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Optimization Of Heavy Truck CHASSIS Design Parameters Using Finite Element Methods

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Abstract

This study investigates the characteristics of chassis of the trailer truck of 113 feet and 105 feet flatbed chassis including stress on frames, suspension systems, load conditions and external impact. Finite Element Method (FEM) can be used to locate the critical point which has the highest stressusing stress analysis. In this study, the stress analysis is accomplished by the commercial finite element package COSMOS. The constraints to be considered in this work are factor of safety. During optimization, either the addition of material or removal of the material, the factor of safety should not be reduced beyond the specified limit. In this study the variations of the whole body stiffness arising from the rotation due to bending deflection, contact deformationand shearing displacementalso considered.Both the high stress and the low stress regions were taken for optimization in this analysis. The proposedModifications are done by increasing thickness of the chassis center section to maximum of 2 mm and additional of stiffeners member located at center of the base plate to maximum of 10 mm for the high stress distributed areas. The materials were removed upto 2 mm for the low stress distributed areas, without changing the factor of safety. In addition, the overall changes carried out from analysis were successfully achieved with increase in the torsion stiffness and reduction in the total deflection. The overall weight of new truck chassis had optimized. Finally, the modifications of the updated TC model was proposed to reduce the vibration, increase the strength, and optimize the weight of the truck chassis.

Keywords: Finite element method, COSMOS, Stress analysis, Optimization, Deflection

1. Introduction

The truck industry has experienced a high demand in market especially in India whereby the economic growths are very significantly changed from time to time. The backbone component of a vehicle systemis truck chassis, as it withatand the entire load of the vehicle. So it should be strong enough and on the other hand, the weight of the chassis should be as least as possible to improve the efficiency. This can be achieved in this work by doing static and dynamics analysis to determine key characteristics of a truck chassis (TC). The static features include finding location of high stress area, bending and determining the stiffness of the chassis. The dynamic features of truck chassis were determined by using finite element method. The investigation on Experimental analysis was carried out by updating the truck chassis model by adjusting the selective properties such as factor of safety, mass density, cross sectional area, and Poisson's ratio. This is a foremost challenge to truck manufactures to improve and optimize their vehicle designs in order to meet the market demand and at the same time improve the vehicles durability and performance. As the truck chassis is a major component in the vehicle system, hence, it is often identified for refinement and improvement for better handling and comfortably. Dave Anderson and Greg Schade [1] developed a Multi-Body Dynamic Model of the Tractor-Semitrailer for ride quality prediction. The studies involved indicating the distributed mass and elasticity of the vehicle structures e.g. frame ladder, the non-linear behaviour of shock absorbers, replicate the fundamental system dynamics that influence ride and provide output of the displacement, velocityand acceleration, measures needed to compute ride quality.A study on the effect of frame flexibility on the ride vibration of trucks is conducted by I.M. Ibrahim, et.al. [2] The aim of the study was to analyze the vehicle dynamic responses to external factors. Rossi Pinto Filho [3], who analyzed on the Automotive Frame Optimization. The study was basically to obtain an optimized chassis design for an off-road vehicle with the appropriate dynamic and structural behaviour.Another case study was conducted by Marco Antonio Alves [8] on the Avoiding Structural Failure via Fault Tolerance Control. The structural modification and secondly by some active modificationwere two approaches or option used. The aims of study were to decrease the vibration on the truck and consequently increase life of the structure. The author from Clemson University, Lonny L. Thompson [12] had conducted a study on the effects of chassis flexibility on roll stiffness of a racecar. The primary objectives of his study were to determine the effects of overall chassis flexibility on roll stiffness and wheel chamber response to the racecar chassis and suspension.For better performance of the truck, it is important to reduce the vibration, improve the strength, and optimize the weight of the truck chassis

