DESIGN AND ANALYSIS OF 30 TON TRAILER CHASSIS FRAME TO REDUCE POLLUTION BY DECREASING THE EMISSION THROUGH WEIGHT REDUCTION USING ADVANCED LIGHTWEIGHT MATERIAL

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ABSTRACT

The automotive chassis is a skeletal frame on which several mechanical parts are bolted. The main purpose of trailer chassis is to withstand all the loads acting on it. Usually, chassis frame of trailers has heavy weight that causes high fuel consumption and emission which pollutes the environment. In present work, an advanced lightweight material has been selected and the trailer structure has been designed and analyzed for weight reduction and significant reduction of 73.61% has been observed in trailer structure weight which leads to reduction in fuel consumption with decrease in CO₂ emission that prevents the environment from pollution.

Keywords: vehicle development, design, weight reduction, trailer chassis frame, metal matrix composite.

Cite this Article: Vyom Bhushan and Dr. Sanjay D. Yadav, Design and Analysis of 30 Ton Trailer Chassis Frame to Reduce Pollution by Decreasing the Emission through Weight Reduction Using Advanced Lightweight Material, International Journal of Mechanical Engineering and Technology, 9(6), 2018, pp. 705–722
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=9&IType=6

1. INTRODUCTION

Each and every vehicle has a chassis frame on which several components such as engine, axles, brakes, wheels and tyres are bolted. The chassis has been considered as the most important component of an automobile. Automotive frames provide strength and flexibility to
the automobile. All motor vehicles had a frame but most of the cars have shifted to uni-body construction while buses and trucks are still using frames.

2. LITERATURE REVIEW

Joel Galos et al. [1] identified double-deck trailers for weight over axle as they are useful in light weighting the trailer and found that double-deck trailers cannot be used on roads due to its poor height clearance in tunnels and under bridges. They designed a lightweight heavy duty goods vehicle trailer and suggested most successful composite solutions for making a balance between cost, performance and weight reduction.

Divyanshu Sharma and Y D Vora [2] studied the chassis design, identified different types of chassis, designed and analyzed a heavy duty trailer chassis using finite element analysis software and reduced the weight of the trailer for proposed sections with same stiffness and rigidity and found negligible deformation at the rear side of the chassis.

Divyanshu Sharma and Y D Vora [3] designed and analyzed a heavy duty trailer for vibration by performing modal analysis using FEA software and concluded that the chassis vibrations are capable of causing deformation and suggested that these chassis vibrations can be sustained by optimization of chassis design through natural frequency.

Gajanan S. Datar et al. [4] analyzed a 40 tonne heavy duty trailer for static as well as dynamic conditions for observing the behaviour of the loads on frame. It has been concluded that the structure was safe with nearly least deflection.

Ahmad O. Moaaz and Nouby M. Ghazaly [5] explained the fatigue analysis of a heavy duty truck frame by exploring different analytical and numerical analysis techniques available for the fatigue analysis by considering dynamic loads acting on the major components of a heavy duty truck frame.

Hemant B. Patil et al. [6] analyzed a ladder type low loader truck chassis structure having C-beams for structural analysis for 7.5 tonne application using finite element analysis software. The side member thickness, cross member thickness and position of cross member from rear end were modified for reducing the stress magnitude at critical point of the chassis frame. It was found that the reduction in stress magnitude can be done by shifting the position of cross member if thickness cannot be changed.

Anand Gosavi et al. [7] designed a six-axle trailer frame and analyzed it structurally for reduction in weight of the frame. It was noticed that the weight of chassis frame was reduced by 37% (approx.). They concluded that the weight of chassis frame can be optimized for six-axle vehicle by using finite element analysis.

O Kurdi et al. [8] analyzed the heavy duty truck chassis for stress analysis using FEA for the positioning of critical point having highest stress. They observed that the critical point was located at the chassis opening which was connected with a bolt. It has been concluded that the reduction in the magnitude of stress at this critical point was needed.

Akash Singh Patel and Jaideep Chitransh [9] designed and analyzed existing heavy vehicle chassis of TATA 2518 TC by considering different cross sections. They concluded that the box-section chassis was more suitable for heavy trucks from other cross sections of the chassis.

Mehdi Mahmoodi-k et al. [10] analyzed the optimized trailer chassis for stress and dynamic analysis by determining different natural frequencies and different mode shapes through modal analysis using FEA. They concluded that the reduction in weight of the chassis by 21% through chassis weight optimization leads to a significant improvement in the vehicle ride, handling and stability.
Henry P. Panganiban et al. [11] introduced a lightweight flatbed trailer frame design using a multi-stage design optimization procedure and determined the optimal beam layout for the frame structure by optimizing the thicknesses, widths and heights of the channel beams through size and shape optimization.

