Abstract - Automotive chassis is an important part of an automobile. The chassis serves as a frame work for supporting the body and different parts of the automobile. Also, it should be rigid enough to withstand the shock, twist, vibration and other stresses. Along with strength, an important consideration in chassis design is to have adequate bending stiffness for better handling characteristics. So, maximum stress, maximum equilateral stress and deflection are important criteria for the design of the chassis. This report is the work performed towards the optimization of the automotive chassis with constraints of maximum shear stress, equivalent stress and deflection of chassis. Structural systems like the chassis can be easily analyzed using the finite element techniques. A sensitivity analysis is carried out for weight reduction. So a proper finite element model of the chassis is to be developed. The chassis is modeled in PRO-E. FEA is done on the modeled chassis using the ANSYS Workbench.

Index Terms—optimization, sensitivity, deformation, stress

I. INTRODUCTION

The major challenge in today’s ground vehicle industry is to overcome the increasing demands for higher performance, lower weight, and longer life of components, all this at a reasonable cost and in a short period of time. The chassis of trucks is the backbone of vehicles and integrates the main truck component systems such as the axles, suspension, power train, cab and trailer. Since the truck chassis is a major component in the vehicle system, it is often identified for refinement. There are many industrial sectors using this truck for their transportations such as the logistics, agricultures, factories and other industries.

II. CALCULATION FOR CHASSIS FRAME

Widths of the members are assumed to be 200 mm.

Total loading area,
\[ A = 8.76 \times 10^6 \text{ mm}^2 \]
As per standard, permissible axle weight is 18 Ton per axle. So, Gross laden weight for trailer having six axles is
\[ F = 108 \text{ tone} = 1059480 \text{ N} \]
Load intensity,
\[ p = \frac{\text{Gross laden Weight}}{\text{Surface Area}} = \frac{F}{A} = 0.12094 \text{ N/mm}. \]
UDL acting on beam,

\[ W = \frac{p \times A}{L} = \frac{p \times (B \times L)}{L} = 24.19 \text{N/mm} \]

Design for Main/Side Cross Member
\[ P_1 = \text{Equivalent point load due to UDL on main long member} = 9071.25 \text{ N} \]
\[ l_1 = 900 \text{mm} \]
Maximum bending moment which occurs at end of the span,
\[ M_c = (P_1 \times l_1) + \left( \frac{w \times l_1^2}{2} \right) = 17962000 \text{ Nmm}. \]
Allowable bending stress,
\[ \sigma_{bt} = \frac{\sigma_y}{2.5} = 100 \text{ N/mm}^2. \]
Modulus of section required is,
\[ Z_{required} = \frac{M_c}{\sigma_{bt}} = 179620 \text{ mm}^3 \]
\[ A_w = \frac{d \times t_w}{(D - 2 \times t_w) \times t_w} = 900 \text{ mm}^2 \]
Average shear stress,
\[ \tau_s = \frac{V}{2 \times A_w} = 17.13 \text{ N/mm}^2. \]
Allowable shear stress,
\[ \tau_{av} = 0.577 \tau_s \times \sigma_{bt} = 57.7 \text{ N/mm}^2 \]
As \( \tau_s < \tau_{av} \), Design is safe in shear.

Check for deflection,
Allowable deflection is,
\[ \delta_{allowable} = \frac{l_1}{325} = 2.769 \text{ mm} \]
Maximum deflection occurs at free end
\[ \delta = \left( \frac{w \times l^3}{8 \times E \times l} \right) + \left( \frac{P_1 \times l^3}{3 \times E \times l} \right) = 122.22 \text{ mm} \]

- Design for Side Long Member
\[ P_1 = 36285 \text{ N} \]
\[ l_1 = 750 \text{ mm} \]
Design for bending stress,
Maximum bending moment which occurs at end of the span,
\[ M_e = 34017187.5 \text{ Nmm} \]
Modulus of section required is,
Check for shear stress

effective area of web,

\[ A_w = 1600 \text{ mm}^2 \]

Average shear stress,

\[ \tau_s = 17 \text{ N/mm}^2 \]

Allowable shear stress,

\[ \tau_{av} = 57.7 \text{ N/mm}^2 \]

As \( \tau_s < \tau_{av} \), Design is safe in shear.