The chassis frame forms the backbone of the truck and its chief function is to safely carry the maximum load wherever the operation demands. Basically, it must absorb engine and axle torque and absorb shock loads over twisting, pounding and uneven roadbeds when the vehicle moving along the road. For this project, the truck chassis is categorized under the ladder frame type chassis. A ladder frame can be considered structurally as grillages. It consists of two side members bridged and held apart by a series of cross members. The side members function as a resistance to the shear forces and bending loads while the cross members give torsion rigidity to the frame. Most of the light commercial vehicle chassis have sturdy and box section steel frames, which provide this vertical and lateral strength and resistance to torsion stress. In this study, Finite Element analysis was used to determine the characteristics of the truck chassis.The models taken for analysis are 113 feet and 105 feet flatbed TC. The type of chassis was known as parallel ladder type frame with box section.The next step was the chassis structural preparation and set up for measurement purposes. The measurement data was performed and modelled in the Solid works software.Then the model was imported to the COSMOS software for further analysis of finite element analysis.

2. Specification of Chassis

Test Sample I

Test Sample: 113 feet flatbed spring suspensionsemitrailer
Material : Mild Steel
Dimension(LxBxH), mm: 34443 X 2700 x 1600
Young Modulus (GPa) : 200
Density (kg/m3) : 7850
Poisson's Ratio : 0.30
Wheel base : 20574 mm
Wheel Track : 2100 mm
Load carrying capacity : 27 Tones
No of tyres : 10
RLW : 27 tones
ULW : 18 tones
GVW : 9 tones

Test Sample II

Test Sample: 105 feet flatbed spring suspension semitrailer
Material : Mild Steel
Dimension (LxBxH), mm : 32004 X 2700 x 1600
Young Modulus (GPa) : 200
Density (kg/m3) : 7850
Poisson's Ratio : 0.30
Wheel base : 20726 mm
Wheel Track : 2100 mm
Load carrying capacity : 27 Tones
No of tyres : 10
RLW : 27 tones
ULW : 18 tones

GVW : 9 tones

3. Stress Distribution Analysis using Finite Element Method

The analysis has been carried out using the finite element analysis to obtain the stress distribution value of the truck chassis. The purposes of this analysis are to evaluate and optimize the results.

Step I:

The truck chassis structure was modelled using SOLIDWORK software to create the model as shown in figure 3.1. The chassis structure are closed rectangular profile longitudinal rails and tubular section cross members.

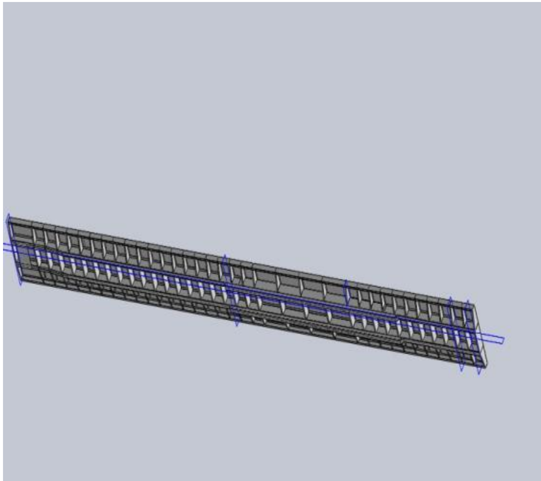


Fig.3.1 105 feet flatbed spring suspension semitrailer

Solid works Model

Step II:

The drawing was then exported to the Solid works – COSMOS software.

Step III:

The neutral format is again imported into the COSMOS software simulation system.

Step IV:

The material and element properties of the chassis structure were then defined. The properties of the chassis were listed as below:

a. Modulus of Elasticity, E = 200Gpa

b. Coefficient of Poisson, $\nu = 0.30$

c. Mass density, $\rho = 7850$ kg/m cubes

Step V:

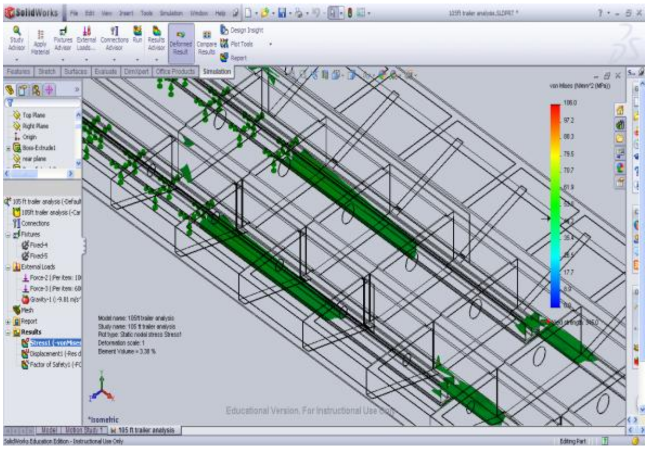
The tetrahedral-10 element was used in the meshing procedure because of 3D and solid modeling of truck chassis and was meshed on auto meshing (Fine). General overview finite element mesh of the truck chassis with 31,489 elements/ 52788 nodes and 30,489 elements/ 62788 nodes respectively. These results were based on the element set-up on the testing parameter.

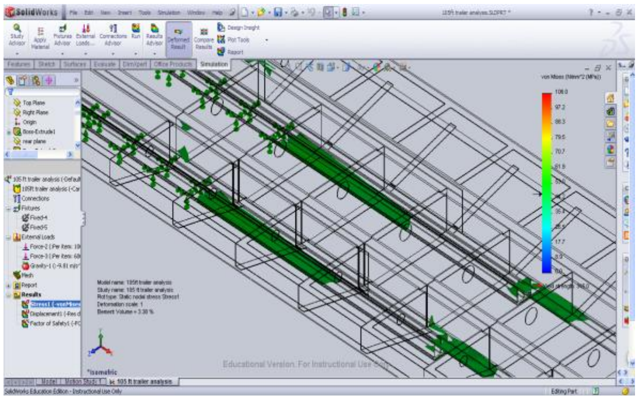
Step VI

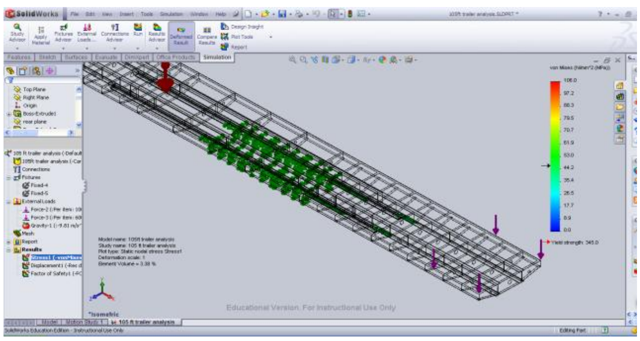
The free-free boundary condition was adopted. Therefore, neither constraints nor loads were assigned in attempt to stimulate the free-free boundary condition which means all the brackets and support such as spring leafs,absorbers and engine were removed from the chassis.

Step VII

The stress distribution analysis was executed and the obtained results were shown in the figure 4.7.







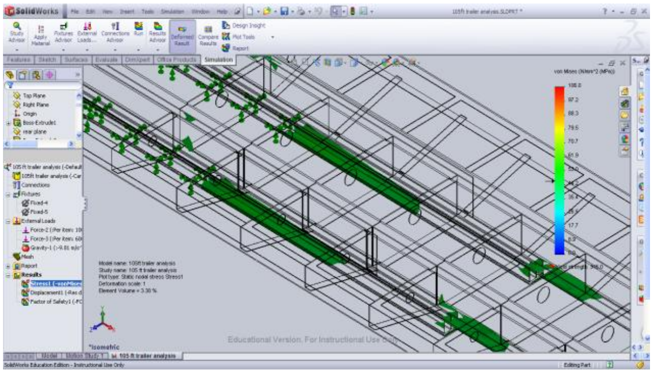


Fig.3.2 High Stressed Area of the Truck chassis

3.1 Structural Modification

The fully updated chassis model from the previous chapter was utilized and several series of testing were performed in order to obtain the optimum structural modification results. Structural modification on the chassis cross members were made and involved both static and dynamic testing.

