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Design Optimization of Tipper Truck Body

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Abstract:—The truck industry is a significant lifeline of the country's economic activity. There is considerable scope to improve the design of their products. In order to save unloading costs tipper trucks are becoming very popular now a day. These bodies are also known as dump bodies. These are useful in a simple way to unload the material. Every extra pound of vehicle weight increases manufacturing cost, lower fuel efficiency and reduces vehicle payload capacity. With this concept of reducing weight and stress reduction the optimized model of tipper dump body is modeled and analyzed. Three models of tipper dump bodies are considered, whose specifications are taken from local industry. The three models are modeled in CAD package Pro-E and Static Structural analysis is done in ANSYS. The three models are 14 cubic meter capacity and bearing cubic load of 18tons. By conducting the Finite Element Analysis on the three Models and according to standards, weight reduction and stress reduction is carried out. With the optimized parameters, optimized Model is developed and analyzed, stress analysis is carried out and the results are obtained.

Keywords:—Tipper dump body, Static Structural analysis, FEA, ANSYS

I. INTRODUCTION

Handling and carrying of large quantities of materials in a truck body of varied construction upon the existing state of materials, its physical properties and required operation which is to be performed is one of the tasks taken by the mechanical and automobile engineers, which are used for carrying sand, metals, iron ore and granite blocks. Truck body is the main part of the vehicle, which contains a number of channels made up of mild steel or aluminum sheet metals. Most processing equipment units are focusing on design of the truck body with various modifications necessary to minimize the stress and improve the load factor of safety. In the design of truck body, a number of factors have to be considered. The most important factor is the selection of type of the body to perform the required operation in a satisfactory manner and the other selection criteria must be considered such as the induced stress and material properties. Vehicles and related structures disclosed in fore mentioned patents mainly worked up on the design to increase the strength, reduce weight, and enhance configurability. Hence there exists a need for the industry sector to optimize the design of dump truck body structure which allows maximizing dump truck payload capacity and simultaneously improvising the strength, reducing weight, and prolonged operational life. The present work is carried out regarding the design optimization of a dump truck body structure by considering different models and the results obtained are analyzed and tabulated for comparison.

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 tipper load/dump body. There is considerable scope to improve the design of their product.

For optimization of dump body design, three models are chosen whose specifications are taken from the local industry. These are having a 14 cu.m capacity of volume.

2.1 OBJECTIVE

The main objectives of the work is

- To reduce body weight.
- To determine the critical point having highest stress.
- To modify the design of tipper body to get an optimized in terms of reducing weight and reducing stresses.

2.2 METHODOLOGY

The methodology of work is outlined below

- Geometric Modeling of three models of tipper load body assembly in Pro-E3.0.
- Static analysis for three models of dump body for same (geometric, volumes) geometric features and loading conditions. In order to solve the problem of the project, a detailed finite element analysis is proposed to determine the total deformation and Equivalent stress in static condition using the analysis software ANSYS WORKBENCH.
- After analyzing the three models, a Fourth model (optimized) is developed and analyzed.

2.3 DESIGN PARAMETER DETAILS

The design parameters are listed below

Body Specifications for Three Models

Volume/load capacity	14cu.m
Dimensions :	
Length	4480mm
Width	2350mm
Height	1300mm
Bottom Floor thickness	6mm
Side guard thickness	5mm
Head Board thickness	5mm
Channels used for Cross Bearers :	
Box channel for Model-I	75mm*75mm*4mm
C-Channel for Model-II,III	200mm*75mm*4mm
Channels used for Long members :	
C-Channel	100mm*50mm*4mm
Material :	
For dump body	Carbon epoxy
Type of material carry	Sand, iron ore, boulders, coal, Road construction Material/Earth

Table.1 Body Specifications for Three Models

2.4 SELECTION OF MATERIAL FOR DUMP BODY

The following factors considered while selecting material:

- Availability of the material
- Suitability of the material for the working condition
- Cost of the material

III. MODELING AND ANALYSIS

3.1 Modeling

The geometries under consideration are generated in the Pro-E CAD Modeling package. It is a powerful program used to create complex designs with great precision. It has properties like Feature-based nature, Bidirectional associative property and parametric nature. Parametric features are helpful in reusing three models of truck dump body to create new variant design. The three models are considered as viz., Model I, Model II and Model III. The three dump bodies are modeled.

