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Finite Element based Weight Reduction of Truck Cargo Bed using Lightweight materials

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ABSTRACT

The transport industry plays a vital role in the global economy. Trucks are an essential part of the modern logistics and transportation system. Reducing the weight of the system helps lower the operating cost of the vehicle, which ultimately leads to a reduction in overall transportation costs. This paper aimed to reduce the weight of the TATA 3518 truck cargo bed while preserving its strength and durability. A comprehensive evaluation of the existing cargo bed structure was conducted, and a 3D model was created using Siemens NX. The structural performance under different loading conditions was examined in ANSYS, and the outcomes were utilized to determine critical regions and support design modifications. Conventional heavy wooden and steel sections were substituted with lightweight materials such as Aluminium Alloy 6061-T6 along with optimized sheet sections. By performing parametric optimization of major components, including horizontal supports, vertical members, and the cargo bed floor, considerable weight reduction and material savings were accomplished. The optimized design enhanced fuel efficiency and payload capacity without affecting structural performance or safety.

Keywords: Truck cargo bed, weight reduction, Aluminium Alloy 6061-T6, Siemens NX, ANSYS, finite element analysis, structural optimization, material saving.

1.INTRODUCTION

Trucks play a vital role in modern logistics and transportation systems. The cargo bed is a key structural component of a truck, designed to carry heavy loads and withstand significant stresses during operation. The weight of the cargo bed has a direct impact on payload capacity, fuel efficiency, and overall vehicle performance [1]. Therefore, selecting appropriate materials and adopting an efficient design for the cargo bed is essential to enhance performance while maintaining structural strength. Traditionally, cargo beds were constructed using wood due to its strength, durability, and cost-effectiveness. However, with increasing demand for fuel-efficient vehicles and stricter environmental regulations, there is a need to adopt advanced materials and improved structural designs. Modern materials such as aluminum alloys, honeycomb structures, and high-strength steels offer substantial weight reduction while maintaining required strength and stiffness. The chassis forms the primary structural framework of a vehicle and functions as its backbone. Major components such as the engine, gearbox, and other assemblies are mounted on it [2]. The vehicle body must support both its own weight and the payload. Structurally, a vehicle consists of two main parts: the chassis and the bodywork. The chassis ensures strength, rigidity, and stability under various operating conditions [3]. The truck industry has experienced significant growth due to economic development and rising demand from sectors such as logistics, agriculture, and manufacturing. However, in many regions, truck development and production rely heavily on foreign technologies. This dependency can sometimes result in vehicles that do not fully satisfy local market requirements in terms of cost, driving performance, and transportation efficiency. The rear section of the truck used for carrying goods is known as the cargo bed. The chassis supports the weight of both the cargo bed and the loaded material [4]. Although materials such as wood or aluminum are commonly used in cargo bed construction, they contribute to the overall vehicle weight. Reducing the cargo bed weight can decrease manufacturing costs and improve vehicle efficiency.

This paper is aimed to reduce the weight of the TATA 3518 truck's cargo bed system by optimizing its primary load-bearing components, including the vertical and horizontal supports. A detailed 3D model of the cargo bed was developed using Siemens NX, and its structural response under various loading conditions was evaluated using ANSYS software. Based on the analysis results, parametric optimization was carried out by modifying the dimensions and geometry of the components to achieve an optimal balance between high strength and reduced weight. A key aspect of the project was the replacement of conventional heavy wooden sections with lighter and more advanced materials such as aluminium alloys. Various materials, including honeycomb-structured panels, aluminium alloys, and steel sheets, were assessed and analyzed to identify the most efficient and feasible solution for maximum weight reduction while maintaining structural integrity and performance.

2.DESIGN OF EXISTING SYSTEM

The Existing system is made of wood. Cargo bed is the area of truck where dead load is loaded. The specifications of the cargo bed of TATA LPT 3518 COWL BS6 is as follows. This truck was customized by the Customer for further requirements.

Table No 1: Existing Cargo bed specifications

1	Vertical support - Qty = 15	Length = 6 foot L channel 75 × 75 × 6 Material - MS
2	Horizontal support - Qty = 15	Length = 8 foot C channel 150 × 75 × 10 mm Material - MS
3	Horizontal cargo area	Length = 30 ft Width = 8 ft Thickness = 1.5 inches Material= Wood
4	Vertical cargo area (Support)	Length = 30 ft Width = 5 ft Thickness = 1.5 inches Material= Wood

2.1. Design of Horizontal support of Existing truck

In the existing design, the horizontal supports or columns are generally fabricated from mild steel (MS). Mild steel is commonly selected due to its low cost, ease of fabrication, and sufficient strength for load-bearing applications. However, its relatively high density contributes significantly to the overall structural weight, which negatively influences fuel efficiency and vehicle handling characteristics.