3.2 105 Feet Truck Analysis on Existing Frame

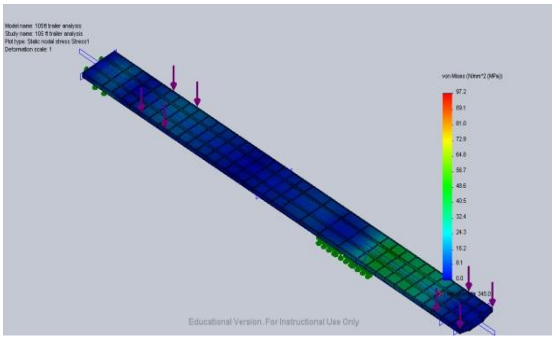


Fig.3.3 105 ft trailer analysis-105 ft trailer analysis Stress-Stress

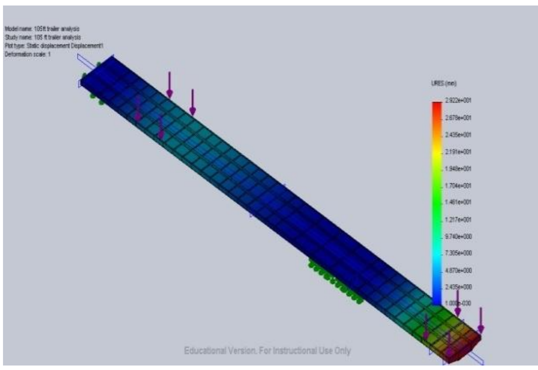


Fig.3.4 105 ft trailer analysis-105 ft trailer analysis Displacement-Displacement

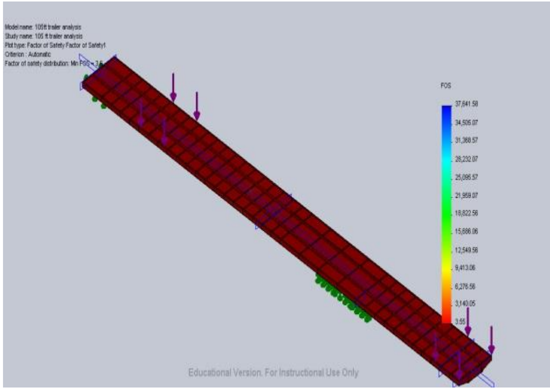


Fig.3.5 105ft trailer analysis-105 ft trailer analysis Factor of Safety-Factor of Safety

This analysis proved that the existing truck frame is safe. The displacement and the stress are in safe level. The maximum stress occurs only near the back side of the truck in which the load is rested. And at the same time, the factor of safety remains same.