3.2 MODEL-I

3.2.1 GEOMETRIC MODEL OF DUMP-BODY

Geometric model of dump body is depicted in figure.1 and is generated in Pro-E3.0 CAD Modeling package. The model has length of 4880mm, width of 2350mm and height of 1300mm.The material of dump body is carbon epoxy with 250MPa of yield strength and 440MPa of allowable stress. The other properties of dump body material are tabulated in table 6.1.These properties above mentioned related to all the three models. No. of parts used for this Model-I are 53. The bottom, sides and head board sheets thicknesses are 6mm,5mm and 5mm respectively for Model-I.

Density □ (kg/m³)	**Poisson Ratio**	**Yield Strength (MPa)**	**Allowable Stress (MPa)**
1600	0.3	250	440

Table.2: Properties of tipper dump body

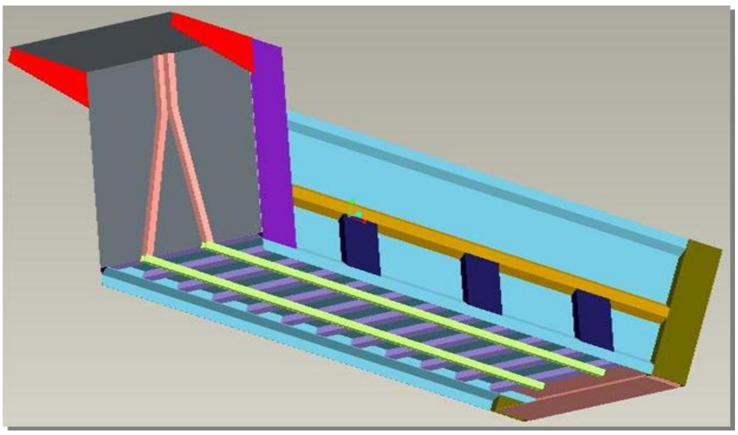

Fig.1 Pro-E Model-I of tipper dump body

Total Mass	485kg
Center of Mass :	
Xc	1838.5mm
Yc	665.45mm
Zc	338.43mm
No. of parts	53

Table.3 Geometry details of Model-I

3.2.2 LOADING

The tipper dump body model is loaded by static forces from material it carry. For this 14cu.m capacity dump body the load it carries is 18tons. The load is assumed as a uniform pressure obtained from the maximum loaded weight divided by the total contact area between load it carry and upper surface of bottom sheet.

Bottom sheet = 18tons of load (Vertical force)
Side sheets = 10% of load (Horizontal force or side trust)
Head Board = 15% of load

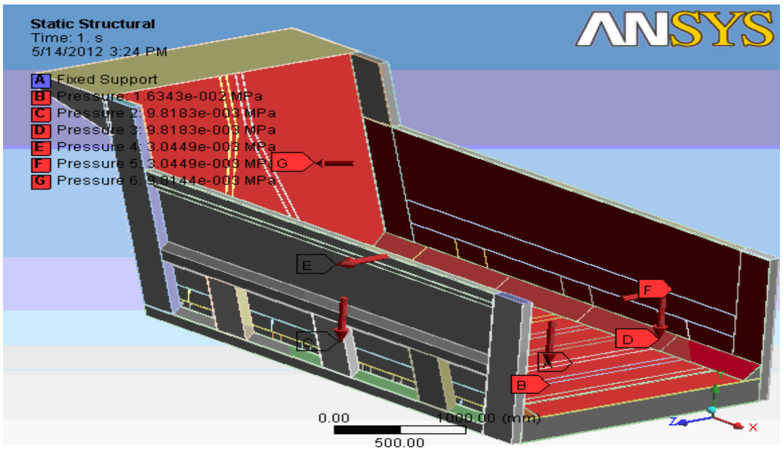

Fig.2 Static load representation of Model-I

3.2.3 SOLUTION

3.2.3.1Equivalent stress

The maximum equivalent stress occurred at front side of cross bearer where hydraulic channel is placed on it. The detailed view is as shown below.

