Investigation of material impact on Truck frame design through Structural Analysis

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Abstract. The truck chassis core purpose is to support the payload due to the various components located on it. The chassis was encountered to dynamic vibration due to the road irregularity and excitation of vibrating mechanisms, when the vehicle is moving on the road. Chassis helps to keep the automobile rigid and stiff. This paper investigates the material impact on the truck frame design. Two different materials were analysed on the heavy truck frame through finite element analysis. The Al alloy and Structural steel materials were applied on for channel cross-section of the truck frame. The results were compared and the best truck chassis material was identified with lower stress and deflection.

1. Introduction
Many investigators in the automotive engineering took the challenge to involve in the design, development and production of chassis. The chassis was encountered to dynamic vibration and forces due to the road irregularity and self-excitation of vibrating mechanisms, when the vehicle is moving on the road. Chassis will experience large amplitude of oscillations which may produce extreme bending and failure on it. Studies are on to obtain an optimized chassis design. To investigate the vibrations, the torsional stress and modal factors were analysed experimentally and then the results were validated with finite element model. Thus chassis was optimized with the enhanced structural stiffness. The operating competences of autos, an excited vibration frequency and dynamic model of the frame was investigated [1]. The base frame helps in supporting the different parts of the Truck. It has to resist the sudden impacts, jerks, twists and other stresses that are obtained during braking, acceleration, shocking road conditions. This carries the maximum load for all the operating conditions. The base frame acts as the spine of a heavy vehicle [2]. Finite element analysis techniques are used to analyse the structural exploration of truck chassis on base frames much easily [3]. Effects of frame geometry on collisions and structure of the ladder frame when subjected to various loads. It states that Frame geometry plays a major role during the collisions and various impacts [4].

An ideal automotive chassis are manufactured using Low weight and High Strength Carbon fibres. They made a structural analysis of the truck chassis frame for carbon fibres and steel. They analysed stresses, strain and various deformations and compared between Steel and carbon fibres [5]. The major issue in the automotive sector is weight reduction. They worked on TATA 2515EX which is a heavy vehicle chassis. They analysed it with different composite materials which are subjected to similar pressure as that of chassis made of steel [6]. In the traditional design process, the chassis design focused
on the strength and to enhance the stiffness of the structure. A very slight attention to the weight of the chassis. This design technique includes the adding the cross members to the present chassis structure to intensify its torsional stiffness. As this step, the heaviness of the chassis increases. This will leads to reduction in fuel efficiency and increases the material cost due to the addition of cross members. Hence, in the modern design, chassis with adequate strength and nominal stiffness is essential. This paper presents the study of material influence in the frame design on truck chassis. Two different materials were analysed on the heavy truck frame through finite element analysis. The al alloy and structural steel materials were applied on for channel cross-section of the truck frame. The results were compared and the best truck chassis material was identified with lower stress and deflection.

2. Frame Design

The chassis consists of longitudinal and cross members on its structure. Longitudinal members are with c-section. The typical model of chassis is shown in Figure 1. Dimensions from the literature is the basis for our models [7]. The frame is designed to handle a weight of 3 tons from the body and 0.6 ton of Engine.

![Figure 1. Chassis with C- Section](image1)

Top view of chassis is shown in Figure 2. 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.

![Figure 2. Plan of Chassis](image2)

Elevation of the chassis is shown in Figure 3. The wheelbase is nothing but the dimension between wheel centres and it is 2350 mm. The overall length of chassis is based on various factors which are out of scope.
Figure 3. Front View of Chassis

In the steel manufacturing industry, AISI 4130 alloy is called Structural Steel. This is generally used in the fabrication of structures. The property of two different frame material is tabulated in Table 1.

