DESIGN AND ANALYSIS OF TIE ROD FOR DIFFERENT MATERIAL

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ABSTRACT

Tie rod is an integral part of vehicle's steering system. Just as its name suggests a Tie rod ties vehicle's steering rack to the steering arm. Tie rod may get fail due to fluctuating forces and bumping of vehicles during steering. The forces from the steering also consider during static condition of car. Buckling of tie rod has been continuously concern which may lead structural failure if the resulting stresses are undesirable and excessive. So, research work is aimed to access buckling strength and compare buckling performance of tie rod for different materials. Finite element models of tie rod also analyzed to obtain stiffness and stress distribution in each component. Based on the experimental test results, theoretical calculation and finite element analysis with ANSYS results, stiffness values are validated. In buckling analysis, the load factor obtained for different materials are analyzed using finite element analysis and best fitting material is validated with experimental testing.

KEYWORDS: Tie Rod, composite material, Tie bar, fiber material, etc...

I. INTRODUCTION

Tie bar is an integral part of vehicle's steering system. Just as its name suggests a Tie bar ties vehicle's steering rack to the steering arm. Tie bar is a slender rod with threaded parts consisting of outer and inner ends. Tie bar end ensure the alignment of wheels and provides adjustment for wheel alignment to prevent tires wearing on inner and outer edges. The primary function of tie bar is to transfer the motion from steering arm to steering knuckle. Tie rod provides the adjustment for wheel alignment that keeps the tires from wearing out on the inner and outer edges. If wear out, the wheels will lose alignment and you may find that the tires and steering wheels are shaking when you drive the car.

So, research work is aimed to assess strength and compare performance of Tie rod for different materials. Finite element models of the Tie rod also analyzed to obtain stiffness and stress distributions in each component. Based on the experimental test results, theoretical calculation results and finite element analysis with ANSYS results, stiffness values are validated.

The mode shape and natural frequency results for different materials obtained in the normal modal analysis are compared. In structural analysis, the load factor obtained for different materials were compared and validated by theoretical calculations.

II. METHODOLOGY

In this work, finite element analyses were carried out to determine the characteristics of the Tie rod. All methodology principles and theories discussed were utilized to achieve the objectives. The combination of all the analysis results were used to develop virtual model created using FEM tools and the model was updated based on the correlation process.

Stiffness of tie rod for different material using FEA result (deformation) is calculated and compared. According to comparison and reduction in weight of tie rod, Glass Fiber material is selected for new tie rod manufacturing. Glass fiber with a matrix of epoxy resin and hardener were used to construct new tie rod.

A tie rod may contain geometrical imperfections. It is very important to accurately predict the buckling loads of structural tie rods, especially ones that are compression critical in automobile industries. Based
on the design criteria of minimizing compression margin safety coupled with the degree of difficulty to predict buckling behavior, buckling test must be done on glass fiber tie rod.

Generally, types of tie rod failure modes include fatigue, impact fracture, wear and stress rupture. In stationary condition or running condition of car, need steering moment to drive it and to control its direction continuously. As steering mechanism is being used frequently while using car, then tie rod will be continuously loaded in every condition of car as stationary or running. Due to continuously loading condition of tie rod, there must be fatigue testing of tie rod to be done for selected material, Glass Fiber tie rod.

### III. MODELING AND ANALYSIS

CAD model of metal tie bar’s used to construct outer layer of composite material tie bar as shown in figure 2. This outer layer thickness is taken 1 mm. Remaining all successive layer from internal diameter is taken of 0.5 mm thickness to maintain internal diameter of 8.5 mm. In composite tie bar, outer diameter is 16 mm as per existing tie bar of metal (carbon steel) and internal diameter of 8.5 mm for accommodating ball joint's M10 threading and same with other end ball joint’s accommodation by press fit and bonding with epoxy and material which are used is presented in this section.
The meshing of Tie bar assembly is carried out in ANSYS software as shown in figure 3. The finite element standard quality criteria considered in meshing of Tie bar component. Total number of elements and nodes used to create the FE model Tie bar assembly is 29413 elements and 49545 nodes.

<table>
<thead>
<tr>
<th>Metals</th>
<th>Displacement in Static analysis (mm)</th>
<th>Stress (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Steel</td>
<td>0.814</td>
<td>130.08</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>1.4858</td>
<td>130.78</td>
</tr>
<tr>
<td>Aluminum Alloy</td>
<td>2.278</td>
<td>129.08</td>
</tr>
<tr>
<td>Magnesium Alloy</td>
<td>3.5767</td>
<td>128.43</td>
</tr>
</tbody>
</table>
IV. RESULTS AND DISCUSSION

In static analysis, FEA results are shown in graph as follows:

**FE Displacement Results for Tie bar**

From the graph 1, FE displacement results for carbon steel Tie bar is 0.814 mm, Cast Iron Tie bar is 1.4858 mm, Aluminum alloy Tie bar is 2.278 mm, Magnesium Alloy Tie bar is 3.5767 mm, Glass Fiber Tie bar is 0.80433 mm and Carbon Fiber Tie bar is 0.4846 mm. According to results glass fiber can be used as alternative material for tie bar instead of carbon steel as its displacement is less than carbon steel.

**Stress Result**

From the above graph 2, the stress for carbon steel Tie bar is 130.08 N/(mm)^2, Cast Iron Tie bar is 130.78 N/(mm)^2, Aluminum alloy Tie bar is 129.08 N/(mm)^2, Magnesium alloy Tie bar is 128.43 N/(mm)^2, Glass Fiber Tie bar is 193 N/(mm)^2 and Carbon Fiber Tie bar is 200.87 N/(mm)^2. According to result glass fiber performance is better than carbon steel. So, glass fiber can be used as alternative material for carbon steel.
Stiffness Calculation Results for Tie bar

Table: Stiffness Results of Tie bar for Composite materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>Carbon Steel Tie bar</th>
<th>Cast Iron Tie bar</th>
<th>Aluminum alloy Tie bar</th>
<th>Magnesium alloy Tie bar</th>
<th>Glass Fiber</th>
<th>Carbon Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>K in (KN/mm) using FE Results</td>
<td>2.334</td>
<td>1.278</td>
<td>0.834</td>
<td>0.531</td>
<td>2.362</td>
<td>3.920</td>
</tr>
</tbody>
</table>

As per the table 5 glass fiber material having close stiffness value to carbon steel but it is slightly greater, so we can use glass fiber material as alternative material for carbon steel tie bar.

V. CONCLUSION

Thus, the standard yield strength of the Glass Fiber is 3445 N/mm² and the analytical yield strength of Glass Fiber is 193 N/mm², which is less than the value of standard yield strength. So, Glass Fiber Tie rod is safe for design of car Tie rod.

In buckling test deformation of glass fiber tie rod is 0.9 mm close to FEA analysis result i.e. 0.80433 mm. Hence Glass Fiber Tie Rod suitable material. Also, Weight has been reduced approximately by 40% since density of glass fiber as topology remains the same, Experimental results are in well arrangement with FEA results and mechanical strength has been increased considerably.

VI. REFERENCES