B. Minaker and R. Rieveley [12] generated mathematical models for vehicle stability analysis including the effects of vehicle and trailer suspensions, suspended trailer loads, and varying hitch configurations. They provided detailed insight into the effects of design configurations, towed vehicle loading and operational speeds on the dynamic response of coupled vehicle systems by generated multi-body models and stability analysis methods.

Jack Lewis [13] designed and developed chassis and suspension systems and predicted the strong potential to develop a lightweight and robust chassis system capable of matching a caravan’s ride quality closer to the tow vehicle's quality having simple manufacturing methods with enhanced weather-proofing characteristics scalable to a wide range of caravan sizes.

2.1. Literature Gap
From the literature review, it has been observed that 30 ton lightweight trailer structure has not been designed for reducing the pollution through weight reduction. Therefore, it is essential to design and analyze a 30 ton lightweight trailer structure for reduction in environmental pollution by decreasing the emission through weight reduction as per the standards.

3. PROBLEM STATEMENT
All chassis frames of commercial trailers have heavy weight due to which the consumption of fuel increases which causes more emission and pollutes the environment.

4. OBJECTIVES
The objectives of the present research are:

- To select advanced lightweight material for chassis frame.
- To analyze the chassis frame structurally with selected material for deflection and reduction in weight so as to decrease the fuel consumption as well as emissions to prevent the environment from vehicular pollution.

5. THEORETICAL DESIGN AND STRUCTURAL ANALYSIS OF STEEL CHASSIS FRAME

5.1. Properties of Structural Steel AISI 1015
- Modulus of Elasticity = 205 GPa
- Poisson's Ratio = 0.30
- Density = 7833.409 kg/m³
- Coefficient of Thermal Expansion = $12 \times 10^{-6}/\text{oK}$
- Critical Damping Ratio = 0.03
- Ultimate Tensile Strength = 385 MPa
- Yield Strength = 325 MPa
5.2. Design of Chassis Frame

The specifications of chassis frame [17] have been shown in the Table 1 below:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Length</td>
<td>6750 mm</td>
</tr>
<tr>
<td>2</td>
<td>Total Width</td>
<td>2750 mm</td>
</tr>
<tr>
<td>3</td>
<td>Wheelbase</td>
<td>3400 mm</td>
</tr>
<tr>
<td>4</td>
<td>Front Overhang</td>
<td>1675 mm</td>
</tr>
<tr>
<td>5</td>
<td>Rear Overhang</td>
<td>1675 mm</td>
</tr>
<tr>
<td>6</td>
<td>Ground Clearance</td>
<td>300 mm</td>
</tr>
<tr>
<td>7</td>
<td>Gross Vehicle Weight (G.V.W.)</td>
<td>33 Ton</td>
</tr>
<tr>
<td>8</td>
<td>Kerb Weight</td>
<td>3 Ton</td>
</tr>
<tr>
<td>9</td>
<td>Payload</td>
<td>30 Ton</td>
</tr>
</tbody>
</table>

5.2.1. Basic Calculations for Trailer Structure

Capacity of trailer (G.V.W.) = 33 Ton (Kerb Weight + Payload)

Factor of Safety = 2

Total capacity of trailer structure with Factor of Safety = 33×2

= 66 Ton = 647.239 kN

Each chassis frame has two beams.

So, Load acting on one beam = \( \frac{647.239}{2} \) = 323.6195 kN per beam.

5.2.2. Load Conditions for Chassis Frame

Load acting on entire span = 323.6195 kN

Length of beam = 6.75 m

Uniformly Distributed Load = \( \frac{323.6195}{6.75} \) = 47.94362 kN/m

~ 48 kN/m

According to loading conditions of the beam, the beam has support of two axles C and D. Total load acting on the beam has been shown below in Figure 1.