Equivalent Stress	**Max** (MPa)	**Min** (MPa)
	185.98	0.02

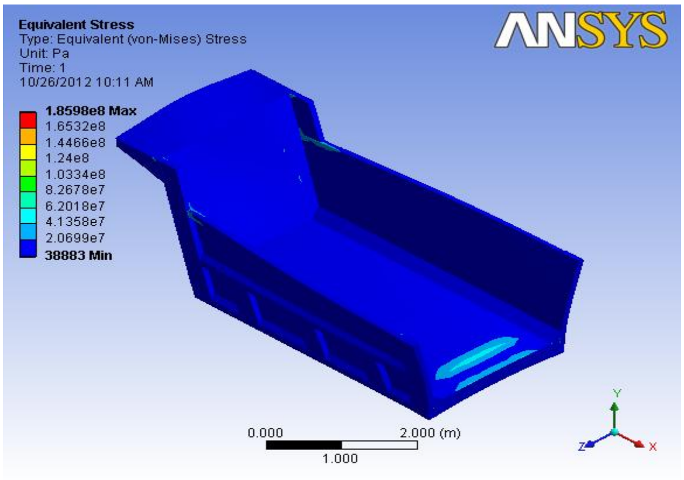

Fig.3 Von-Misses stress distribution and critical point location of Model-I

3.2.3.2 Total deformation

The maximum deformation occurred at side sheet top surface.

Total deformation	Max(mm)	Min(mm)
	23.892	0

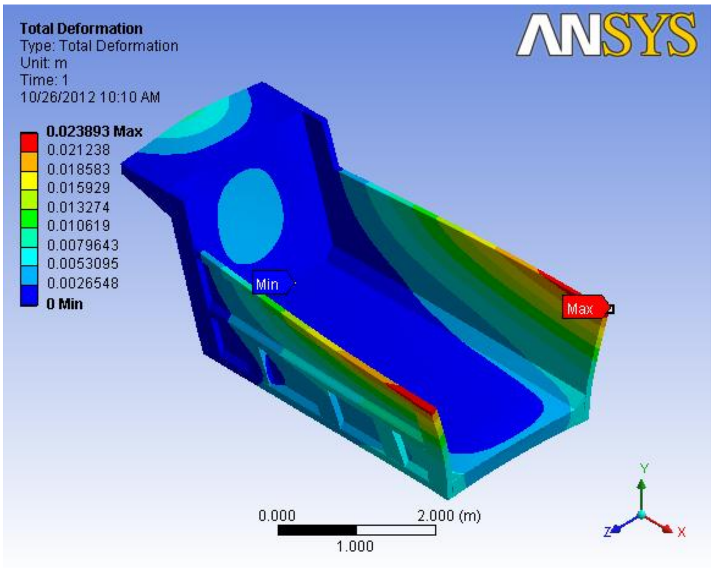

Fig.4 Total deformation and maximum displacement location of Model-I

3.3 MODEL-II

3.3.1 GEOMETRIC MODEL OF DUMP BODY

The model-II of dump body is modeled in Pro-E. The no. of parts used for this model-II is 105. The bottom, sides and head board sheets thicknesses are 6mm, 5mm and 5mm respectively for Model-II.

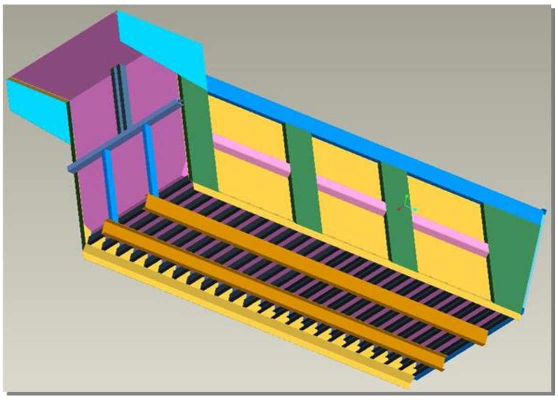

Fig.5 Pro-E Model-II of dump body

Total Mass	504.9kg
Center of Mass :	
Xc	501.27mm
Yc	718.68mm
Zc	-2653.8mm
No. of parts	105

Table.4 Geometry details of Model-II

3.3.2 LOADING

The tipper dump body model is loaded by static forces from material it carry. For this 14cu.m capacity dump body the load it carries is 18tons. The load is assumed as a uniform pressure obtained from the maximum loaded weight divided by the total contact area between load it carry and upper surface of bottom sheet.