3.3 105 Feet Truck Chassis Analysis by Reducing Material

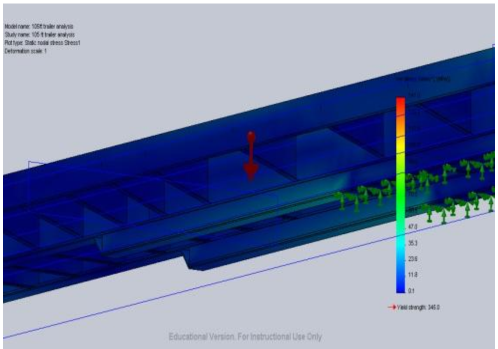


Fig.3.6 105 ft trailer analysis-105 ft trailer analysis Stress-Stress

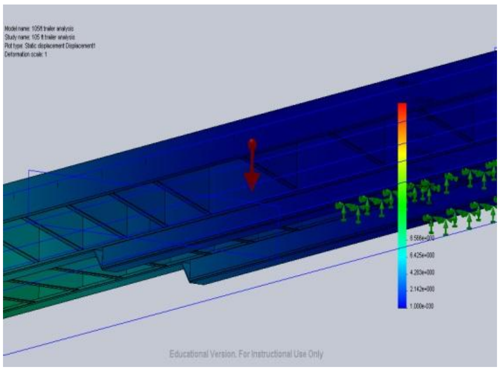


Fig.3.7 ft trailer analysis-105 ft trailer analysis Displacement-Displacement

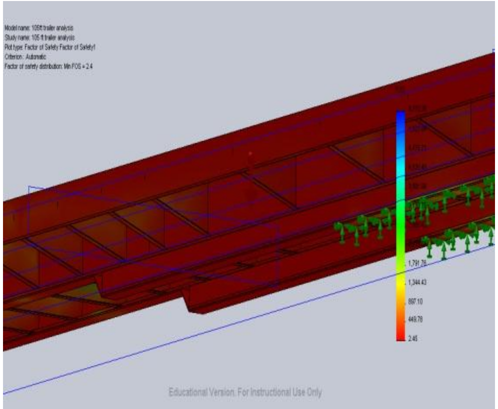


Fig.3.8 105 ft trailer analysis-105 ft trailer analysis Factor of Safety-Factor of Safety

3.4 105 Feet Truck Chassis Analysis by generating Holes

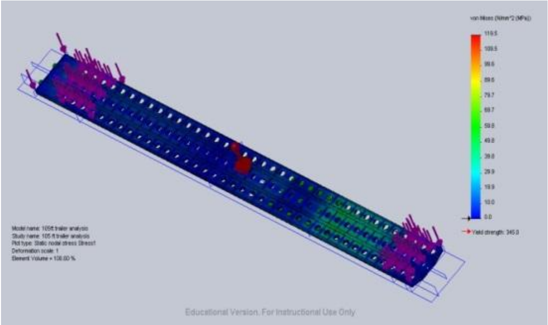


Fig.3.9 105 ft trailer analysis-105 ft trailer analysis Stress-Stress

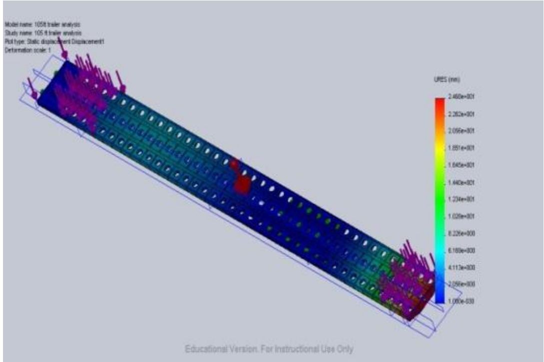


Fig.3.10 105 ft trailer analysis-105 ft trailer analysis Displacement-Displacement

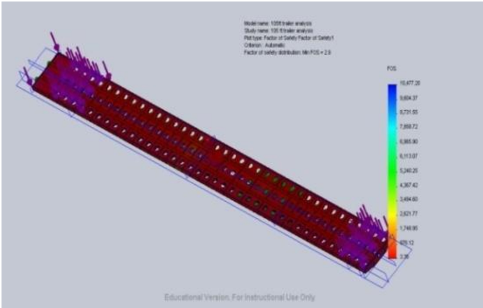


Fig.3.11 105 ft trailer analysis-105 ft trailer analysis Factor of Safety-Factor of Safety

3.5 105 Feet Truck Chassis Analysis – Holes on Side Frame

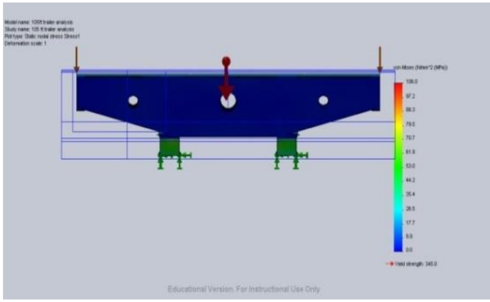


Fig.3.12 105 ft trailer analysis-105 ft trailer analysis Stress-Stress

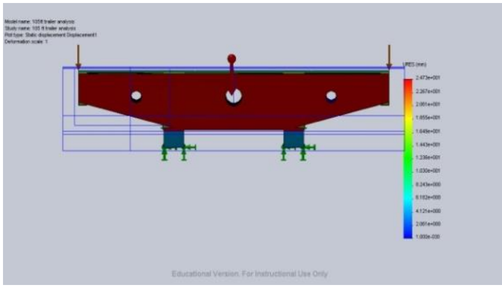


Fig.3.12 105 ft trailer analysis-105 ft trailer analysis Displacement-Displacement