![Figure 1 Total Load acting on the Beam](image)

5.2.3. Fixed End Moments

Fixed end moments always develop as reaction moments in any member of a statically indeterminate beam under particular conditions of load having both ends fixed. The beam shown below in Figure 2 has indeterminate structure.
5.2.4. Calculations for Reactions and Shear Forces

Shear force acts in the beam perpendicular to the longitudinal axis and it has been usually generated due to the applied loads and support reactions. In designing, the ability of beam to resist shear force plays a vital role than the ability to resist an axial force. An axial force acts parallel to the longitudinal axis. The shear force diagram has been shown in Figure 4.

\[
\begin{align*}
R_{CL} &= 48 \times 1.675 = 80.4 \text{ kN} \\
R_{CR} &= \frac{48 \times 3.4}{2} = \frac{21.095}{3.4} = 81.6 \text{ kN} \\
R_{DL} &= (48 \times 3.4) - 81.6 = 81.6 \text{ kN} \\
R_{DR} &= 48 \times 1.675 = 80.4 \text{ kN} \\
RC &= R_{CL} + R_{CR} \\
RC &= 80.4 + 81.6 = 162 \text{ kN}
\end{align*}
\]
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\[ RD = RDL + RDR \]
\[ RD = 81.6 + 80.4 = 162 \text{ kN} \]

**Figure 4** Shear Force Diagram

### 5.2.5. Calculations for Bending Moments
The bending moment diagram has been shown in Figure 5.

\[ MA = 0 \text{ kN m} \]
\[ MC = - MCA = - 67.335 \text{ kN m} \]
\[ MP = \frac{40 \times 3.4 \times 3.4}{8} = 69.36 \text{ kN m} \]
\[ MD = MDB = - 67.335 \text{ kN m} \]
\[ MB = 0 \text{ kN m} \]

Maximum Bending Moment occurs at P.
\[ M_{\text{Max}} = MP = 69.36 \text{ kN m} \]

**Figure 5** Bending Moment Diagram

### 5.2.6. Calculations for Maximum Deflection
The reactions acting on the beam have been shown in Figure 6.

A section X-X has been considered in span DB at a distance \( x \) from A.
Taking moment of all forces about section X-X,
\[ M_{XX} = -\frac{48x^2}{2} + RC[x-1.675] + RD[x-5.075] \]
According to Macaulay’s theorem [18],
\[ M_{XX} = EI \frac{d^2y}{dx^2} = -\frac{48x^2}{2} + 162[x-1.675] + 162[x-5.075] \]
Integrating w. r. t. x, we get
\[ EI \frac{dy}{dx} = -\frac{48x^3}{6} + 162\frac{(x-1.675)^2}{2} + 162\frac{(x-5.075)^2}{2} + C1 \]
Again, integrating w. r. t. x, we get
\[ Ely = -\frac{48x^4}{24} + 162\frac{(x-1.675)^3}{6} + 162\frac{(x-5.075)^3}{6} + C1x + C2 \]
Now, applying boundary conditions,
At C, \( x = 1.675 \) m, \( y = 0 \)
\[ 0 = -\frac{48(1.675)^4}{24} + 1.675C_1 + C_2 \]
At D, \( x = 5.075 \) m, \( y = 0 \)
\[ 0 = -\frac{48(5.075)^4}{24} + 162\frac{(5.075-1.675)^3}{6} + 5.075C_1 + C_2 \]
Solving equations (2) and (3), we get
\( C1 = 73.457 \) and \( C2 = -107.298 \)
Putting values of \( C1 \) and \( C2 \) in equation (1), we get
\[ y = \frac{1}{EI} \left[-\frac{48x^4}{24} + 162\frac{(x-1.675)^3}{6} + 162\frac{(x-5.075)^3}{6} + 73.457x - 107.298\right] \]
Equation (4) is the general equation of deflection.
The deflections at the supports (C and D) are zero.
Deflection at A, i.e. at \( x = 0 \)
\[ yA = -\frac{107.298 \times 10^9}{EI} \]
Therefore, \( yA = -\frac{107.298 \times 10^9}{EI} \)
Deflection at B, i.e. at \( x = 6.75 \) m
\[ yB = -\frac{107.298 \times 10^9}{EI} \]
Therefore, \( yB = -\frac{107.298 \times 10^9}{EI} \)
So, maximum deflection has been found at point A and B.
\[ \therefore \ y_{Max} = yA = yB = -\frac{107.298 \times 10^9}{EI} \]
According to IS 800:2007 [15],
Maximum allowable deflection = \( \frac{\text{Span}}{300} = \frac{6750}{300} = 22.5 \) mm
\[ \therefore \text{Maximum allowable deflection in beam} = 22.5 \] mm

**5.2.7. Selection of 'C'-Channels for Structural Steel AISI 1015**
The proposed trailer structure has two longitudinal members and seven cross members. Generally, 'C'-channels are used in most of the trailer structures available in the market. The
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'C'-channels have been selected on the basis of bending stress induced in the structure, deflection produced in the structure for Structural Steel AISI 1015.

For ISMC 'C'-Channels [14]:
The ISMC 400 channel has been selected for longitudinal members whereas ISMC 350 channel has been selected for cross members. The channels have been shown in Figure 7.

