Design and Structural Analysis of Truck Frame

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Abstract. The chassis construction is the larger element in every automobile, it integrates the heavy vehicle main systems such as the power train, drive axles, suspension and trailer. The vehicle structural shape dependent on this skeleton, it absorbs the impacts from front, side and overturn effects. There are many industrialized sectors using this truck as means of transportation for logistics, agricultures, factories and other industries. In this paper, two different material was adopted on the C-section truck frame design. Mild steel and Titanium alloy were structurally analysed on the heavy truck frame through finite element analysis. The results were compared and the best truck chassis material was identified with lower stress and deflection.

1. Introduction
An automotive chassis will go through high amplitude of vibrations on running due to the road irregularity, which will lead to the notable changes in the structural elements. The chassis vibration will roots the stress formation at specific parts with maximum magnitude. It also creates weakness of the vehicle structure and formation of noise due to looseness of mechanical parts and leads to vehicle uncomfotred. To rectify the above difficulties, the study of static and dynamic characteristics of vehicle chassis is essential. The road irregularity causes the structural vibration, which is the vital factors that will sources the fatigue failure. The amount of the stress excited on vibration can forecast the lifecycle of the automotive truck chassis [1]. The resonance may occur, when the high amplitude of vibrations of the vehicle structure matches with the amplitude of the external excitation, which will produce the unnecessary deflections on structure and failure on chassis [2]. The modal investigation of the vehicle frame will help to calculate the natural frequency and modal shapes of the parts. The rigidity of the system can be evaluated and resonance might be bypassed [3]. Structural optimization analysis with the constraints on the vehicle chassis can be used to investigate maximum shear stress and deflection at the maximum load condition [4]. The design analysis of truck frame using finite element method was useful to identified the performance of the chassis system, as its design strength cannot be found using empirical formulas [5]. In automotive sector, modal analysis is used in effective way to study the modal behaviour of car chassis. It is used to collect the important data to the inspect vehicle dynamic behaviour [6].

The amount stress developed on the chassis used to examine the lifecycles of the truck chassis. The precision of estimated lifespan of the vehicle chassis is subjected to the outcome of stress analysis [7]. On the investigation load sharing on the vehicle chassis is not constant across its total span area, so that to the concentration of load it can be vary the area of ladder chassis. On this analysis, the effect of decrease in cross-section area with limitations of various stresses and deflection, decrease in the
area will make difference in the quantity of material used for ladder chassis [8]. In this paper, two different material was adopted on the C-section truck frame design. Mild steel and Titanium alloy were structurally analysed on the heavy truck frame through finite element analysis. The results were compared and the best truck chassis material was identified with lower stress and deflection.

2. Truck Frame Design

The ladder frame chassis (Figure 1) is the oldest and simplest frame in all sectors. It contains of two proportioned beams and rails, running on the entire length of the vehicle. Many transverse cross-members are connected with that and mostly used on the trucks.

Figure 1. Ladder Frame chassis

Chassis consists of longitudinal members and cross members. Longitudinal members are with c-section. The typical model of chassis is shown in Figure 2. Dimensions on basis of literature for our models [1]. The frame is designed to handle a weight of 3 tons from the body and 0.6 ton of Engine.

Figure 2. Ladder Chassis with C-Section

Top view of chassis is shown in Fig 3. Width at the front is less compared to the width at the rear. When the wheels are steered, they should not interfere with the chassis and this is the reason why less width is maintained in the front. Width at the front – 710 mm; Width at the rear – 880 mm.
Front view of the chassis is shown in Fig 4. Wheel base is the dimension between wheel centres. Wheel Base – 2350 mm; length – 3580 mm.

The main influences of selecting material especially for frame is wide variation of characteristics such as mechanical and thermal resistance, easiness of production and durability. The first choice for the frame material with these features, Steel is leading choice. There was numerous progresses in irons and steels over the previous decades that through the steel stronger, harder and light-weight and refining other performance features. Titanium has an suggestion with space-technology and is observed by several people as an "eventual" material. It has a density roughly half that of steel, and also a slight over half of the stiffness value. It's a like condition with regards to ultimate and yield strengths. Mild steel and Titanium alloy were selected for the analyse. The property of two different frame material is tabulated in Table 1.

| Design Property          | Mild Steel | Al Alloy |
|--------------------------|------------|----------|
| Young’s Modulus, N/mm²   | 200000     | 120000   |
| Poison’s Ratio           | 0.3        | 0.3      |
| Yield Strength, N/mm²    | 225        | 450      |
| Ultimate Tensile Strength, N/mm² | 500  | 970      |