The total load acting on the vehicle is 30 tons. For analysis purposes, the same total load is assumed to act on the horizontal supports. If 15 horizontal supports are considered, the load applied on each horizontal column is 2000 Kg. Furthermore, it is assumed that this load is uniformly distributed over each horizontal member, which is modeled as a simply supported beam for structural analysis.

Consider ULD acting on system

Maximum Moment, 14577 N-m

Maximum bending stress is $\sigma b = 11.89$ MPa.

Thus, maximum Deformation is

$(Y_{max}) = 1.92$ mm.

The weight of the system = $L \times w \times t \times \rho \times 15 = 803.8$ Kg.

2.2. Design of horizontal Cargo bed:

Cargo bed is the body of vehicle was dead load is loaded. The maximum load on the cargo bed is 30000 Kg. The existing cargo bed is made of wood. This wood is having good strength and it is wear resistance. The material used for the cargo bed is wood. Thus now we calculate the stress and deformation in the cargo bed. We will calculate this by using three moment method.

The 30 ton load is uniformly distributed on it the cargo bed.

Now,

Bending stress = $(M_{max} / I) \times Y_{max} = 0.33$ MPa

Maximum deformation

$(Y_{max}) = 5 \times W \times L^3/384 \times E \times I$

$(Y_{max}) = 0.0059$ mm.

Weight= Area × width × density

= $L \times w \times t \times \rho$

= 637 Kg.

When moisture increased into the wood, the weight of it increases by 30 % and hence the weight of Cargo bed becomes 828 Kg.

2.3. Calculation of vertical cargo bed and vertical columns

The vertical cargo bed functions to support the load and prevent it from falling. These supports, known as vertical cargo supports, are made of wood in the existing system. As the vertical cargo bed primarily provides support rather than carrying the full load, only 50% of the total load is considered, resulting in an effective load of 15000 kg. The wood's mechanical properties are identical to those used in the horizontal cargo bed.

Thus now we calculate the stress and deformation in the cargo bed.

The Cargo bed is supported by 15 supports, on which 15 ton load is uniformly distributed on it.

Bending stress = (Mmax /I) × Ymax = 0.169 MPa
Maximum deformation
(Ymax)= $5 \times W \times L^3/384 \times E \times I$ = 0.0029 mm.
Weight= Area × width × density = 398 Kg.
When moisture increased into the wood, the weight of it increases by 30 % and hence the weight of Cargo bed becomes 517 Kg.
Thus, if we go through the results then we can conclude that the stress acting on the system is very less. So further weight reduction can be done.

3.DESIGN FOR OPTIMISED SYSTEM

Our review of the existing system shows that the stress it experiences is within the safe limit, and overall, the stress is quite low. Furthermore, there are few stress bearing components. This means we have an opportunity for weight reduction. To achieve this, we will change the geometric parameters, materials, and cross sections of the elements we use.

3.1. Design of Horizontal support

We have modified the horizontal support by changing the geometric parameters of the existing channel section. They also studied an alternative section, the I-section. In the design the standard values for both the I and C sections that were easily available in the market are considered.

C section Horizontal supports

The calculations of the horizontal support ladder for C section was carried out for various sizes. After studying the deformation and stress results, the best solution of c channel we have selected is
H = 125 mm, W = 60 mm T=5 mm
The best part of this material it doesn't absorb the moisture and increase the weight.
1. Stress results:
After applying the force of 2916 Kg on each horizontal support. We have achieved the maximum stress as 44.24 MPa and shown in red colour. The Minimum stress was 0.002 and shown in blue colour.

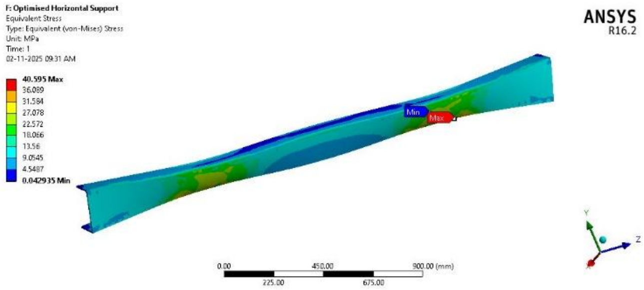

Figure No 1: Optimized system horizontal support stress results

2. Deformation results:
After applying the force of 2916 Kg on each horizontal support. We have achieved the maximum deformation of 0.28847 mm and shown in red colour. The Minimum deformation of 0mm and shown in blue colour.