![Figure 7 ISMC 'C'-Channels [14]](image)

For 'C'-Channel ISMC 400 [14]:
\[ h = 400 \text{ mm}, \quad b = 100 \text{ mm} \]
Thickness of flange, \( t_f = 15.3 \text{ mm} \)
Thickness of web, \( t_w = 8.6 \text{ mm} \)
\[ I_{XX} = 15082.8 \text{ cm}^4 = 150828000 \text{ mm}^4 \]
Section Modulus, \( Z_{XX} = 754.1 \text{ cm}^3 = 754100 \text{ mm}^3 \)
\[ M_{Max} = 69.36 \text{ kN m} = 69360000 \text{ N mm} \]
\[ E = 205 \text{ GPa} = 205 \text{ kN/mm}^2 \]
Yield Strength = 325 MPa = 325 N/mm2
Permissible Stress = \[ \frac{\text{Yield Strength}}{\text{Factor of Safety}} \] = \[ \frac{325}{2} \] = 162.5 N/mm2
According to general bending equation,
\[ \frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R} \]
Stress produced in the beam,
\[ \sigma = \frac{M_{Max}}{Z_{XX}} = \frac{69360000}{754100} = 91.977 \text{ N/mm}^2 \]
Since, 91.977 N/mm2 is less than the permissible stress 162.5 N/mm2.
Hence, Design is safe.
Maximum deflection produced in Steel beam,
\[ y_{Max} = -\frac{107.298 \times 10^9}{205 \times 150828000} = -3.470 \text{ mm Downward} \]
Since, 3.470 mm is less than the maximum allowable deflection 22.5 mm.
Hence, Design is safe.
For 'C'-Channel ISMC 350 [14]:
\[ h = 350 \text{ mm}, \quad b = 100 \text{ mm} \]
Thickness of flange, \( t_f = 13.5 \) mm  
Thickness of web, \( t_w = 8.1 \) mm  
\( I_{XX} = 10008.0 \) cm\(^4\) = 100080000 mm\(^4\); \( Z_{XX} = 571.9 \) cm\(^3\) = 571900 mm\(^3\)  
\( M_{Max} = 69.36 \) kN m = 69360000 N mm  
Stress produced in the beam,  
\[ \sigma = \frac{M_{Max}}{Z_{XX}} = \frac{69360000}{571900} = 121.280 \text{ N/mm}^2 \]  
Since, 121.280 N/mm\(^2\) is less than the permissible stress 162.5 N/mm\(^2\).  
Hence, Design is safe.  
Maximum deflection produced in Steel beam,  
\[ y_{Max} = -\frac{107.298 \times 10^9}{E I} = -\frac{107.298 \times 10^9}{205 \times 100080000} = 5.230 \text{ mm Downward} \]  
Since, 5.230 mm is less than the maximum allowable deflection 22.5 mm.  
Hence, Design is safe.  
For ISLC 'C'-Channels [14]:  
The ISLC 400 channel has been selected for longitudinal members whereas ISLC 350 channel has been selected for cross members. The channels have been shown in Figure 8.  
\[ \begin{align*}  &h = 400 \text{ mm}, \ b = 100 \text{ mm} \\
&\text{Thickness of flange, } t_f = 14.0 \text{ mm} \\
&\text{Thickness of web, } t_w = 8.0 \text{ mm} \\
&I_{XX} = 13989.5 \text{ cm}^4 = 139895000 \text{ mm}^4; \ Z_{XX} = 699.5 \text{ cm}^3 = 699500 \text{ mm}^3 \\
&M_{Max} = 69.36 \text{ kN m} = 69360000 \text{ N mm} \\
&\text{Yield Strength} = 325 \text{ MPa} = 325 \text{ N/mm}^2 \\
&\text{Stress produced in the beam, } \\
&\sigma = \frac{M_{Max}}{Z_{XX}} = \frac{69360000}{699500} = 99.157 \text{ N/mm}^2 \\
&\text{Since, 99.157 N/mm}^2 \text{ is less than the permissible stress 162.5 N/mm}^2. \\
&\text{Hence, Design is safe.} \\
&\text{Maximum deflection produced in Steel beam,} \\
\end{align*} \]
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\[ y_{\text{Max}} = - \frac{107.298 \times 10^9}{E \cdot I} = - \frac{107.298 \times 10^9}{205 \times 139895000} = 3.741 \text{ mm Downward} \]

Since, 3.741 mm is less than the maximum allowable deflection 22.5 mm. Hence, Design is safe.

