STRESS ANALYSIS OF TRACTOR TRAILER CHASSIS FOR SELF WEIGHT REDUCTION

N.K.Ingole
Pg Student of Dept of Mechanical Engineering, R.C.E.R.T
Chandrapur, Maharashtra, India
niteshingole@in.com

D.V. Bhope
Professor, Dept of Mechanical Engineering, R.C.E.R.T,
Chandrapur, Maharashtra, India.
dvbhope@rediffmail.com

Abstract:
Tractor Trailers are very popular and cheaper mode of goods transport in rural as well as urban area. But these trailers are manufactured in small scale to moderate scale industry; due to which design of chassis is at primary level. In Present work finite element method has been implemented to modify existing chassis of tractor trailer which ultimately results in reduction of weight and manufacturing cost. For analysis, a 8 ton 4 wheeler trailer manufactured by Awachat Industries. Ltd.Wardha is selected. The finite element analysis of existing chassis revealed the stresses distribution on chassis members. So, an effort is made to modify the structure of existing chassis so that advantage of weight reduction along with safe stress can be obtained.

Keywords: Trailer chassis; finite element method; stress analysis.

1. Introduction
Trailers are widely used for transporting agriculture product, building construction material, and industrial equipment. The power required to pull the trailer is provided by human, animals and machines. In trailer many varieties are available and use of particular trailer depends upon the application. The main requirements of trailer manufacturing are high performance, easy to maintain, longer working life and robust construction.

In this work, the tractor trailer which is used for the agriculture work and some times used for transporting building construction material is considered. These trailers are divided into two types as two wheeler and four wheeler. They are further classified as tipping and non tipping type. In tipping type, hydraulic system is used to tilt the trailer box. The tractor trailers are available in various capacities like 3 ton, 5 ton, 8 ton.

Many researches carried out studies on chassis of various vehicles. Roslan Abd Rahman, Mohd Nasir Tamin, and Ojo Kurdi [1] investigated stress analysis of heavy duty truck chassis using finite element method. Finite element result shows that the critical point of stress occurred at opening of chassis which is in contacted with the bolt. Thus, it is important to take note to reduce stress magnitude at this point. The location of maximum deflection agrees well with the maximum location of simple beam loaded by uniform distributed force. Ebrahim Ebrahimi, Alimohamad Borhefi, and Morteza Almasi [2] constructed a hay trailer Model and analysis of components was carried out. Analysis revealed the maximum stresses and maximum deformation in the chassis of trailer. J. Gadus [3] used optimization procedure for a mass optimization of a welded framework of a special tractor trailer designed for transport of seeding machines. This work reports that, on the basis of the optimization procedure more than 35% savings of the material mass has been achieved. S.Sane, G.Jadhav, and Anandaraj.h [4] carried out stress analysis on light commercial vehicle chassis using iterative procedure for reduction of stress level at critical locations. P.Meshram and R.Tayade [5] investigated, analyzed and optimized an automobile chassis. The bending stiffness and torsional stiffness of existing chassis and new modified chassis have improved the performance by 59% and 20%. The total weight of chassis is also reduced by 10% as compared to original weight.
2. Finite Element Analysis of Existing Chassis

For the FE Analysis, it is necessary to create a solid model of chassis and also to create a FE model. In the present work, static analysis has been carried out for the chassis considering sudden load effects. The chassis of Tractor trailer integrates the main components of system such as rear table, main frame, and extension frame. It is considered that extension frame is integral with main frame of chassis which carries the weight of side panel and pay load acting on top plate. Main frame of chassis is used to mount rear table at the end, which is used for attachment of leaf spring suspension. The front part of main frame is used for attachment of circular plate. Main frame is composed of longitudinal members and cross members as shown in figure 1.

PRO-E is used for modeling the chassis of tractor trailer. The model has a main frame and extension frame with length 3750 mm and width 1890 mm.

