Review on Structural Analysis of Tata Truck Chassis Frame Using Finite Element Analysis Tools

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Abstract— The biggest challenge in present earth-based vehicle industry is to come up with the growing insistent demand for higher performance, reduced weight, and prolonged life of components, all this at a minimum cost and within a small period of time. The chassis of any vehicle is the base part of the vehicles where all the main components of the vehicle such as the axles, power train, suspension, cab & trailer get assembled together. Since, the chassis is the massive component of the vehicle that is why it is often gets identified for continuous improvements. There are so many industrial and domestic sectors which uses TATA TRUCK vehicle for the transportation of logistics, agricultures, factories and other industries also. This thesis reflects the work which is performed for TATA 2518-TC Truck vehicle towards the advancement of the automotive chassis with parameters like maximum shear stress, equivalent stress and deflection of chassis along with the alternative material suggestions to reduce the chassis weight. Chassis is the structural system which is simply analysed using the finite element techniques. The analysis is carried out to find out the best chassis in terms of thickness. The model of chassis is made in Solid works and analysis work is done on the chassis frame using the ANSYS software.

Keywords: Chassis Frame, Structural Analysis, Solid works 2021, ANSYS 14.5, Equivalent Von-Mises Stress, Total Deformation

I. INTRODUCTION

To effectively address the problem at hand, it is important to gain an in-depth understanding of the different chassis types and their history, materials used, the different load cases and the relevant load paths. Below, different chassis design types and their characteristics are introduced.

Basically, chassis is look attentively as a framework to bear all the part of the vehicle and the weight of the body, engine and other parts which make up the complete vehicle. Chassis contribute or add (a quality) to the whole vehicle support and rigidity. Chassis usually includes a set of longitudinally increasing channels and involving several transverse cross members that divide by passing or lying across it the channels. The cross members usually have a lessen cross-section in order to permit for a longitudinally increasing storage space. The chassis supports various components which are needed for the vehicle and also being based around compartment of the driver. The safety of the chassis is a major consideration in the design, and should be inspected through all stages. The types of chassis are-backbone type chassis, ladder, space frame and monocoque.

A. *Types of Chassis Frames*

1) *Twin-tube or Ladder Frame Chassis:*

The twin-tube type of chassis frame consists of two bearing tubes that are extended up to the driving direction of the vehicle. Mainly, these frames usually fabricated by the steel tubes. Ladder type chassis frame is one of the earliest forms which generally used as automotive or automobile chassis that is still being used by greatest in amount of the SUV’s till today. It is also looking like a ladder which having two side members internally linked by many lateral and cross members. These two members provide rigidity to the structure (Wakeham, 2009).

2) *Multi-Tubular Chassis:*

In theory the term multi-tubular refers to a chassis that is built up with more than two bearing beams, which is used to define all chassis types beside the twin-tube described above. In practice, the term is perhaps best applied to those chassis, which utilizes four main side rails but cannot be classified in the true space frame category. Essentially, this chassis offers poor performance, but has proven to be a successful compromise between the twin-tube chassis and the space frame in terms of stiffness and production cost. Often, the frame member diameter, which is the outer diameter of the frame, has to be increased to attain a suitable torsional stiffness. This results in a heavier chassis, in comparison to for example, a space frame.

3) *Monocoque chassis:*

This chassis is a single-piece structure, which constructs the complete shape of the vehicle. At the beginning of the manufacturing of monocoque chassis it was mostly used in aircraft in the 1930s. The 1960s vehicles, which used the Monocoque chassis, generally having the cylindrically formed construction to improve the torsional rigidity of the vehicle. The Monocoque chassis provides the main support to structure, and thus absorbs all the loads affecting the vehicle. In vehicles today, the basic type of Monocoque chassis are made of different types of composites, for example Vehicle on Fibre Reinforced Polymers (CFRP). The benefits of this chassis (in particular, composite Monocoque chassis) include high torsional stiffness and light weight.

4) *Space Frame:*

This type of chassis is usually rigid in structure, light in weight, looks like a truss is kind of structure which is constructed by fixing the struts in a geometric pattern. This chassis is generally used in aircrafts, and sometimes used in cars. The advantage of using this type of chassis is that it resists the torsional forces in a better way.

