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Design, Analysis And Optimization Of Tie Rod Of Four Wheeler Car

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Abstract — ***Tie rods are 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. While the vehicle is at rest or in static condition there exist some forces acting on tie rod due to weight of the vehicle. Due to its weight forces acting on tie rod, it buckles by some amount after prolonged period. So to avoid the buckling effect we need to increase the strength of material by changing its existing material or to change its dimensions. We are analyzing the existing tie rod using FEA and comparing result which includes critical buckling load, displacement, stress with different material and also doing theoretical calculations and Experimental validation followed by the optimization on the basis of different common materials available in the market.***

Keywords- Tie rod, Static force, Stiffness, Critical Buckling load, Displacement, Stress in ANSYS Analysis and Theoretical and Experimental Validation.

I. INTRODUCTION

While designing the component we must ensure the safety. The tie rod is an important part of suspension system. It connects the steering to the suspension in order to transform the motion. Tie rods connect the center link to the steering knuckle on automobiles with conventional suspension systems and recirculating ball steering gears.On automobiles with MacPherson strut suspension and rack and pinion steering gears, tie rods connect the end of the rack to the steering knuckle which is shown in Fig. 1.1. A tie rod consists of an inner and an outer end, the outer tie rod end connects with an adjusting sleeve, which allows the length of the tie rod to be adjustable. This adjustment is used to set a vehicle's toes, a critical alignment angle, sometimes referred to as the caster and camber angles. A vehicle's steering and suspension systems should be checked regularly, at least once a year along with a complete wheel alignment.

We have taken the car's tie rod as sample to check its critical buckling effect as shown in Fig. 1.2 and to increase its critical buckling effect and also to reduce its displacement.

Fig. 1.1 Tie Rod End Connected joint

Fig. 1.2: Sample Tie Rod

II. PROBLEM DEFINITION

While the vehicle is at rest or in static condition there exists compression force acting on tie rod due to weight of the vehicle. So due to the forces acting on tie rod, it buckle by some amount after prolonged period. So to avoid the buckling effect we need to increase the strength of material by changing its existing material or to change its dimensions. Hence it is necessary to make the design simple and cost effective such that it gives overall effectiveness in terms of weight, cost and load carrying capacity. The main task in this study is to find the critical buckling load for the existing design. Observe the deformation and Buckling induced in the Tie rod. Try to evaluate the possibility with different material combinations for optimized design. Pre-processing will be carried out using finite element analysis software named **ANSYS**. The results will be compared with practical and theoretical results. From the variables better tie rod will be selected and evaluated.

III. 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 will used to develop virtual model created using FEM tools and the model was updated based on the correlation process. The research methodology flowchart for this project is shown in the below Figure 3.1.