![Fig1. Solid Model](image)

The total weight of trailer including laden and unladen weight is 9000 kg. This load is considered to be distributed over the top plate area of 1890 x 3750 mm². Thus, the distributed load considered for analysis is 0.0126 N/mm². The trailer is also subjected to tractive force which is given by

\[ F = G \times (\sin \theta + r) \]

Where, \( r \) is rolling resistance of 0.26 for sand surface. Thus tractive force is 79461 N.

The properties of Structural steel material of trailer are as shown in table 1. The model is discretized using solid 187 elements with 52443 elements and 106801 nodes as shown fig 2.

![Fig2. Discretized Model of Chassis](image)

<table>
<thead>
<tr>
<th>Table1. Material Properties Used for Discretization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's Modulus</td>
</tr>
<tr>
<td>Poisson's Ratio</td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>Tensile Yield Strength</td>
</tr>
</tbody>
</table>

Supports for tractor trailer chassis are present at rear end of chassis and at rotary table as shown in photograph given in 3 and 4 respectively. The rear end of the trailer chassis is attached with rear table which is used for attachment of two leaf spring suspensions. This area is considered for boundary conditions and degrees of freedoms at this area are constrained with zero displacement. Front portion of chassis is resting on rotary plate, so the displacements only in y direction are constrained for plate area as shown in figure 5.

![Fig3. Supports for Rear End of Chassis](image)  
![Fig4. Support for Front End of Chassis](image)
The FE analysis of existing chassis revealed that, the max stresses are concentrated only over small portion of chassis member. For existing chassis it is seen that maximum stress in longitudinal member is 75 Mpa. If sudden loads effects are considered then stress level may rise to approximately to twice that of static stress of 75 Mpa. Thus the maximum stress will be approximately 150 Mpa. Thus the factor of safety of 1.66 is present for existing chassis. In actual case due to suspensions provided to the chassis, the chassis is subjected to lesser shock loads. The Maximum stress in longitudinal member of extension frame is observed to be 5.78Mpa. Remaining members of chassis are under the minimum stress as shown in fig 6. The weight of existing chassis is 751.82 Kg.

3. Modification of Existing Tractor Trailer Chassis

An effort is made to modify the chassis by modifying the cross sectional areas of members so that the maximum static stress of around 75 Mpa which will give factor of safety around 1.66 under sudden load situation, which is considered satisfactory as per performances of existing trailer. The objective of this modification is to get the advantage of weight reduction of chassis members with adequate factor of safety. Different cases are considered during modification of exiting chassis are as follows.

- Case1: Variation in Cross sectional areas of cross members.
- Case 2: Variation in Cross sectional areas of cross and longitudinal members.
- Case 3: Variation in Cross sectional areas of cross and longitudinal members and changing the position of cross members of main frames of chassis.
- Case 4: Considering Variable cross sectional areas of cross and longitudinal members.

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Various cases</th>
<th>Cross sectional area for longitudinal members In mm²</th>
<th>Cross sectional area for Cross members. In mm²</th>
<th>Variable cross sections of cross and longitudinal members in mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Existing Chassis</td>
<td>2272</td>
<td>1278</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Case 1</td>
<td>-</td>
<td>2072, 858</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Case 2</td>
<td>2072</td>
<td>2072, 858</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Case 3</td>
<td>2072</td>
<td>858,2072</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Case 4</td>
<td>2272, 2072</td>
<td>858,708, 2072</td>
<td>2072, 1872</td>
</tr>
</tbody>
</table>
The finite element analysis of modified chassis as per loading and boundary condition revealed the stress distribution in form of stress contours. The results for this analysis are given in forthcoming sections.

### 3.1 Case 1: Variation in Cross sectional areas of cross members

The cross sectional areas of cross member of main frame and cross members of rear table are varied as given in table 2. A cross member which is in between longitudinal members of main frame of chassis is removed and equal spacing is provided between other cross members. The von mises stress contours is shown in fig 7.

![Fig 7. Von Mises Stresses on Chassis (Case 1)](image)

It is seen from Fig 7 that, the stresses on longitudinal member near rear table are in the range from 28 MPa to 69 MPa.