For 'C'-Channel ISLC 350 [14]:

- \( h = 350 \text{ mm, } b = 100 \text{ mm} \)
- Thickness of flange, \( t_f = 12.5 \text{ mm} \)
- Thickness of web, \( t_w = 7.4 \text{ mm} \)
- \( I_{XX} = 9312.6 \text{ cm}^4 = 93126000 \text{ mm}^4; Z_{XX} = 532.1 \text{ cm}^3 = 532100 \text{ mm}^3 \)
- \( M_{\text{Max}} = 69.36 \text{ kN m} = 69360000 \text{ N mm} \)

Stress produced in the beam,

\[ \sigma = \frac{M_{\text{Max}}}{Z_{XX}} = \frac{69360000}{532100} = 130.351 \text{ N/mm}^2 \]

Since, 130.351 N/mm\(^2\) is less than the permissible stress 162.5 N/mm\(^2\).
Hence, Design is safe.

Maximum deflection produced in Steel beam,

\[ y_{\text{Max}} = - \frac{107.298 \times 10^9}{E \cdot I} = - \frac{107.298 \times 10^9}{205 \times 93126000} = 5.620 \text{ mm Downward} \]

Since, 5.620 mm is less than the maximum allowable deflection 22.5 mm. Hence, Design is safe.

6. STRUCTURAL ANALYSIS OF STEEL CHASSIS FRAME USING SOFTWARE

6.1. Modeling of Chassis Frame in STAAD.Pro V8i

The chassis frame has been modeled in STAAD.Pro V8i as shown in Figure 9.

![Figure 9 Model of Chassis Frame](image)

6.2. Load Conditions for Chassis Frame

Total load acting on the beam is 48 kN/m which has been uniformly distributed up to the entire span as shown in Figure 10 below.

![Figure 10 Load acting on the Chassis Frame](image)
6.3. Shear Force Diagram
The shear force diagram has been shown in Figure 11 which shows the different shear forces acting on the beam.

![Shear Force Diagram](image)

*Figure 11 Shear Force Diagram*

6.4. Bending Moment Diagram
The bending moment diagram has been shown in Figure 12 which shows maximum bending moment with all other bending moments acting on the beam.

![Bending Moment Diagram](image)

*Figure 12 Bending Moment Diagram*

6.5. Reactions Acting on the Beam
The reactions’ acting at the supports of the beam has been shown in Figure 13.
\[
R_C = 162 \text{ kN} \\
R_D = 162 \text{ kN}
\]

![Reactions Acting on the Beam](image)

*Figure 13 Reactions acting on the Beam*

6.6. Bending Stresses in the Beam with ISMC 400
The bending stresses induced in the beam has been shown in Figure 14 which shows maximum bending stress with all other bending stresses acting on the beam.

Max. Bending Stress = 89.287 N/mm²

![Bending Stresses in the Beam with ISMC 400](image)

*Figure 14 Bending Stresses in the Beam with ISMC 400*
6.7. **Bending Stresses in the Beam with ISLC 400**
The bending stresses induced in the beam has been shown in Figure 15 which shows maximum bending stress with all other bending stresses acting on the beam.

Max. Bending Stress = 96.265 N/mm²

![Figure 15 Bending Stresses in the Beam with ISLC 400](image)

6.8. **Deflection in Beam with ISMC 400**
The deflection occurred in the beam has been shown in Figure 16 which shows maximum deflection with all other deflections occurring on the beam.

Max. Deflection with Steel = 3.718 mm Downward at Points A and B.

![Figure 16 Deflection in the Beam with ISMC 400](image)

6.9. **Deflection in Beam with ISLC 400**
The deflection occurred in the beam has been shown in Figure 17 which shows maximum deflection with all other deflections occurring on the beam.

Max. Deflection with Steel = 4.008 mm Downward at Points A and B.

![Figure 17 Deflections in the Beam with ISLC 400](image)

7. **SELECTION OF ADVANCED LIGHTWEIGHT MATERIAL FOR CHASSIS FRAME**
The metal matrix composite of Aluminum-Beryllium has high modulus of elasticity and low-density. It offers exceptional specific stiffness and processing features. AlBeMet AM162 has 62 wt% commercially pure beryllium and 38 wt% commercially pure aluminum. It has high thermal conductivity and low density.
7.1. Properties of AlBeMet AM 162 Extruded Bar

- Modulus of Elasticity = 202 GPa
- Poisson's Ratio = 0.17
- Density = 2071 kg/m³
- Coeff. of Thermal Expansion = 13.91×10⁻⁶/°K
- Critical Damping Ratio = 1.5×10⁻³
- Ultimate Tensile Strength = 400 MPa
- Yield Strength = 276 MPa

8. THEORETICAL STRUCTURAL ANALYSIS OF ADVANCED LIGHTWEIGHT MATERIAL CHASSIS FRAME

8.1. Selection of 'C'-Channels for Advanced Lightweight Material

The 'C'-channels has been selected on the basis of bending stress induced in the structure, deflection produced in the structure for AlBeMet AM162 Extruded Bar.