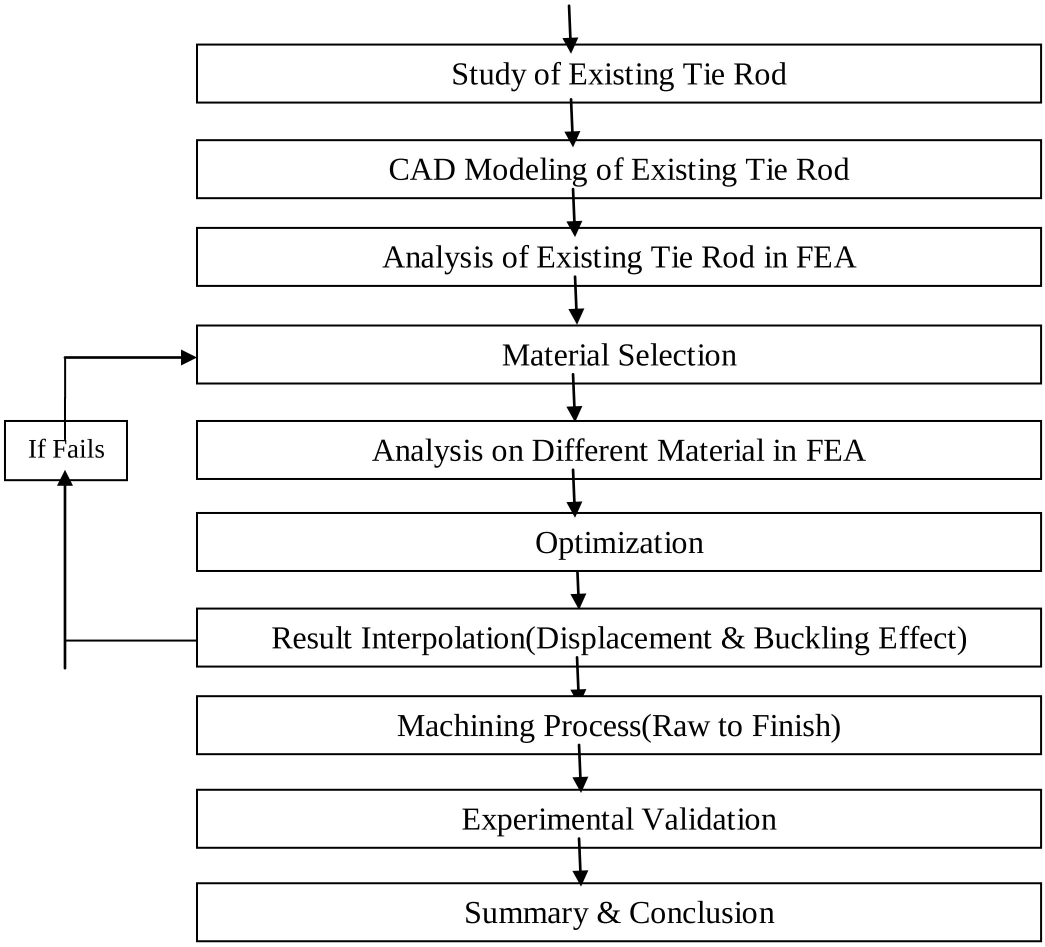

Fig. 3.1: Flow Chart of Methodology

3.1 Sample Procedure

3.1.1 CAD Model:

The CAD model of Hyundai i20 car Tie rod is taken for analysis. The model with the same dimension of the present Tie rod is considered for analysis.

3.1.2 2D Drafted CAD Model:

Autocad is commercial computer aided Design(CAD) and Drafting Software application. AutoCAD is used across a wide range of industries, by architects, project managers, engineers, graphic designers, and many other professionals. We are also going generate drawing to use version 2017 and to create protection view by using third angle projection method. Below fig. shows the all the dimensions details of the sample Tie rod.

3.1.3 3D ANSYS Model:

After completing of 2D drawing, solid model is generating in ANSYS software. In that finite element meshing is one of the geometric input requirements while carrying an FEA and it involves discretization of a domain existing in one, two or three dimensions. In other words, Meshing is a process in FEA in which the model to be analyzed is divided into smaller discrete elements. The mesh sizes used greatly affect the solutions obtained in finite element analysis. Generally, discretization error reduces as the mesh is made finer and hence a more accurate result is obtained. However, the finer the mesh sizes, the more the computation time is required. As the mesh sizes are refined, the solutions obtained keeps changing until a point is reached when further refinement of the mesh produces little or no change in the solutions obtained after taking a long time for the solver to generate results. When further reduction in the mesh size has little or no effect on the result obtained, the mesh is said to have converged and the result at this point is taken as the solution to the problem. Mesh generation in FEA can be achieved directly from a solid model for detailed part design in a three-dimensional (3D) CAD analysis model. Depending on the computational techniques the detailed solid model may affect the computational time or become too complex to analyze properly, some simplification with an appropriate idealization process such as reducing mesh size in the FE model was necessitated in order to reduce the long computation time.

3.1.4 Boundary Conditions:

The proper specification of boundary conditions is just as important for static analysis. The improper specification of the boundary conditions leads to incorrect answers. One such improper specification of boundary conditions is forgetting to fully constrain the structure. The boundary conditions applied fig. 3.2 which shows Blue colour shows fixed point and Red colour shows applied load (P).

Fig.3.2: Boundary Conditions

3.1.5 Theoretical Calculations Details:

Three types of calculation are to be carried out:

A. Buckling FE Analysis for Tie Rod:

If a rod is subjected to longitudinal forces, as implied in the sketch, it can fail in two ways. On the one hand, it can be plasticized and flattened if its admissible compressive strain is exceeded (see Fig.). On the other hand, it is possible that it will suddenly shift to one side and buckle before attaining the admissible compressive strain. This effect is called buckling.

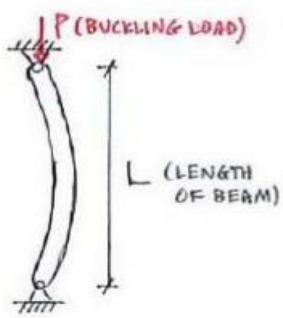

Fig.3.3 Buckling Effect

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

Where,

Pcr= Critical/Max. Load in N.

E =Modulus of Elasticity in N/mm^2.
I = Moment of Inertia in mm^2.
L = Actual length in mm.
E, I and L are variables which can control the critical load value.
$I = \frac{\pi}{64}(d_4)$.
d_4 = Diameter of rod.

For design against the buckling loads, one should select the material having maximum E value, keeping length as minimum as possible, select maximum outer diameter in order to maximize the inertia value and lower the $\frac{L}{d}$ ratio.