Bottom sheet = 18tons of load (Vertical force)
Side sheets = 10% of load (Horizontal force or side trust)
Head Board = 15% of load

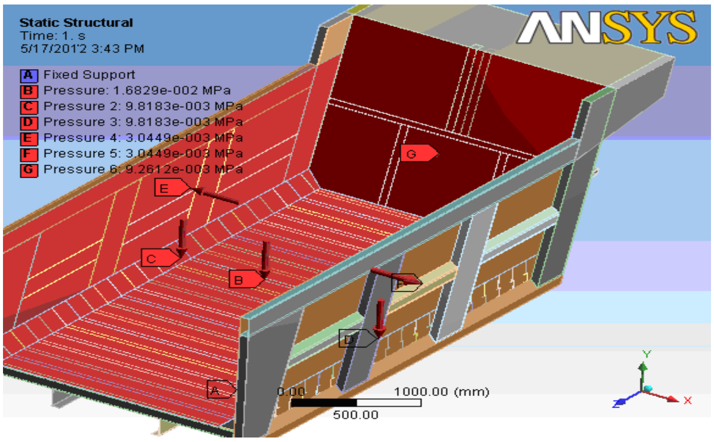

Fig.6 Static load representation of Model-II

3.3.3 SOLUTION

3.3.3.1 Equivalent Stress

The maximum equivalent stress occurred at bottom inner side of cross bearer. The detailed view is as shown below.

Equivalent Stress	**Max** (MPa)	**Min**(MPa)
	240.43	0

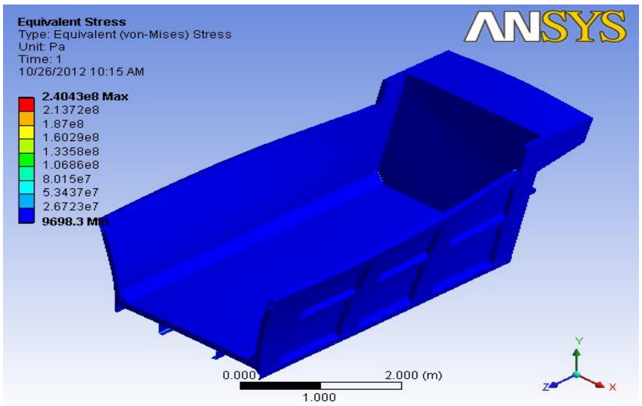

Figure.7 Von-Misses stress distribution and critical point location of Model-II

3.3.3.2Total deformation

The maximum deformation occurred at side sheet of top channel surface.

Total deformation	**Max**(mm)	**Min**(mm)
	15.099	0

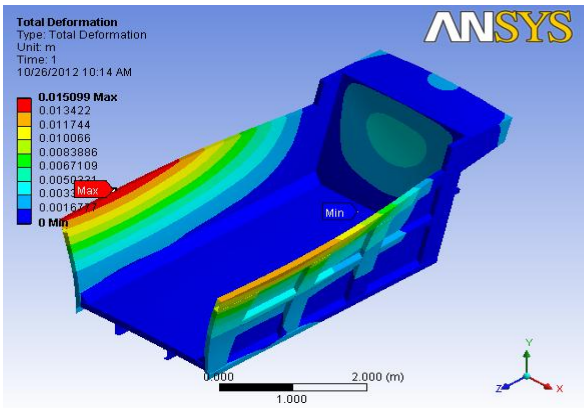

Fig.8 Total deformation and maximum displacement location of Model-II

3.4 MODEL-III

3.4.1 GEOMETRIC MODEL OF TIPPER DUMP BODY

The model-III of dump body is modeled in Pro-E. The no. of parts used for this model-III is 169. The bottom, sides and head board sheets thicknesses are 6mm, 5mm and 5mm respectively for Model-III.

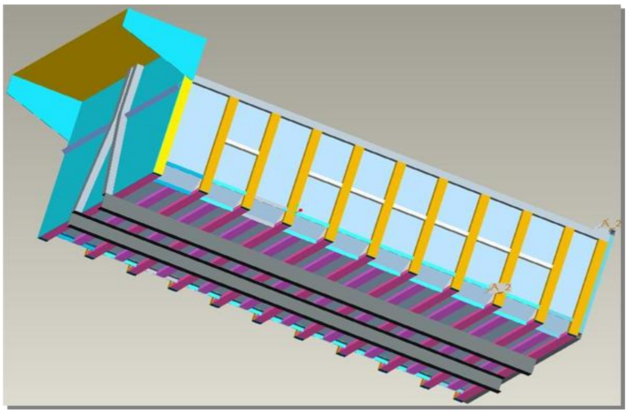

Fig.9 Pro-E Model-III of Dump Body

Total Mass	422.96kg
Center of Mass :	
Xc	-79.614mm
Yc	623.21mm
Zc	-2050.9mm
No. of parts	169

Table.5 Geometry details of Model-III

3.4.2 LOADING

The tipper dump body model is loaded by static forces from material it carry. For this 14cu.m capacity dump body the load it carries is 18tons. The load is assumed as a uniform pressure obtained from the maximum loaded weight divided by the total contact area between load it carry and upper surface of bottom sheet.