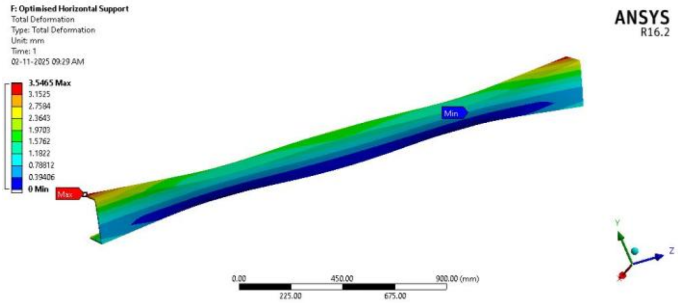

Figure No 2: Optimized system horizontal support deformation results

3.2. Design of Optimized cargo bed

While designing the cargo bed for optimization, we will study the following materials.
1. 6061-T6 Aluminum Alloy 2. ASTM A572 Grade 50
We have performed the calculations and selected Aluminium alloy as the best solution and dimensions as follows
L = 9144 mm W = 2438 mm T = 3 mm
We have also performed the Analysis results.

1. Stress results:

After applying the force on horizontal cargo bed. We have achieved the maximum stress as 34.92 MPa and shown in red colour. The Minimum stress was 0 and shown in blue colour.

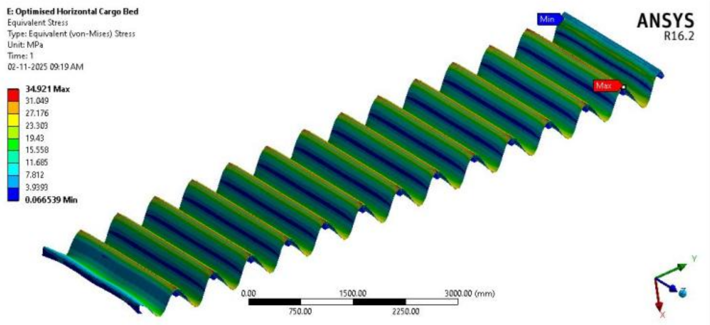

Figure No 3: Optimized system bed stress results

2. Deformation results:

After applying the force on horizontal cargo bed. We have achieved the maximum deformation of 2.25 mm and shown in red colour. The Minimum deformation of 0 mm and shown in blue colour.

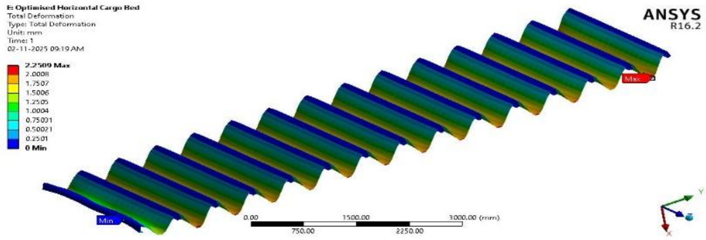

Figure No 4: Optimized system horizontal bed deformation results

3.3. Calculation of vertical cargo bed and vertical columns

We have selected the same specifications as the best solution which are used for Horizontal cargo bed. This will be easy while manufacturing to keep the same types of materials throughout the Cargo bed.

Thus the best solution for Vertical cargo bed is

L = 9144 mm W = 1524 mm T = 3 mm

1. Stress results:

After applying the force on vertical column and cargo bed. We have achieved the maximum stress as 32.53 MPa and shown in red colour. The Minimum stress was 0 and shown in blue colour.

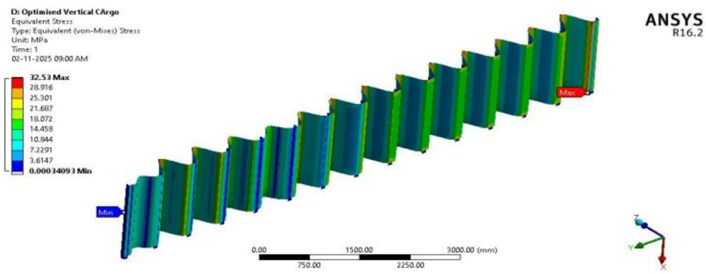

Figure No. 5: Optimized system vertical column & bed stress results

2. Deformation results:

After applying the force on vertical column and cargo bed. We have achieved the maximum deformation of 1.8714 mm and shown in red colour. The Minimum deformation of 0 mm and shown in blue colour.