### 3.2 Case 2: Variation in Cross sectional areas of cross and longitudinal members

The cross sectional areas of longitudinal and cross members are varied as given in table 2. A cross member which is between longitudinal members of main frame of chassis is removed and equal spacing is providing between other cross members. The von mises stress contours is shown in fig 8.

![Fig 8. Von Mises Stresses on Chassis (Case 2)](image)

It is seen from Fig 8 that, the stresses on longitudinal member near rear table are in the range from 30 MPa to 75 MPa.

### 3.3 Case 3: Variation in Cross sectional areas of cross and longitudinal members and changing the position of cross members of main frames of chassis

The cross sectional areas of longitudinal and cross members are varied as given in table 2. A cross member which is between longitudinal members of main frame of chassis is removed and cross arrangement of cross members are provide between longitudinal members of main frame of chassis. The von mises stress contours is shown in fig 10. It is seen from Fig 9 that, the stresses on longitudinal member near rear table are in the range from 41 MPa to 75MPa.
3.4 Case 4: Considering Variable cross sectional areas of cross and longitudinal members

In this case used variable sections which are combination of two different areas. In previous cases replacement of different areas concept is used but in this case joining the different areas concept is used as given in table 2.

It is seen that from Fig 10 that, the stresses on longitudinal member near rear table are in the range from 42 MPa to 75MPa.

4. Effects of Plates Stiffeners on Stresses in Modified Chassis

It is seen that the maximum von mises stresses are present on members near to rear table. The stress level is up to 75 MPa on longitudinal member of main frame. This maximum stress can be reduced by strengthening the contact portion. So, the Plates of 8mm thickness are provided on longitudinal member over the length of 300 mm near to rear table. Two outer plates are used. The solid model and FE model of tractor trailer chassis for Case3 are shown in Figure 11 and Figure 12 respectively as an illustration.

The finite element analysis of modified chassis for case 1 to Case 4 as per loading and boundary condition revealed the stress distribution in form of stress contours and detail are presented in forthcoming section.
4.1 Case 1 Variation in Cross sectional areas of cross members

It is seen from Fig 13 that, the stresses on longitudinal member near rear table are in the range from 28 MPa to 75 MPa and from fig 14 that, the stresses on longitudinal member near rear table are in the range from 18 MPa to 37 MPa which is much lesser than earlier. Thus, the stresses are reduced drastically with the use of plates on longitudinal members, though there is slight increase in overall weight of chassis. Thus the use of plates on longitudinal members is recommended. The factor of safety under sudden load condition for this Case is 3.37.

4.2 Case 2: Variation in Cross sectional areas of cross and longitudinal members.

It is seen from Fig 15 that, the stresses on longitudinal member near rear table are in the range from 30 MPa to 75 MPa from fig 16 that, the stresses on longitudinal member near rear table are in the range from 18 MPa to 46 MPa which is much lesser than earlier. Thus, the stresses are reduced drastically with the use of plates on longitudinal members, though there is slight increase in overall weight of chassis. Thus the use of plates on longitudinal members is recommended. The factor of safety under sudden load condition for this Case is 2.71.

4.3 Case 3: Variation in Cross sectional areas of cross and longitudinal members and changing the position of cross members of main frames of chassis.

It is seen from Fig 17 that, the stresses on longitudinal member near rear table are in the range from 41 MPa to 75 MPa and from fig 18 that, the stresses on longitudinal member near rear table are in the range from 28 MPa to 46 MPa which is much lesser than earlier, The stresses are reduced drastically with the use of plates on longitudinal members, though there is slight increase in overall weight of chassis. Thus the use of plates on longitudinal members is recommended. The factor of safety under sudden load condition for this Case is 2.71.