Bottom sheet = 18tons of load (Vertical force)
Side sheets = 10% of load (Horizontal force or side trust)
Head Board = 15% of load

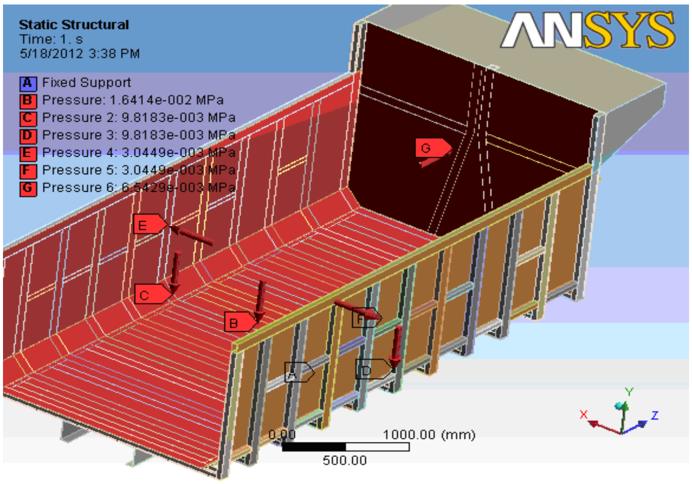

Fig.10 Static load representation of Model-III

3.4.3 SOLUTION

3.4.3.1 Equivalent Stress

The maximum equivalent stress occurred at bottom inner side of angular section. The detailed view is as shown below.

Equivalent Stress	**Max** (MPa)	**Min**(MPa)
	214.2	0

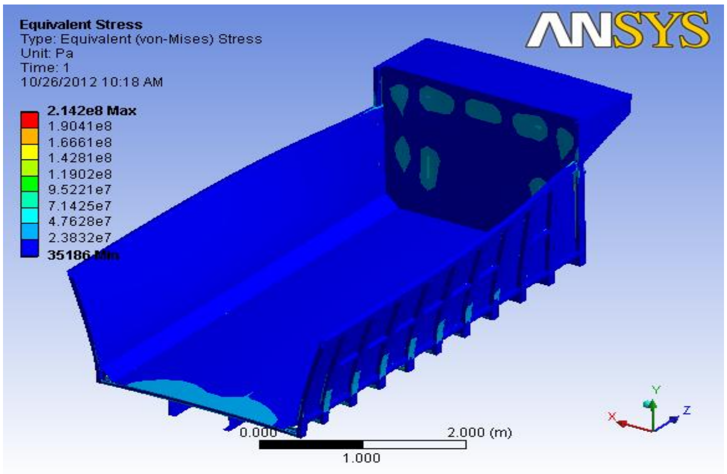

Fig.11 Von-Misses stress distribution and critical point location of Model-III

3.4.3.2Total deformation

The maximum deformation occurred at side sheet of top channel surface.