Table 1. Properties of Frame materials

| Design Property                        | Structural Steel | Al Alloy |
|----------------------------------------|------------------|---------|
| Young’s Modulus, N/mm²                 | 207000           | 70000   |
| Poison’s Ratio                        | 0.3              | 0.3     |
| Yield Strength, N/mm²                 | 910              | 500     |
| Ultimate Tensile Strength, N/mm²      | 1030             | 550     |

The Finite Element Method used in an engineering as computational tool to achieve an estimated results for a bounded problems. It uses the different boundary constraints for every analysis. The free-free boundary limit will be applied with no constraint is applied to chassis, when it tested for a normal mode. At the same time, real operating condition was applied to the chassis at the static analysis. At the suspension mountings, the pinned boundaries are applied to the chassis because at these mountings won’t allow any translation but permit only rotation about its axis.

Figure 4. Finite Element Model
The model has meshed and the meshed model is shown in Figure 4. 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.

3. Result and Discussion

Plot results for Max Principal, Max Shear & Von Mises Stresses can be easily seen for the Al 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.

This key point is one of the reasons that may cause the loss of exhaustion. The existing truck chassis is fitted with stiffeners for modification and study. Initially the model's thickness, where the highest deflection occurs in bending analysis, has been increased to a certain value with appropriate limit. And at the middle of the wheel foundation, one more cross beam was added to add stiffness to the platform. In order to reinforce and improve the chassis stiffness as well as the overall chassis performance, a series of modifications and tests were carried out by adding the stiffener [7].
Maximum deflection is noticed near one of the Body mounting points as shown in the Figure 8. Deflection value obtained is verified with the allowable limits obtained from experiments. The results of aluminium alloy on the truck frame is tabulated in Table 2.

| Description       | UTS (N/mm²) | Values Obtained (N/mm²) | RF | Deflection (mm) |
|-------------------|-------------|-------------------------|----|-----------------|
| Max Principal Stress | 550         | 251                     | 2.2 |                 |
| Max Shear stress  | 330         | 125                     | 2.6 | 4.1             |
| Von Mises stress  | 550         | 225                     | 2.4 |                 |

The material changed to Structural 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 Principal Stress – Structural Steel

Figure 10. Max Shear Stress – Structural Steel

Figure 11. Von Mises Stress – Structural Steel
Analyses the stress state and performs the static strength test and dynamic strength check of the whole fracturing truck chassis, measures the tension of 15 chassis measuring points under the totally charged static condition and the correct front wheel lifting condition respectively and figures out the distribution of the frame stress and strain. The results show that the frame's maximum stress position under migration condition lies at the root of the tank's rear support [8].

Table 3: Stress values obtained for Structural Steel

| Description           | UTS (N/mm²) | Values Obtained (N/mm²) | RF  | Deflection (mm) |
|-----------------------|-------------|------------------------|-----|-----------------|
| Max Principal Stress  | 1030        | 251                    | 4.1 |                 |
| Max Shear stress      | 618         | 125                    | 4.9 | 1.4             |
| Von Mises stress      | 1030        | 225                    | 4.6 |                 |

The comparison of aluminium steel and structural steel on the C-section truck frame, structural steel having higher results than the al alloy. The defection was also proven with minimum deflection. The comparison table was presented in table 4.

Table 4. Comparison of RF for Al Alloy and Structural Steel

| Description | Al Alloy | Structural Steel |
|-------------|----------|------------------|
| RF 1        | 2.2      | 4.3              |
| RF 2        | 2.6      | 5.1              |
| RF 3        | 2.4      | 4.8              |
| Deflection  | 4.1      | 0.6              |

4. Conclusion

Automotive chassis structure ensures less noise, vibration and harshness on the vehicle. This paper presents the study of material influence in the frame design on truck chassis. Two different materials were analysed on the heavy truck frame through finite element analysis. The al alloy and structural steel materials were applied on for channel cross-section of the truck frame. An evaluation of different two materials under this scenario shows that structural steel material- has potential for the frame structure
than a simple change of materials. The FEA analysis was contacted with the same type of load and results were compared for best truck chassis material identification with lower stress and deflection. From the results, it is found that structural steel has better RF values when compared to Al alloy. It is also found that structural steel has less deflection than that of Al alloy.

References

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