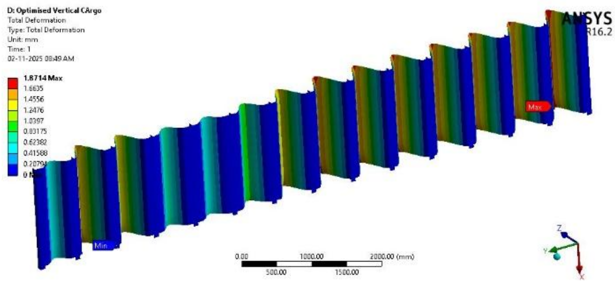

Figure No. 6: Optimized system vertical column & bed deformation results

4.RESULTS AND DISCUSSION

The primary objective of this project was to redesign and analyze a truck cargo bed using alternative materials to achieve maximum weight reduction while maintaining adequate strength, stiffness, and durability. The existing cargo bed constructed from mild steel was replaced with lightweight materials such as Aluminium Alloy 6061-T6 and Aluminium Honeycomb Structured Panels. The outcomes obtained from the Finite Element Analysis (FEA) performed in ANSYS are presented and discussed in this chapter. For the horizontal support structure, a total of 48 design iterations were carried out by modifying the geometry and dimensions of the original model. Based on comparative analysis of the results, the most efficient design was selected and is described in this section. For both the horizontal and vertical components of the cargo bed, Aluminium Alloy 6061-T6 was identified as the most suitable material due to its favorable strength-to-weight ratio, reduced density, and market availability. No modifications were implemented for the vertical supports, as the existing configuration satisfied the required strength criteria. The final optimized results are presented below.

4.1. Weight comparision of Existing and Optimized system

The comparision of the Existing and optimised systems are done and they are as follow:

Table No. 2: Weight comparision of Existing and Optimised system

Sr No	Components	Weight of Existing system (Kg)	Weight of optimized system (Kg)	Weight reduced (Kg)
1.	Horizontal Column	803.8	337.3	466.5
2.	Horizontal Cargo bed	828	180.6	647.4
3.	Vertical Cargo bed	517	113	404
Total Weight		2149	631	1518

Thus, the graphical representation of above table is as follows:

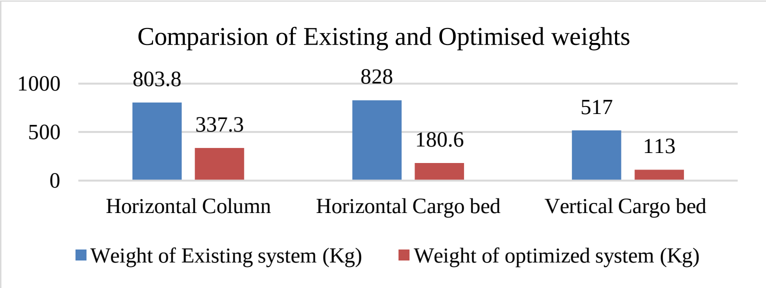

Figure No 7: Graphical representation of weight comparison

4.2. Comparison of material saving in Existing and Optimized system

The material saving in the optimized system is achieved upto 54.2 % compare to the existing system. This is a good result. The part wise detail results are tabulated below.

Table No 3: Comparison of material used by Optimized system and Existing system

Sr No	Component	Weight of Existing system (Kg)	Weight of Optimized system (Kg)	Material used by optimized system compare to existing system (%)	Material Saving %
1	Horizontal Column	803.8	337.3	41.96	58.04
2	Horizontal Cargo Area	828	180.6	21.81	78.19
3	Vertical Cargo area and Column	517	113	21.86	78.14
Total Weight		2149	631	29.36	70.64

5.CONCLUSION

The primary objective of this project to reduce the overall weight of the truck cargo bed has been successfully accomplished. A comprehensive evaluation of the existing cargo bed structure was performed, with emphasis on load-bearing components, material properties, and geometric configuration. Through systematic redesign and the implementation of lightweight materials, substantial weight reduction was achieved without compromising structural strength, stiffness, or durability. The analysis and design optimization produced significant improvements across different sections of the cargo bed:

1. **Horizontal Supports:** By optimizing the cross-sectional geometry and replacing the existing material with Aluminium Alloy 6061-T6, the weight of the horizontal supports was reduced by 466.5 kg, resulting in a 58.04% material saving. This modification contributed to overall weight reduction and also reduced manufacturing costs.
2. **Horizontal Cargo Bed:** The horizontal cargo bed section achieved a weight reduction of 647.4 kg, corresponding to a 78.19% material saving. The redesigned lightweight structure provides an improved strength-to-weight ratio, enhancing both efficiency and economic feasibility.
3. **Vertical Cargo Area and Vertical Columns:** These components experienced a weight reduction of 404 kg, leading to a 78.14% material saving. The optimized design maintains the required load-bearing capacity while utilizing significantly less material. Overall, the complete cargo bed system achieved a total weight reduction of 1518 kg, with an average material saving of 70.64% compared to the existing steel and wood-based structure. This represents a substantial advancement in terms of structural efficiency, cost-effectiveness, and sustainability. Furthermore, replacing wooden sections in the vertical cargo structure reduced environmental impact by minimizing deforestation. The adoption of aluminium enhances recyclability, corrosion resistance, and long-term durability, thereby improving the overall service life of the cargo bed system.

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