5) *Box and No-Box frame chassis:*

There are two different design solutions for the rear of a formula vehicle chassis, a box and a no box solution. The difference between the two is that in the box solution the rear frame encloses the differential and parts of the drive shaft, while in the no box solution the rear frame ends before the differential and drive shaft. It is easier to design the box solution, but it adds more weight to the construction over the no box solution. Also, the no box solution makes it easier to access the different parts in the rear end and is a more compact solution, but is more complex to design.

B. Material Taken for Chassis Frame

As we know that for manufacturing any component, material is the basic need to make the component in solid form. Presently the material which is used for manufacturing the chassis of TATA 2518TC as per IS: - 9345 standard is structural steel having St 37. Structural steel in simple words by changing the chemical composition of material leads to changes in their names.

The basic chemical composition of the material is 0.56%C, 1.8% Si, 0.7%Mn, 0.04%P and 0.04%S. The other different materials are:

1) Structural Steel

The composition of this material is- C (0.120%), Mn (1.6%), Si (0.50%), P (0.03%).

2) Gray Cast Iron

The composition of grey cast iron is- C (up to 4%), S (up to 3%), Mn (0.8%), S (.07%), P (0.2%), Mo (up to 0.75%), Cr (0.35%), V (0.15%)

3) AISI 4130 Alloy Steel

The full form of AISI is 'American Iron and Steel Institute', which has defined the steel alloy with the specified composition of material like AISI 4130, AISI 4140. AISI 4130 is also called chrome-moly alloy steel which is also stands for chromium-molybdenum alloy steel. The chemical composition of the AISI 4130 steel alloy is given as follows- C (0.28-0.33%), Cr (0.8-1.1%), Fe (97.3-98.22%), Mn (0.4-0.6%), Mo (0.15-0.25%), P (0.035%), S (0.04%), Si (0.2-0.3%).

4) ASTM A710 Steel Grade A Class (III)

ASTM reflects American Society for Testing and Materials, which has given the designation to the alloy steel the grade of ASTM A710 steel with a particular composition. The chemical composition is given as follows- C (0.07), Mn (0.4-0.7), P (0.025), S (0.025), Si (0.035), Cr (0.60-0.90), Ni (0.7-1), Mo (0.15-0.25), Cu (1-1.3), Niobium (0.02).

Material	Modulus of Elasticity (GPa)	Density (kg/m^3)	Tensile Strength (MPa)	Yield Strength (MPa)
Structural Steel	210	7850	460	260
Gray Cast Iron	110	7200	240	_
AISI 4130 Steel Alloy	260	7798	1030	910
ASTM A710 Steel	205	7850	515	450

Table 3.2: Physical Properties of Materials.

II. LITERATURE REVIEW

The chassis must be enough rigid to endure the suspension forces and maximum loads. Therefore, strong chassis points are needed there. The suspension will be adjustable; the most important variable is the roll-stiffness. To be definite that the adjustment has the expected effect the chassis must have sufficient stiffness. There are many researchers who did the research on the chassis design; some of the research works are as:

Akash Singh Patel and Atul Srivastava (2016) has taken the dimensions of the chassis frame of TATA 2518TC Truck to perform the structural analysis of the heavy vehicle chassis. Structural analysis is carried out on chassis frame by using different materials like, Gray cast iron, AISI 4130 alloy steel and ASTM A710 steel grade A class (III). He solid model of chassis is modelled in CATIA V5 and the analysis work is done using ANSYS 14.0 software. The results of the analysis are validated with numerical results. Also, the two optimization techniques i.e. Boxing and Reinforcement are used to optimize the chassis frame. The final result shows that AISI 4130 alloy steel material is suitable for heavy vehicle chassis as compare to other materials.

B. Ramana Naik and C. Shashikanth (2015) has analyse an automobile chassis which is having the capacity of 10-tonne. The model is created using Pro-E, and analysis is done on ANSYS software. The elongation in chassis are calculated analytically for the stresses and deflections and the results are compared to computational value. Modal analysis is also performed to find out the natural frequency of the chassis frame. It is seen that the value of frequency is above than its excitation frequency. After the comparison of theoretical and FEA it is observed that they are within the material properties. This frequency is more than 4 times to '33Hz' which is the highest frequency of the excitation. Hence the chassis can truly transmit the input excitation to the vehicle body without any amplification.