8.1.1. For ISMC 'C'-Channels [14]

The ISMC 400 channel has been selected for longitudinal members whereas ISMC 350 channel has been selected for cross members.

For 'C'-Channel ISMC 400 [14]:

\[ h = 400 \text{ mm}, b = 100 \text{ mm}; \text{tf} = 15.3 \text{ mm}, \text{tw} = 8.6 \text{ mm} \]

\[ \text{IXX} = 15082.8 \text{ cm}^4 = 150828000 \text{ mm}^4; \text{ZXX} = 754.1 \text{ cm}^3 = 754100 \text{ mm}^3 \]

\[ \text{MMax} = 69.36 \text{ kN m} = 69360000 \text{ N mm} \]

\[ E = 202 \text{ GPa} = 202 \text{ kN/mm}^2, \text{Yield Strength} = 276 \text{ MPa} = 276 \text{ N/mm}^2 \]

\[ \text{Permissible Stress} = \frac{\text{Yield Strength}}{\text{Factor of Safety}} = \frac{276}{2} = 138 \text{ N/mm}^2 \]

Stress produced in the beam,

\[ \sigma = \frac{\text{MMax}}{\text{ZXX}} = \frac{69360000}{754100} = 91.977 \text{ N/mm}^2 \]

Since, 91.977 N/mm² is less than the permissible stress 138 N/mm².

Hence, Design is safe.

Maximum deflection produced in Advanced Lightweight Material beam,

\[ y_{\text{Max}} = -\frac{107.298 \times 10^9}{202 \times 150828000} = 3.521 \text{ mm Downward} \]

Since, 3.521 mm is less than the maximum allowable deflection 22.5 mm.

Hence, Design is safe.

For 'C'-Channel ISMC 350 [14]:

\[ h = 350 \text{ mm}, b = 100 \text{ mm}; \text{tf} = 13.5 \text{ mm}, \text{tw} = 8.1 \text{ mm} \]

\[ \text{IXX} = 10008.0 \text{ cm}^4 = 100080000 \text{ mm}^4; \text{ZXX} = 571.9 \text{ cm}^3 = 571900 \text{ mm}^3 \]

\[ \text{MMax} = 69.36 \text{ kN m} = 69360000 \text{ N mm} \]

Stress produced in the beam,

\[ \sigma = \frac{\text{MMax}}{\text{ZXX}} = \frac{69360000}{571900} = 121.280 \text{ N/mm}^2 \]

Since, 121.280 N/mm² is less than the permissible stress 138 N/mm².
Hence, Design is safe.

Maximum deflection produced in Advanced Lightweight Material beam,

$$y_{\text{Max}} = -\frac{107,298 \times 10^9}{E I} = -\frac{107,298 \times 10^9}{202 \times 100080000} = 5.307 \text{ mm Downward}$$

Since, 5.307 mm is less than the maximum allowable deflection 22.5 mm.

Hence, Design is safe.

### 8.1.2. For ISLC 'C'-Channels [14]

The ISLC 400 channel has been selected for longitudinal members whereas ISLC 350 channel has been selected for cross members.

For 'C'-Channel ISLC 400 [14]:

- $h = 400 \text{ mm}$, $b = 100 \text{ mm}$; $t_f = 14.0 \text{ mm}$, $t_w = 8.0 \text{ mm}$
- $I_{XX} = 13989.5 \text{ cm}^4 = 13989500 \text{ mm}^4$; $Z_{XX} = 699.5 \text{ cm}^3 = 699500 \text{ mm}^3$
- $M_{\text{Max}} = 69.36 \text{ kN m} = 69360000 \text{ N mm}$
- Yield Strength $= 276 \text{ MPa} = 276 \text{ N/mm}^2$

Stress produced in the beam,

$$\sigma = \frac{M_{\text{Max}}}{Z_{XX}} = \frac{69360000}{699500} = 99.157 \text{ N/mm}^2$$

Since, 99.157 N/mm$^2$ is less than the permissible stress 138 N/mm$^2$.

Hence, Design is safe.

Maximum deflection produced in Advanced Lightweight Material beam,

$$y_{\text{Max}} = -\frac{107,298 \times 10^9}{E I} = -\frac{107,298 \times 10^9}{202 \times 13989500} = 3.80 \text{ mm Downward}$$

Since, 3.80 mm is less than the maximum allowable deflection 22.5 mm.