Total deformation	**Max**(mm)	**Min**(mm)
	8.741	0

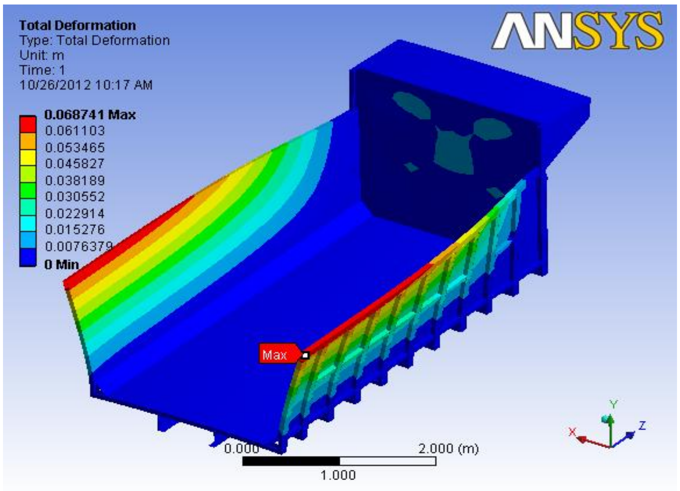

Fig.12 Total deformation and maximum displacement location of Model-III

3.5 MODEL-IV (OPTIMISED MODEL)
3.5.1 GEOMETRIC MODEL OF DUMP BODY

The model-IV of dump body is modeled in Pro-E. The no. of parts used for this model-IV is 51. The bottom, sides and head board sheets thicknesses are 5mm, 4mm and 4mm respectively for Model-IV.

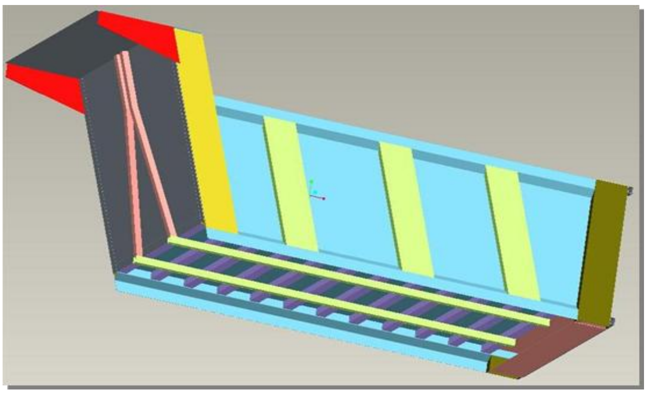

Fig.13 Pro-E Model-IV of Dump Body

Total Mass	413.04kg
Center of Mass :	
Xc	1818.9mm
Yc	661.33mm
Zc	327.27mm
No. of parts	51

Table.6 Geometry details of Model-IV

3.5.2 LOADING

The tipper dump body model is loaded by static forces from material it carry. For this 14cu.m capacity dump body the load it carries is 18tons. The load is assumed as a uniform pressure obtained from the maximum loaded weight divided by the total contact area between load it carry and upper surface of bottom sheet.

Bottom sheet = 18tons of load (Vertical force)
Side sheets = 10% of load (Horizontal force or side trust)
Head Board = 15% of load

