Design and Optimization of Truck Load Body

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Abstract— This Paper highlights the development of Truck industry which is a major source of transportation. With an average truck travelling about 300 kilometers per day, every kilogram of truck weight is of concern to the industry in order to get the best out of the truck. The main objective of this project is to increase the payload capacity of automotive truck load body. Every kilogram of increased vehicle weight will decrease the vehicle payload capacity in turn increasing the manufacturing cost and reducing the fuel economy by increase in the fuel consumption. With the intension of weight reduction, standard truck body has been designed in Catia V5-21 and analyzed in ANSYS software. At the initial stage we are using both C-Section beams and conventional rectangular box sections to reduce the weight of the body. We are using Structural Steel and Light-weight Aluminum alloy Al 6061 T6 material by comparing both properties used to increase the payload capacity. The strength of the Truck platform is monitored in terms of deformation and stress concentration. These parameters will be obtained in structural analysis test condition environment. Accordingly necessary modifications are done so that the optimized model has a better stress distribution and much lesser weight compared to the conventional model. The results obtained by analyzing modified model are compared with standard model.

Keywords: Truck Load Body, Analysis, Payload Capacity, Modified Model, Standard Model, Optimization

I. INTRODUCTION

Transport industry plays a crucial role in development of modern industrialized countries economy. The total weight of the load carried on the truck has been increasing drastically. Today's difficult challenge of transport vehicle is to meet the increasing demand for better performance, less weight and more reliability. All this criteria has to achieve in short duration of time. There is a considerable focus on design of the truck body, for increasing payload capacity. Replacement of rectangular cross section beams with C-cross section beams, use of Aluminum alloys instead of structural steel will be the feasible solutions for increasing payload capacity of the truck. With the use of aluminum the strength of the truck reduces, which can be augmented by using the concept of beams of uniform strength.

A. Objective: The Main Objectives of the Work is:

- The main objective of this study is to increase the payload capacity of the automotive truck.
- Comparing Specifications of Standard Load Body with Modified Load Body
- To reduce stress concentration by using concept of beams of uniform strength.

B. Methodology:

- Geometric modelling of the models in Catia V5-21.
- Meshing and Analysis of the models at various tons.
- After analyzing the models a third model is developed and analyzed.

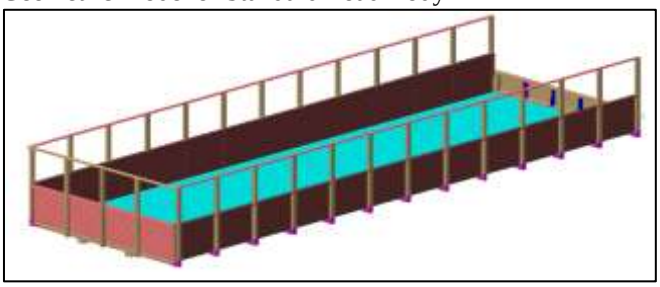
II. PROBLEM DESCRIPTION

Today there is demand on trucks, not only on the cost and weight aspects but also on the improved complete vehicle features and overall work performance. In addition to this number of variants that are possible due to different types of designs and modularization, call for several design iterations to arrive at a suitable combination. The project work deals with load/dump body. There is considerable scope to improve the design of their product. For optimization of dump body design, one standard model is taken from the local industry.

A. Design Parameters Details:

Load capacity of the truck	15 tons
Length of the truck body	75338mm
Width of the truck body	2316mm
Height of truck body	2297.2563mm
Bottom Floor thickness	2mm
Side guard thickness	2mm
Head board thickness	2mm
Material of the truck body	Structural Steel
Side vertical members on both sides	13 (thickness=4mm)

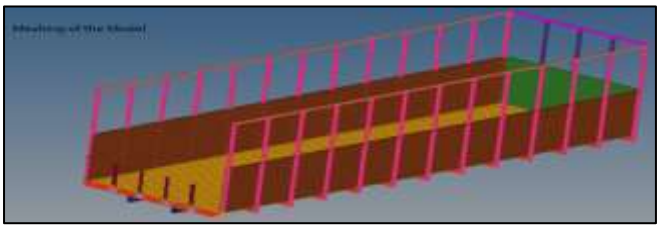
Geometric Model of Standard Load Body



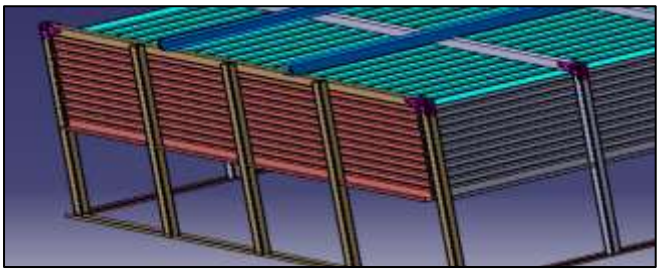
B. Properties of Structural Steel:

Modulus of Elasticity (GPa)	200
Yield Strength (MPa)	250
Ultimate Tensile Strength (MPa)	460
Poisson's ratio	0.3
Density (kg/m^3)	7850

C. Meshing of the Model:



D. New model with C-Beam:



E. Properties of Aluminum 6061 T6

Modules of Elasticity (GPa)	68.9
Yield Strength (MPa)	276
Ultimate tensile strength (MPa)	310
Fatigue strength (MPa)	96.5
Poisson's ratio	0.33
Density (kg/m^3)	2700

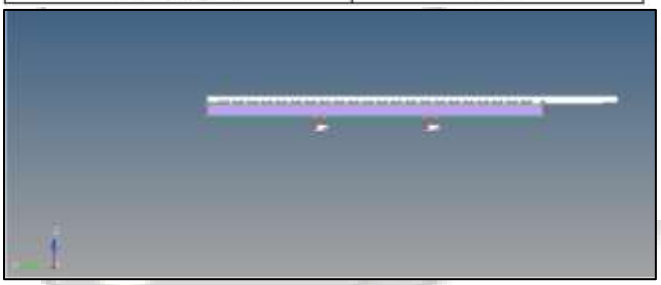


Fig. 1: Boundary Conditions

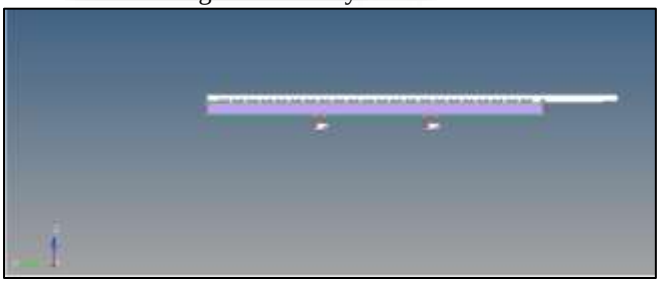


Fig. 2: Loading Methodology

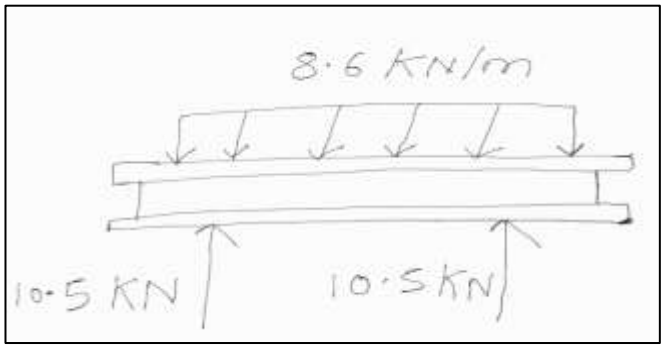
The boundary applied to the model such that the fixed supports had given to the longitudinal bars at the bottom of the truck body, as shown in the figure. Since the longitudinal bars are placed on the chassis frame, so the Ux, Uy, Uz are taken as zero displacement.

The modelled Truck body is loaded by transferring the forces from material it carries. The main load bearing elements of the truck body are floor, head board, and side guard. The side guard and head board are designed in such a way that, it will carry the part load when the braking, turning, travel on the slopes.

- Floor : 100% of Load carried
- Side wall : 15% of Load carried
- Front wall : 15% of Load carried

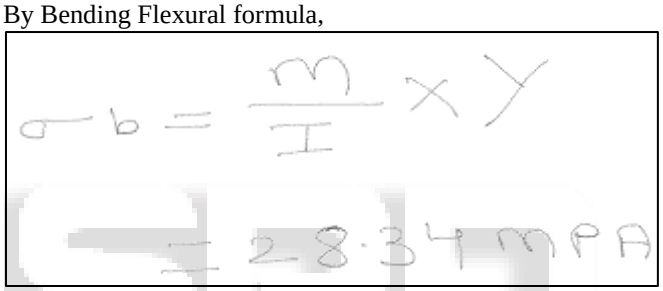
III. CALCULATION

1) The truck has the capacity of carrying load up to 15 tons.
Force exerted = 15000*9.81 = 147150 N.
So there are 13 members so force acting on each member = 147150/13 = 11319.23 N.
σt= F/A=6.6 N/mm^2