Hence, Design is safe.

For 'C'-Channel ISLC 350 [14]:

- $h = 350 \text{ mm}$, $b = 100 \text{ mm}$
- $t_f = 12.5 \text{ mm}$; $t_w = 7.4 \text{ mm}$
- $I_{XX} = 9312.6 \text{ cm}^4 = 93126000 \text{ mm}^4$; $Z_{XX} = 532.1 \text{ cm}^3 = 532100 \text{ mm}^3$
- $M_{\text{Max}} = 69.36 \text{ kN m} = 69360000 \text{ N mm}$

Stress produced in the beam,

$$\sigma = \frac{M_{\text{Max}}}{Z_{XX}} = \frac{69360000}{532100} = 130.351 \text{ N/mm}^2$$

Since, 130.351 N/mm$^2$ is less than the permissible stress 138 N/mm$^2$.

Hence, Design is safe.

Maximum deflection produced in Advanced Lightweight Material beam,

$$y_{\text{Max}} = -\frac{107,298 \times 10^9}{E I} = -\frac{107,298 \times 10^9}{202 \times 93126000} = 5.703 \text{ mm Downward}$$

Since, 5.703 mm is less than the maximum allowable deflection 22.5 mm.

Hence, Design is safe.
9. STRUCTURAL ANALYSIS OF ADVANCED LIGHTWEIGHT MATERIAL CHASSIS FRAME USING SOFTWARE

9.1. Deflection in Beam with ISMC 400
The deflection occurred in the beam has been shown in Figure 18 which shows maximum deflection with all other deflections occurring on the beam.

Max. Deflection with Advanced Lightweight Material, AlBeMet AM 162 Extruded Bar = 3.725 mm Downward at Points A and B.

![Figure 18 Deflection in the Beam with ISMC 400](image)

9.2. Deflection in Beam with ISLC 400
The deflection occurred in the beam has been shown in Figure 19 which shows maximum deflection with all other deflections occurring on the beam.

Max. Deflection with Advanced Lightweight Material, AlBeMet AM 162 Extruded Bar = 4.015 mm Downward at Points A and B.

![Figure 19 Deflection in the Beam with ISLC 400](image)

10. CALCULATIONS FOR WEIGHT OF TRAILER STRUCTURE
Standard Dimensions of 'C'-Channels have been shown below in Table 2.

- Length of Longitudinal Member (L1) = 6750 mm = 6.75 m
- Length of Cross Member (L2) = 2750 mm = 2.75 m
- Number of Longitudinal Members (N1) = 2
- Number of Cross Members (N2) = 7
- Density of AlBeMet AM162 EB (d) = 2071 kg/m³

<table>
<thead>
<tr>
<th>Designation</th>
<th>Weight per metre (kg) Structural Steel</th>
<th>Sectional Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISMC 400</td>
<td>w1</td>
<td>a1</td>
</tr>
<tr>
<td>ISMC 350</td>
<td>w2</td>
<td>a2</td>
</tr>
<tr>
<td>ISLC 400</td>
<td>w3</td>
<td>a3</td>
</tr>
<tr>
<td>ISLC 350</td>
<td>w4</td>
<td>a4</td>
</tr>
</tbody>
</table>

Weight of Trailer Structure for ISMC 400 and ISMC 350 Structural Steel

= N1 L1 w1 + N2 L2 w2
= (2 × 6.75 × 49.4) + (7 × 2.75 × 42.1)
Design and Analysis of 30 Ton Trailer Chassis Frame to Reduce Pollution by Decreasing the Emission through Weight Reduction Using Advanced Lightweight Material

\[ = 1477.325 \text{ kg} \]

Weight of Trailer Structure for ISLC 400 and ISLC 350 Structural Steel
\[ = N_1 L_1 w_3 + N_2 L_2 w_4 \]
\[ = (2 \times 6.75 \times 45.7) + (7 \times 2.75 \times 38.8) \]
\[ = 1363.85 \text{ kg} \]

Weight of Trailer Structure for ISMC 400 and ISMC 350 AlBeMet AM162 EB
\[ = (N_1 L_1 a_1 + N_2 L_2 a_2) d \]
\[ = (2 \times 6.75 \times 62.93 \times 10^{-4} + 7 \times 2.75 \times 53.66 \times 10^{-4}) \times 2071 \]
\[ = 389.868 \text{ kg} \]

Weight of Trailer Structure for ISLC 400 and ISLC 350 AlBeMet AM162 EB
\[ = (N_1 L_1 a_3 + N_2 L_2 a_4) d \]
\[ = (2 \times 6.75 \times 58.25 \times 10^{-4} + 7 \times 2.75 \times 49.47 \times 10^{-4}) \times 2071 \]
\[ = 360.079 \text{ kg} \]

11. REDUCTION IN WEIGHT

The reduction in weight of the selected 'C'-channels has been shown below in Table 3.