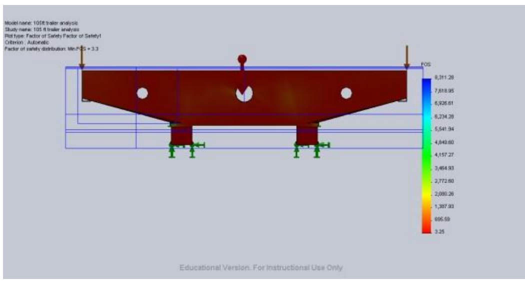


Fig.3.13 105 ft trailer analysis-105 ft trailer analysis Factor of Safety-Factor of Safety

4. Structural Modifications and Parametric Analysis

Basically, the stress generated in the chassis is a very importance parameter. Damages can occur if the truck chassis is excited at the ultimate stress during operation. Therefore, the modification on the chassis from FE model was analyzed in order to improve strength as well as reducing in vibration. For the modifications and analysis, the current truck chassis were added with stiffener and some material properties were slightly changed as described below.

1. Increased thin wall thickness by 2 mm, so that there will be negligible stress in the frame.
2. Reduced the wall thickness by 2 mm all over will be safe design and the factor of safety also remains same and with allowable limit.
3. Formation of the holes all over the frame helps in reducing the weight of the frame and the factor of safety remains same all over the frame.
4. Additional hollow bar at front chassis @ thickness 2mm
5. Additional plate on the center cross member @ thickness 10 mm

By doing so, the life span of the truck chassis will be increased.

5. Results

Material: Carbon steelst52.3

Boundary condition:

Fixed-4 <105ft trailer analysis> on 1 Edge(s), 11 Face(s) fixed.

Fixed-5 <105ft trailer analysis> on 1 Face(s) fixed.

Table 1 Results of stress and displacement analysis

	Load (N)		Stress (MPa)	Displacement (mm)
	Force 2 (N)	Force 3 (N)		
105 Feet Truck Chassis Analysis on Existing Frame	90000	90000	97.16	29.212
105 Feet Truck Chassis Analysis by Reducing Material	1e+005	60000	141	25.6994
105 Feet Truck Chassis Analysis by generating Holes	1e+005	60000	119.48	24.6776
105 Feet Truck Chassis Analysis – Holes on Side Frame	1e+005	60000	106.004	24.7287
113 Feet Truck Chassis Analysis on Existing Frame	1e+005	60000	101.102	47.5439
113 Feet Truck Chassis Analysis by Reducing Material	1e+005	60000	132.243	51.6525
113Feet Truck Chassis Analysis by generating Holes	1e+005	60000	110.398	49.0553
113 Feet Truck Chassis Analysis – Holes on Side Frame	1e+005	60000	106.515	44.5433

6. Conclusion

The study of static and dynamic behaviour of truck chassis had been executed successfully. The application of dynamic correlation technique together with Finite Element Tools had been utilized in order to verify the simulation and experimental analysis of the chassis. Experimental results were used in conjunction with the finite element to predict the dynamic characteristic of truck chassis. Basically, the occurrence of the stress is the important parameters in chassis design. Damage can occur if the truck chassis is excited at higher stress level during operation. Therefore, based on the result gained from the finite element analysis, further enhancement of the current chassis had been done through the chassis FE model in order to improve its torsional stiffness as well as reduce the vibration level. Series of modifications and tests were conducted by adding the stiffener in order to strengthen and improved the chassis stiffness as well as the overall chassis performances. These facts were due to the imperfection of the model and real structure. The overall torsion stiffness was significantly improved by 25% over the base line model. The total deflection also reduced by 16%. There were seven total number of test variables conducted to the existing chassis and it was shown that the combination of increasing the wall thickness by 2 mm and adding plate on the center cross member gave optimum results.

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