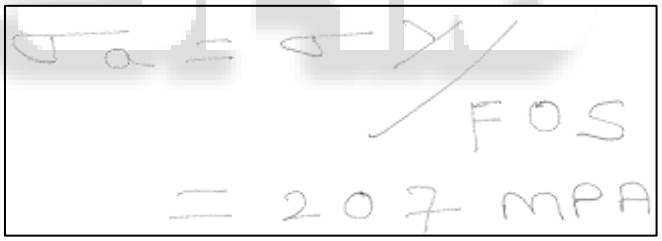


∑fy=0
Ra=10.5 KN
Rb= 10.5 KN

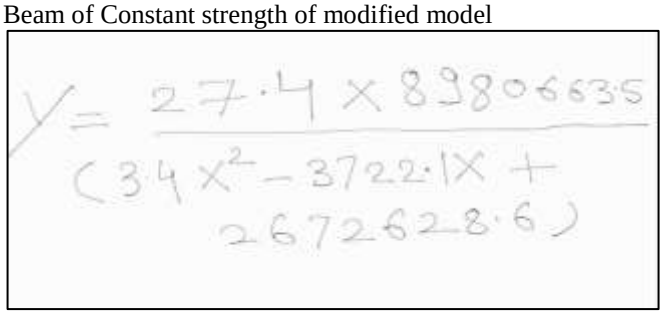
By Bending Flexural formula,



Allowable Stress,



Beam of Constant strength of modified model



A. Solution

1) Model 1-A (Iteration 1)

The Standard Truck body with Structural Steel as a material is loaded for different loads such as 10,15,20 tons.

2) Model 1-B

To increase the payload capacity the light weight material in automotive applications such as aluminum can be used.

Now the Standard Load Body with Aluminum alloy as a material is tested for different loads such as 10,15,20 tons

3) Model-2 (Iteration 2)

The standard truck body consists of rectangular cross section longitudinal beams at the bottom. Here the rectangular cross section beams are replaced by cross section beams. The weight of the truck will be reduced to some extent which leads to increase in payload capacity.

4) Model 2-A

Model 2-A represents the modified model having the C-Cross section longitudinal beams with structural steel as a material. The model is tested under different loads as 110,15,20 tons.

5) Model 2-B

Model 2-B represents the modified model having the C-Cross section longitudinal beams with aluminum alloy as a material. The model is tested with load conditions of 10,15,20 tons.

6) Model -3 (Iteration 3)

From the literature to reduce the stress concentration of the aluminum truck the concept of beams of uniform strength is used. The strength of the beam is dependent on the cross section of the beam. The concept of beams of uniform strength is the varying cross section which reduces the stress concentration by maintaining the constant bending moment.

B. Observation

The following table shows the weight of the different models:-

Model 1-A	1396.6 kg
Model 1-B	1252.63 kg
Model 2-A	1355.7 kg
Model 2-B	1239.2 kg
Model 3	1082.1 kg

Results for 10 tons load:

Model	Equivalent stress (MPa)	Total deformation (mm)
Model 1-A	75.4	0.5
Model 1-B	74.4	1.8
Model 2-A	48.6	0.6
Model 2-B	48.03	2.01
Model 3	37.6	1.8

Results for 15 tons load:

Model	Equivalent stress (MPa)	Total deformation (mm)
Model 1-A	112.6	1.1
Model 1-B	111.1	2.8
Model 2-A	72.3	1.01
Model 2-B	71.6	2.02
Model 3	56.01	1.8

Results for 20 tons load:

Model	Equivalent stress (MPa)	Total deformation (mm)
Model 1-A	152	1.2
Model 1-B	150	2.8
Model 2-A	97.7	1.3
Model 2-B	97.8	3.2
Model 3	76.3	2.8

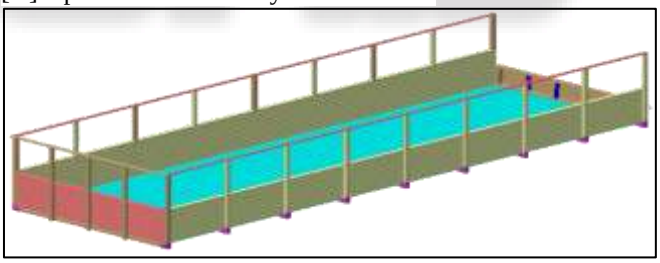
for 25 tons load:

Model	Equivalent stress (MPa)	Total deformation (mm)
Model 1-A	171.01	1.5
Model 1-B	166.3	3.7
Model 2-A	122.5	1.7
Model 2-B	120.4	4.3
Model 3	95.1	3.7

Payload Capacity of different models:

Model	Increase in payload capacity	% Increase in payload capacity
Model 1-A	-	-
Model 1-B	1.01	10.6
Model 2-A	0.3	0.3
Model 2-B	1.01	10.2
Model 3	0.8	8.6

[X] Optimized Load Body with C-beam:



C. Results and Discussion

- The Model 1-A is the standard truck having the original dimensions and structural steel as a material considering the FOS=2 having the allowable yield strength 125 MPa has failed at 20 tons. This is because of at 20 tons load the equivalent stress is more than the allowable yield strength. The deformation is 1.2mm and the weight of the truck is 1.6 tons.
- The model 1-B also tested under the same loads it is also failed at 20 tons because of the equivalent stress 150 MPa is more than the allowable yield strength 137 mPa. The deformation is more than the Model 1-A but the payload capacity is increases by 1.01 tons.
- Model-2A is tested under the loads of 10, 15, 20, 25 tons load. The model is safe even at 25 tons, but the deformation is quite higher than the Model-1A at 20 tons. Here the increased payload capacity is 0.3 tons.

- Model 2-B has increase in payload capacity of 1.1 tons which is more than the previous models. The model is having the load carrying capacity of 25 tons keeping the minimum FOS=2 because the equivalent stress 120.4 MPa is less than the allowable yield strength 137 MPa of the aluminum alloy.
- The Model-3 has the increase in payload capacity of 0.8tons. The equivalent stress is less than all models at the respective loading conditions, which is desirable one. The deformation also less than the Model-2B. Comparing all the models of truck body the model-3 has the best result in terms of equivalent stress and total deformation.

D. Cost Analysis

Cost per kilogram of Structural Steel = Rs. 25
Cost per kilogram of Aluminum 6061 = Rs. 300

1) Model 1-A
Weight of Structural Steel Body = 1396.6 kg
Material Cost= 1396.6*25 = Rs. 34915

2) Model 1-B
Weight of the Body = 1252.6 kg
Material Cost = 1252.6*300 = Rs. 375780

3) Model 2-A
Weight of the Body = 1355.7 kg
Material Cost = 1355.7*25 = Rs. 33892

4) Model 2-B
Weight of the Body = 1239.2 kg
Material Cost = 1239.2*300 = Rs. 371760

5) Model 3
Weight of the optimized Body = 1082.1 kg
Material Cost = 1082.1*300 = Rs. 324630

Cost difference for building a Baseline model and optimized model (Model-4) of body = Rs.176500. For every 100 kg reduction in weight of a truck, the fuel efficiency increases by 0.5L per every 100 km.

By considering the model-4, a total of about 314 kg of weight reduction is obtained, so the reduction of fuel consumption is 3.1*0.5 Liters per 100 km i.e., 1.55 Liters per 100 km. Overall cost reduction when the truck fitted with optimized Body runs for 100 km = 1.55*55 = 82.5 Rs.
Number of kilometer the truck has to run to compensate the increased price = (289715/82.55)*100= 46915 km.

On an average a truck travels about 300 kilometers per day , taking this into account, the number of days required to recover the extra money invested in aluminum body = 46915/300 = 156 days which is approximately equal to 5 and half months. After this period, for every 100 km run of the truck the owner gets an advantage of Rs. 201

IV. CONCLUSION

- The Aluminum alloy truck body with rectangular tube stiffener (Model 2B) of 4mm thickness for side wall has improved payload capacity by 1.01 ton, and the equivalent stress 120.4 MPa for 25 ton capacity compared to standard model.
- The Aluminum alloy truck body with uniform strength beams (Model-3) has the increasing payload capacity of 0.8 tons, and the equivalent stress 95.1 MPa at 25 tons loading condition.
- Out of these two models Model-3 has the better results in terms of equivalent stress and total deformation.
- The cost of aluminum alloy body is quite high. Cost analysis has done to explain the Breakeven point, that is after five and half month the advantage of the aluminum body can be achieved.

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