<table>
<thead>
<tr>
<th>Designation</th>
<th>ISMC 400 and ISMC 350</th>
<th>ISLC 400 and ISLC 350</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Steel AISI 1015</td>
<td>1477.325 kg</td>
<td>1363.85 kg</td>
</tr>
<tr>
<td>AlBeMet AM162 EB</td>
<td>389.868 kg</td>
<td>360.79 kg</td>
</tr>
<tr>
<td>Reduction in Weight</td>
<td>73.61%</td>
<td>73.55%</td>
</tr>
</tbody>
</table>

It has been observed that the weight of trailer structure has been reduced by 73.61% and 73.55% using advanced lightweight material, i.e. AlBeMet AM162 Extruded Bar with ISMC 400 as longitudinal members; ISMC 350 as cross members and ISLC 400 as longitudinal members; ISLC 350 as cross members, instead of Structural Steel AISI 1015 with same channel designations respectively.

12. SELECTION OF APPROPRIATE CHANNELS FOR TRAILER STRUCTURE

The appropriate channels have been selected on the basis of different materials and their properties as shown in Table 4.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Designation of 'C'-Channel</th>
<th>Structural Steel AISI 1015</th>
<th>AlBeMet AM162 EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Deflection Downward (mm)</td>
<td>ISMC 400</td>
<td>3.47</td>
<td>3.521</td>
</tr>
<tr>
<td></td>
<td>ISMC 350</td>
<td>5.23</td>
<td>5.307</td>
</tr>
<tr>
<td></td>
<td>ISLC 400</td>
<td>3.74</td>
<td>3.80</td>
</tr>
<tr>
<td></td>
<td>ISLC 350</td>
<td>5.62</td>
<td>5.703</td>
</tr>
<tr>
<td>Allowable Deflection (mm)</td>
<td></td>
<td>22.50</td>
<td>22.50</td>
</tr>
<tr>
<td>Permissible Stress (N/mm²)</td>
<td>ISMC 400</td>
<td>162.5</td>
<td>138.0</td>
</tr>
<tr>
<td></td>
<td>ISMC 350</td>
<td>121.98</td>
<td>121.98</td>
</tr>
<tr>
<td>Bending Stress (N/mm²)</td>
<td>ISLC 400</td>
<td>99.16</td>
<td>99.16</td>
</tr>
</tbody>
</table>
It has been observed that ISMC 'C'-Channels have better strength with similar deflection and sufficient reduction in weight in comparison to ISLC 'C'-Channels.

13. RESULTS

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight (kg)</th>
<th>Payload (kg)</th>
<th>Gross Vehicle Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Steel AISI 1015</td>
<td>1477.325</td>
<td>30000</td>
<td>31477.325</td>
</tr>
<tr>
<td>AlBeMet AM162 Extruded Bar</td>
<td>389.868</td>
<td>30000</td>
<td>30389.868</td>
</tr>
</tbody>
</table>

Reduction in Weight: 1087.457 kg; 73.61%
Reduction in Fuel Consumption: Up to 40% [16]
Reduction in CO2 Emission: Up to 100 g/km [16]

From Table 5, it has been observed that the G.V.W. of trailer chassis frame has been reduced by 1087.457 kg, i.e. 73.61% using advanced lightweight material with ISMC 400 and ISMC 350 channels instead of Structural Steel AISI 1015 with same channel designations, with the reduction in fuel consumption and CO2 emission up to 40% [16] and up to 100 g/km [16] respectively.

14. CONCLUSION

From the results, an appreciable weight reduction of 73.61% has been observed in the trailer structure using a metal matrix composite of Aluminum-Beryllium as advanced lightweight material, i.e. AlBeMet AM162 Extruded Bar for 'C'-Channels ISMC 400 as longitudinal members and ISMC 350 as cross members having sufficient strength to withstand all the loads with a maximum deflection of 5.307 mm and leads to the decrease in fuel consumption up to 40% and reduction in CO2 emission up to 100 g/km as per NHTSA report which prevents the environment from vehicular pollution.

REFERENCES

Design and Analysis of 30 Ton Trailer Chassis Frame to Reduce Pollution by Decreasing the Emission through Weight Reduction Using Advanced Lightweight Material