Hemant B. Patil et. al carried out a stress analysis of ladder type chassis frame for loader truck having capacity of 7.5 tonnes by sing finite element analysis. The whole work is completed by using CATIA V5 software. The numerical result shows that if the thickness of the chassis is not possible to change, then we can also change the position of the cross members to find out the changes in results. The computed result is compared with the analytical results. Here the final result is that maximum deflection is similar to the theoretical results but varies on the magnitude aspect.

Hirak Patel, et al. (2013) carried a sensitivity analysis of chassis frame for the reduction of weight of the chassis. The model of chassis is created in Pro-E software and the analysis is done on ANSYS workbench. The result shows that after the weight optimization, 17% reduction of weight is obtained after the sensitivity analysis.

Ketan Gajanan Nalawade, et al. (2014) perform the structural analysis of a TATA 407 truck chassis. 3-D chassis is created in CATIA and finite element analysis is done on ANSYS workbench. The result of this work represents that the maximum value of shear stress and equivalent stress generated in E-glass material is under tolerable limit and total deformation is also in the suitable value. It is also seen that for the same loading conditions, E- glass is more suitable than steel and thereby able to reduce the weight by approx. 68% and increase in stiffness.

Monika S. Agrawal (2018) has conducted analysis to rectify the problems which are associated with the chassis frames such as strength, stiffness and fatigue. The modelling of chassis is done in CATIA V5 and the analysis is performed using ANSYS software. The results represent that the results which we from FEA analysis are 13.33% greater than analytical value.

Padmanabhan S. et al. (2012) uses two different material i.e. Mild steel and Titanium alloy to perform the structural analysis of chassis having cross-section of C. In the present work the results are like that, the Titanium alloy shows higher result than the mild steel but, the mild steel shows the minimum deflection.

Potdar et al. (2015) uses the dimensions N1 type of TATA Ace chassis to model the chassis frame in CATIA V5. After the modelling, the analysis work is completed in ANSYS Workbench. The conclusion is that, the deflection due to bending of the Chassis Members can be evaluated using Static Finite Element Analysis instead of conventional time-consuming calculations. The value of complete bending stiffness of the Chassis is 13724 N/m which is under the permissible range of 22000N/m, for N1 Vehicle Category.

P. Bhowmick et al. (2017) has created a model of pick-up truck chassis and carried out finite element analysis on that chassis. Static structural analysis is done using ANASYS software for four different materials i.e. ASTM A710 steel, ASTM A320 steel, HSLA steel and ISO 1018 steel. The 3-D replica of chassis is made using CATIA V5R2 and then imported to ANSYS to perform the structural analysis. HSLA steel is found to be the best material as compared to other materials for designing the chassis because the value of deformation is very less in this material.

Rohan Y Garud, et al. (2018) perform the FEA analysis for the maximum stress, deformation and critical regions on chassis frame under loading conditions. The CATIA software is used for the CAD modelling of chassis and the analysis work is completed in ANSYS Workbench. The results show that after the optimization, the chassis having thickness of 8mm with high strength steel shows good result as compared to other materials.

S.S. Chappar and Mahantesha.S. Hiremath (2017) has performed the structural analysis of chassis Mercedes Benz truck. The three-dimensional solid model is created in CATIA V5 R20 software and then the analysis is performed in ANSYS 2017 software. The numerical results are then validated by analytical calculation on the bases of stress and deformation. After this, slots have been made in chassis frame for the reduction in weight of the chassis. The optimization of slots is done only in ANSYS software.

Vijayan. S. N. et al. (2015) conducted analysis of heavy vehicle chassis by using the dimensions of EICHER 10.9 for creating the CAD figure of chassis in Pro-E and the analysis work is performed using ANSYS 14.5. Three different cross-sections are created i.e. C, I and Box and the S-Glass Epoxy and Steel is taken as a material for the analysis. Results of the work shows that I-section chassis with steel material is very much suited for the heavy vehicle chassis as compared to S-Glass Epoxy material.

III. Conclusion

In conclusion, from the literature survey and methodology, we find that chassis the thickness and weight of chassis is major issue for analysis the deformation of chassis.as the chassis has less thickness so the deformation of chassis is more so for finding the appropriate thickness of material for different loading condition using different material is important for chassis.

The chassis frame of the truck which is taken for design and analysis for different thickness by applying different materials. The chassis is modeled in Solidworks 2021 and then analyzed in ANSYS 14.5 by applying some loading conditions. After analysis a comparison will take place on the bases of materials and thickness.

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