4.4 Case 4: Considering Variable cross sectional areas of cross and longitudinal members.

It is seen from Fig 19 that, the stresses on longitudinal member near rear table are in the range from 42 MPa to 75 MPa and from fig 20 that, the stresses on longitudinal member near rear table are in the range from 21 MPa to 54 MPa which is much lesser than earlier. The stresses are reduced drastically with the use of plates on...
longitudinal members, though there is slight increase in overall weight of chassis. Thus the use of plates on longitudinal members is recommended. The factor of safety under sudden load condition for this Case is 2.3.

![Fig -19.Von Mises Stresses on selected area (Without plate)](image1)
![Fig -20.Von Mises Stresses on selected area (With plate)](image2)

5. Results and Discussions

Table 3: Comparison of Result for Different Cases

<table>
<thead>
<tr>
<th>S.N</th>
<th>Various Cases</th>
<th>Weight in Kg</th>
<th>Range of Equivalent Stresses on members in Mpa</th>
<th>Final Reduction in weight Kg</th>
<th>Factor of safety under sudden load (without plates)</th>
<th>Factor of safety under sudden load (with plates)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Existing Chassis</td>
<td>751.82</td>
<td>28 to 75</td>
<td>-</td>
<td>1.66</td>
<td>3.37</td>
</tr>
<tr>
<td>2</td>
<td>Case 1</td>
<td>705.88</td>
<td>17 to 69</td>
<td>45.88</td>
<td>1.78</td>
<td>2.71</td>
</tr>
<tr>
<td>3</td>
<td>Case 2</td>
<td>674.67</td>
<td>22 to 75</td>
<td>77.15</td>
<td>1.66</td>
<td>2.71</td>
</tr>
<tr>
<td>4</td>
<td>Case 3</td>
<td>663.87</td>
<td>25 to 66</td>
<td>87.95</td>
<td>1.89</td>
<td>2.31</td>
</tr>
<tr>
<td>5</td>
<td>Case 4</td>
<td>640.09</td>
<td>42 to 75</td>
<td>111.73</td>
<td>1.66</td>
<td>3.37</td>
</tr>
</tbody>
</table>

From table 3, it has been found that, maximum stress present in existing chassis is 75 Mpa and weight of chassis is 751.82 kg. Under this stress level, the tractor trailer is working satisfactorily without any evidence of failure. It is also seen that for cases from 1 to 4. The stresses varied with the use of different cross sectional area of longitudinal members and cross member. Case 1 to Case 3 involves modifications, which does not require any additional manufacturing resources and expertise, but Case 4 requires additional manufacturing resources and expertise due to variable cross sections.

It is seen from table 3 that Case 1 leads to the least weight reduction of only 46 kg, but Case 2 has yielded more weight reduction of 77 kg with maximum stress in range of 17 Mpa to 75 Mpa. For case 3 the weight reduction is 88 kg with maximum stress level in range of 25Mpa to 66 Mpa. Thus, the stress level for Case 2 and Case 3 are in closed range with large weight reduction of chassis. Hence modifications as described in Case 2 or Case 3 are recommended.

From table 3, it is also seen that case 4 leads to maximum weight reduction of approx 112 kg as compared to case 1, 2 and 3. So modifications as per case 4 are also recommended.

It is seen from table 3 that, the factor of safety is increased for various cases with the use of plate stiffeners. Though the weight of tractor trailer marginally increases by only 5 kg as compared to previous cases, but the life of tractor trailer is enhanced due to increased factor of safety. Hence the use of plate stiffeners on longitudinal member is recommended for previously recommended cases 2, 3 and 4.
6. Conclusion

The material cost of existing chassis is Rs 31500/-. The material cost of chassis as per modifications suggested in Case 2 and Case 3 is approx Rs 28000/- and 27500/- and for Case 4, is Rs 26500/- respectively. But manufacturing cost increases drastically for Case 4 as compared to Case 2 and Case 3. Though recommendations are made for Case 2, Case 3 and Case 4 the final choice should be made looking in to cost of manufacturing. So for small manufacturing quantity Case 2 or Case 3 is recommended but for mass production case 4 is recommended.

References


[7] National code of practice” Heavy vehicle modifications” section h chassis frame