Check for deflection

Allowable deflection is,

\[ \delta_{allowable} = 2.3076 \text{ mm} \]

Maximum deflection occurs at free end,

\[ \delta = 21.79 \text{ mm} \]

- Design for End Cross Member

\[ P_1 = 43542 \text{ N} \]

\[ P_2 = 72570 \text{ N} \]

\[ l_1 = 1500 \text{ mm} \]

\[ l_2 = 600 \text{ mm} \]

Design for bending stress,

Maximum bending moments are found near to extreme supports a and e,

\[ M_a = M_e = 136068750 \text{ Nmm} \]

Modulus of section required is,

\[ Z_{required} = 5124865 \text{ mm}^3 \]

Check for shear stress

effective area of web,

\[ A_w = 12600 \text{ mm}^2 \]

Average shear stress,

\[ \tau_s = 4.6 \text{ N/mm}^2 \]

Allowable shear stress,

\[ \tau_{av} = 57.7 \text{ N/mm}^2 \]

As \( \tau_s < \tau_{av} \), Design is safe in shear.

Check for deflection

Allowable deflection is,

\[ \delta_{allowable} = 27.69 \text{ mm} \]

Maximum deflection occurs at free end,

\[ \delta = 21.79 \text{ mm} \]

- Design for Main Long Member

\[ P_1 = 18145 \text{ N} \]

\[ P_2 = 72570 \text{ N} \]

\[ l_1 = 1800 \text{ mm} \]

\[ l_2 = 600 \text{ mm} \]

Design for bending stress,

Maximum bending moment which occurs at end of the span,

\[ M_c = 68037750 \text{ Nmm} \]

Modulus of section required is,

\[ Z_{required} = 680377.5 \text{ mm}^3 \]

Check for shear stress

effective area of web,

\[ A_w = 2800 \text{ mm}^2 \]

Average shear stress,

\[ \tau_s = 5.5 \text{ N/mm}^2 \]

Allowable shear stress,

\[ \tau_{av} = 57.7 \text{ N/mm}^2 \]

As \( \tau_s < \tau_{av} \), Design is safe in shear.

Check for deflection

Allowable deflection is,

\[ \delta_{allowable} = 5.54 \text{ mm} \]

Maximum deflection occurs at free end,

\[ \delta = 5.2414 \text{ mm} \]

III. OPTIMIZATION OF CHASSIS FRAME

Optimization is define as a maximization of wanted properties and minimization of unwanted properties.

In case of structural optimization the chassis:

Desired Properties are:

- Strength
- Stiffness
- Deflection etc…

Undesired Properties:

- Material
- Cost
- Weight etc…

In the case of chassis we can reduce the weight of chassis frame by reducing its thickness, but it will increase the deflection as well as the shear stress. To omit this problem the sensitivity analysis will be helpful to reduce thickness of cross section of chassis frame.

- Sensitivity analysis

To analyze the sensitivity of frame web height to the change in thickness and viceversa. For the approximately same section modulus and flange width.

Case 1: Changing height and width.

Cross section of the frame in case 1

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>1A</th>
<th>1B</th>
<th>1C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W</td>
<td>H</td>
<td>W</td>
</tr>
<tr>
<td>Main cross</td>
<td>100</td>
<td>500</td>
<td>200</td>
</tr>
<tr>
<td>Side long</td>
<td>100</td>
<td>600</td>
<td>200</td>
</tr>
<tr>
<td>End cross</td>
<td>100</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>Main long</td>
<td>100</td>
<td>800</td>
<td>200</td>
</tr>
</tbody>
</table>

Case 1A: Results

Stress
Deformation

Case 1B: Results
Stress

Result Table for Case 1

<table>
<thead>
<tr>
<th>Cases</th>
<th>Stress</th>
<th>Deformation</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1A</td>
<td>21.733</td>
<td>0.22656</td>
<td>2.64</td>
</tr>
<tr>
<td>Case 1B</td>
<td>20.64</td>
<td>0.13861</td>
<td>4.98</td>
</tr>
<tr>
<td>Case 1C</td>
<td>23.296</td>
<td>0.17526</td>
<td>3.732</td>
</tr>
</tbody>
</table>

Case 2: Changing in height.
Cross section of the frame in case 2.

<table>
<thead>
<tr>
<th>Member</th>
<th>2A</th>
<th>2B</th>
<th>2C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main cross</td>
<td>600</td>
<td>800</td>
<td>750</td>
</tr>
<tr>
<td>Side long</td>
<td>700</td>
<td>900</td>
<td>750</td>
</tr>
<tr>
<td>End cross</td>
<td>400</td>
<td>600</td>
<td>500</td>
</tr>
<tr>
<td>Main long</td>
<td>1100</td>
<td>1300</td>
<td>1300</td>
</tr>
</tbody>
</table>

Deformation

Case 1C: Results
Stress
The truck chassis design is done analytically and the weight optimization is done by sensitivity analysis. In sensitivity analysis different cross sections are used for stress analysis and we find a 17% weight reduction in the truck chassis. The stress and deformation are also compared for the different cross section.

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