3. Results and Discussion

The key factor in today’s automobile truck manufacturing is to overwhelmed the growing needs for advanced performance, minimum weight, and extended life of automobile parts, all are should be at a realistic price and in a affordable time. Structural chassis analysis using Finite Element Method is to trace the important area which has the maximum stress concentration. The road irregularity causes the structural vibration, which is the vital factors that will sources the fatigue failure. The amount of the stress excited on vibration can forecast the lifecycle of the automotive truck chassis.
The chassis was modelled and meshed by using 2D – 4 noded – Quad – Iso mesh solid elements. Shackle mounting point at 4 locations is arrested with 6 DOF. Leaf spring mounting points at 4 locations are arrested with 6 DOF. This is known as solution sequence 101. There will be reaction force at shock absorber mounting points. We can consider 3 as FOS while designing the Chassis. A load of 0.6 ton is assumed for Engine. This load is equally distributed to the 4 mounting locations. Plot results for Max Principal, Max Shear & Von Mises Stresses can be easily seen for the Ti alloy in Figure 5 to 7. Von Mises stress is one of the parameters considered while designing any structure. Stress values obtained are compared with the allowable stress limits.

Figure 5. Max Principal Stress – Ti alloy

Figure 6. Max Shear Stress – Ti alloy
Figure 7. Von Mises Stress – Ti alloy

Figure 8. Displacement – Ti alloy

Table 2: Stress values obtained for Ti alloy

| Description        | UTS (N/mm²) | Values Obtained (N/mm²) | RF  | Deflection (mm) |
|--------------------|-------------|-------------------------|-----|-----------------|
| Max Principal Stress| 970         | 251                     | 3.9 |                 |
| Max Shear Stress   | 582         | 125                     | 4.6 | 2.4             |
| Von Mises Stress   | 970         | 225                     | 4.3 |                 |

This main argument is one of the factors that may cause fatigue failure. The existing truck chassis is for modification and study equipped with stiffeners. Initially, the thickness of the model, where the highest deflection occurs in bending analysis, was increased to a given value with appropriate limit. Then one more cross beam was added at the centre of the wheel frame to give steadiness to the base. To strengthen and improve the rigidity of the chassis as well as the overall performance of the chassis, a series of modifications and tests were carried out by adding the stiffener.
The material changed to Mild Steel, and it was the most used widely in the design of an automobile frame. The plots at the made for Max Principal, Max Shear & Von Mises Stresses and deflection in Figure 9 to 12.

**Figure 9.** Max Principle Stress – Mild Steel

**Figure 10.** Max Shear Stress – Mild Steel
The stress state is analyzed and the entire fracturing truck chassis is tested and its static strength tested, the tension of 15 chassis points is measured under the statical condition fully charged and the right front wheel lifting conditions are calculated and the stresses and stress distribution are determined.

Table 3. Stress values obtained for Mild Steel

| Description          | UTS (N/mm²) | Values Obtained (N/mm²) | RF  | Deflection (mm) |
|----------------------|-------------|-------------------------|-----|-----------------|
| Max Principal Stress | 500         | 251                     | 2.1 |                 |
| Max Shear stress     | 300         | 125                     | 2.4 | 1.4             |
| Von Mises stress     | 500         | 225                     | 2.2 |                 |

The comparison of Mild steel and Titanium alloy on the C-section truck frame, Titanium alloy having higher results than the Mild Steel. Where as in the defection mild steel proven with minimum defection. The comparison table was presented in table 4.
Table 4. Comparison of RF for Mils Steel and Ti alloy

| Description | Mild Steel | Ti alloy |
|-------------|------------|---------|
| RF 1        | 2.1        | 3.9     |
| RF 2        | 2.4        | 4.6     |
| RF 3        | 2.2        | 4.3     |
| Deflection  | 1.4        | 2.4     |

4. Conclusion

The selection of vital materials for an automobile is the major and utmost significant aspect for automotive design. The huge availability of materials can be selected on the heavy vehicle frame and chassis, but the main challenge for its design constraints. The most significant conditions that a material choice should meet the light-weight capacity, design safety, commercial effectiveness, recyclability and lifespan considerations. In this paper, two different material was adopted on the C-section truck frame design. Mild steel and Titanium alloy were structurally analysed on the heavy truck frame through finite element analysis. The structural analysis of Mild steel and Titanium alloy on the C-section truck frame, Titanium alloy having higher results than the Mild Steel. Where as in the defection mild steel proven with minimum deflection.

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