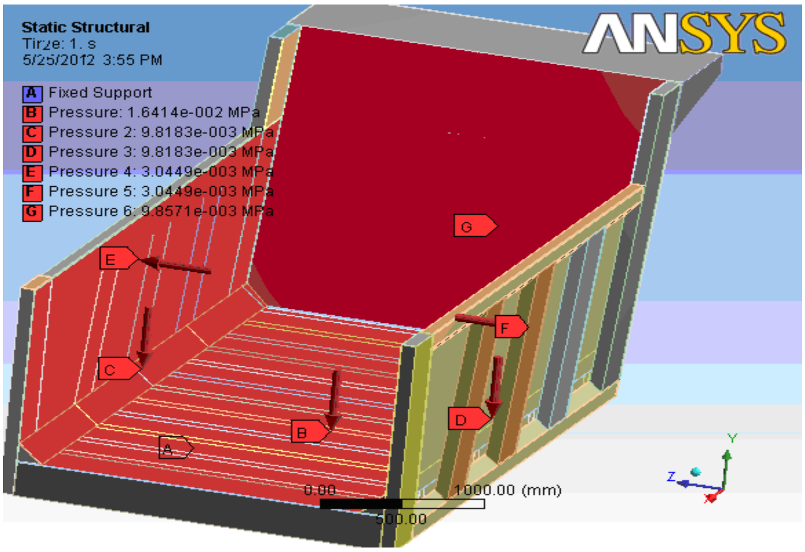

Fig.14 Static load representation of Model-IV

3.5.2.1 Equivalent Stress:

Equivalent Stress	**Max** (MPa)	**Min**(MPa)
	166.01	0

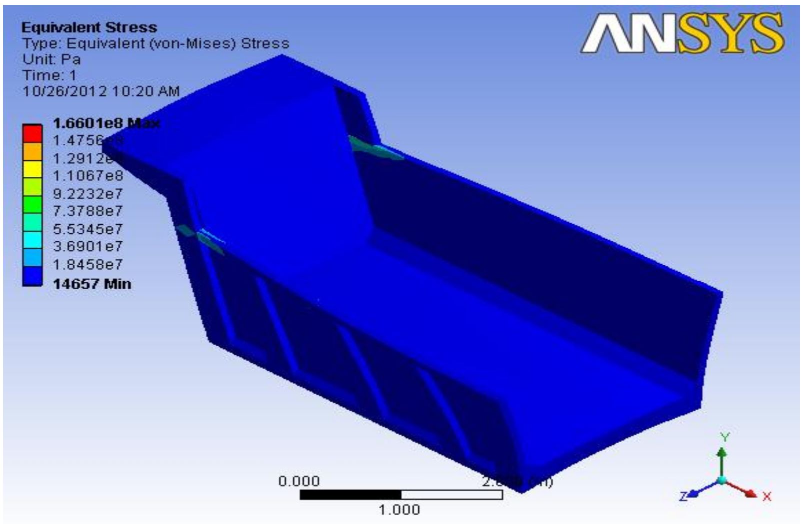

Fig.15 Von-Misses stress distribution and critical point location of Optimized Model

3.5.2.2 Total Deformation:

The maximum deformation occurred at the top surface of the side sheet and is shown in the fig.16. The values are:

Total deformation	**Max**(mm)	**Min**(mm)
	16.215	0

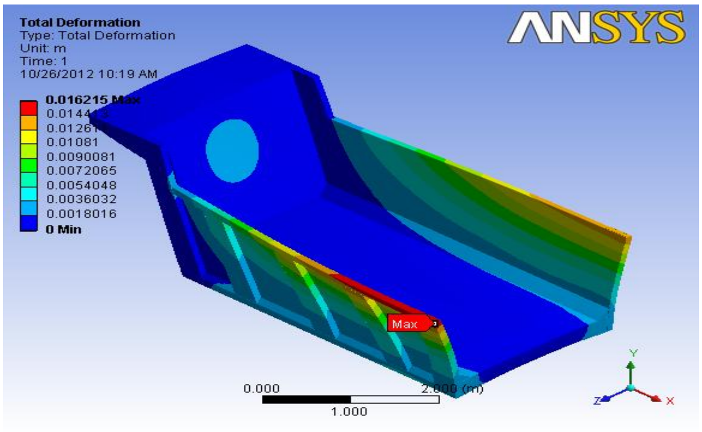

Fig.16 Total deformation and maximum displacement location of Optimized Model

The three models are analyzed in ANSYS WORKBENCH. The obtained results are compared. An optimized model is developed. All the models are compared for stress and deformation. The results obtained for the optimized model are shown in the fig.15 and fig.16. The maximum equivalent stress occurred at bottom side of first rib section. Therefore the maximum stress obtained for the Optimized Model-IV is below the allowable stress of 125 MPa for Mild steel with factor of safety of 2, and the design is safe in static condition. If more than 18 tons load is applied on this model the maximum stress will not exceed the allowable stress and the model can withstand the load.

IV. RESULTS AND DISCUSSION

The weights of the models are shown in the Table.7 and the weight of the optimized model is 413.04kgs. It is giving a saving in weight of 72kgs comparing with Model-I, 91kgs comparing with Model-2 and 9kgs comparing with Model-III.

S.No.	MASS (kg)	TOTAL DEFORMATION Maximum (mm)	EQUIVALENT STRESS (N/mm²)	No. of parts for fabrication
MODEL-I	485	23.892	185.98	53
MODEL-II	504.9	15.099	240.43	105
MODEL-III	422.96	8.741	214.2	169
MODEL-IV (Optimized)	**413.04**	**16.215**	**166.01**	**51**

Table.7 Comparison of Mass, total deformation and Equivalent stress values of four models

V. CONCLUSIONS

By conducting the FEM Analysis on the three Models of existing tipper dump bodies and by using AIS-093 code amended by ARAI weight reduction and stress reduction is done.

The following are the conclusions made from the investigation:

- ➢ By comparing the three Model parameters Optimized Model is generated.
- ➢ For the Optimized Model stress analysis is carried out and the equivalent stress is 166.01MPa and total deformation is 16.215mm is obtained.
- ➢ Weight reduction of optimized model comparing with the other three models is 16.3%, 19.6% and 4% respectively.
- ➢ By weight reduction, the material cost and fabrication cost is reduced for the vehicle.
- ➢ Numbers of parts in the fabrication for the optimized model are reduced compared to the three models.

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