B. Deflection of Tie Rod:

$\delta L = \delta 1 + \delta 2 + \delta 3 + \delta 4$

$\delta L = \frac{PL_1}{A_1 E} + \frac{PL_2}{A_2 E} + \frac{PL_3}{A_3 E} + \frac{PL_4}{A_4 E}$

Where,
P=Max. Load, N
L=Length, m
A=Cross-Section Area,mm^2

C. Stiffness Calculation for Tie Rod:

Stiffness calculation for Tie rod using theoretical results is carried out by taking load and deflection for Tie rod Therefore, Stiffness (K) is given by,

$K = \frac{LOAD}{DEFLECTION}$

Where,
K=Stiffness in N/mm
P=Max. Load,N
δ=Deflection, mm

3.2 Validation Method (UTM)

A. Universal Testing Machine:

A **universal testing machine** (**UTM**), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures.

IV. COMPARISON OF ANALYTICAL, THEORETICAL AND EXPERIMENTAL RESULTS

From below table we can see that, for sample tie rod the results for analytical displacement and stress obtained as 0.18384mm and 255.09N/mm^2 and for theoretical we obtained as 0.18mm and 256.24 N/mm^2resp. with Experimental Buckling load of 38.70 kN.

For test piece 1 the results for analytical Displacement and Stress obtained as 0.19376mm, 255.74 N/mm^2 and theoretically obtained as 0.18mm and 240.27 N/mm^2resp. with Experimental Buckling load of 37.10 kN.

For test piece 2 the results for analytical Displacement and Stress obtained as 0.14412mm, 189.65,51N/mm^2 and Theoretically obtained as 0.140mm and 162.27 $N/mm^2$with Experimental Buckling load of 51.70 kN.

Table 4.1: Comparison of Analytical, Theoretical and Experimental results

	Analytical		Theoretical		Experimental
	Displacement (mm)	Stress (N/mm^2)	Displacement (mm)	Stress (N/mm^2)	Buckling (KN)
Sample Tie Rod	0.18384	255.09	0.18	256.24	38.70
Test Piece 1	0.19376	255.74	0.19	240.27	37.10
Test Piece 2	0.14412	189.65	0.140	162.27	51.75

V. SUMMARY, CONCLUSION AND FUTURE SCOPE

5.1 Summary

In this chapter we have discussed the different result for the different material, which are to be compared.

A. Comparisons of various results on ANSYS:

Table 5.1: Comparisons of Displacement & Stress

Material	Displacement (mm)	Stress (N/mm^2)
Sample Tie Rod	0.18384	255.09
Test Piece 1	0.19376	255.74
Test Piece 2	0.14412	189.65

B. Comparisons of various results Theoretically:

Table 5.2: Comparisons of Displacement, Stress, Stiffness & Buckling

Material	Displacement (mm)	Stress (N/mm^2)	Stiffness(kN/mm)	Buckling (KN)
Sample Tie Rod	0.18	256.24	59.87	39.61
Test Piece 1	0.19	240.27	42.08	37.68
Test Piece 2	0.140	162.27	70.30	55.89

C. Experimental Critical Buckling Load results:

Table 5.3: Comparisons of Buckling

Material	Buckling (KN)
Sample Tie Rod	38.70
Test Piece 1	37.10
Test Piece 2	51.75

Table 5.4: Comparisons of Displacement & Stress

Material	Displacement (mm)	Stress (N/mm^2)
EN31	0.1307	177.76
Al. Alloy	0.37823	189.34

5.2 Conclusion:

A. Tie Rod plays an important role in a steering system and should be carefully selected.

B. We got the value of displacement, stress, stiffness and buckling load.

C. The result we got for the selected material shows the good performance as compared to the other two materials of tie rod.

D. The Stiffness value for the selected Material EN24 is 70.30 kN/mm which is higher than the sample tie rod and EN18 and its stiffness value is 59.89kN/mm and 42.08 kN/mm respectively, so the stiffness of selected tie rod increased by **14.83%**

E. The Displacement from the FEA Analysis for the selected Material EN24 is 0.1838mm which is lower than the sample tie rod and EN18 and its displacement value is 0.193mm and 0.144mm respectively, so the Displacement of selected tie rod increased by **12.78%**

F. From the experimenting value, the critical buckling effect point of selected material EN24 is 51.75kn which is higher than the sample tie rod and EN18 test piece.And the selected tie rod is increased by **18.30%**

G. We have optimize the result by changing the diameter and material property of the material EN31 and result for displacement is 0.1307mm

5.3 Future Scope:

A. Optimized Tie Rod design based on Dimensional parameters.
B. Hollow Tie Rod design testing
C. Dynamic analysis can be carried out for the impact loading and random changes of the load on Tie Rod due to uneven road.

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