Min. MPa	Max MPa	Min. MPa
Von misses stress	29.8	0.032	28.96	0.0047	30.09	0.0075
Shear stress	16.33	0.00173	5.19	-3.57	5.84	-3.64
Design stress	75.00		11.67		18.33	

Table 1 Result

V. Conclusion

In the present work, ladder type chassis frame for jeep was analysed using ANSYS 14 software, based on the analysis following conclusion can be done.

1) The generated shear stresses are less than the permissiblevalue so the design is safe for all three materials.
2) shear stress was found minimum in aluminium alloy and maximum in mild sheet steel under given boundary conditions.
3) Von mises stresswas found minimum in aluminium alloy and maximum in titanium alloy under given boundary conditions.

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