

Evaluation of the Performance of Tie Rod and Optimization Using FEA

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ABSTRACT : Tie rod is the part of steering system of an automobile. Tie rod is slender in structure and used to tie and sustains compressive and tensile loads. Fluctuating Forces and vibration due to bumps form automobile vehicle transmits to tie rod which may cause it to fail. The most percentage of forces on tie rod is compressive. Structural failure also takes place due to high severity of vibration and forces. Tie rods transmit force from the steering center link or the rack gear to the steering knuckle, causing the wheels to turn. A worn tie rod end, due to rubbing and wearing, can cause wandering, erratic steering and excessive tire wear. If tie rod replacement is necessary, a wheel alignment is also required because tie rod replacement disturbs the toe setting. Tie rods may fail in many different ways, and except for a slight increase in noise level and vibration, there is often no indication of difficulty until total failure occurs. Design of suspensions components in an automotive is very critical as they are constantly under varying loads. While designing the component, we must ensure the safety. Apart from design prospective it is important to focus on the weight and cost of an individual component. Here we are going to focus on the tie rod as a structural member, its functioning and performance. Here we are analyzing the existing Tie rod using FEA.

KEYWORDS: FEA; Modal FEA; Natural frequency; Forces coming on tie rod;

I. INTRODUCTION

Design of suspensions components in an vehicle is very critical as they are constantly under varying loads. While designing the component, we must ensure the safety. Apart from design prospective it is important to focus on weight and cost of an individual component. The tie rod is an important part of suspension system. It connects the steering to the suspension in order to transform the motion. Here we are going to focus on the tie rod as a structural member, its functioning and performance. Here we are analysing the existing Tie rod using FEA. The current design of tie rod is made of three parts as hollow, solid and ball joint. So the design of the current tie rod is quiet critical and time consuming. Also here three different parts are assembled to manufacturing; so the manufacturing is quiet complicated. There are chances of failure in the attachment region. Hence it is necessary to make the design simpler, easy of manufacturing, saving of the overall cost, time and weight. In this project an efforts are taken to propose a new design for tie rod that is reduce weight, cost, load carrying capacity, simpler design, and easy manufacturing process. This will give an overall enhanced performance of tie rod.

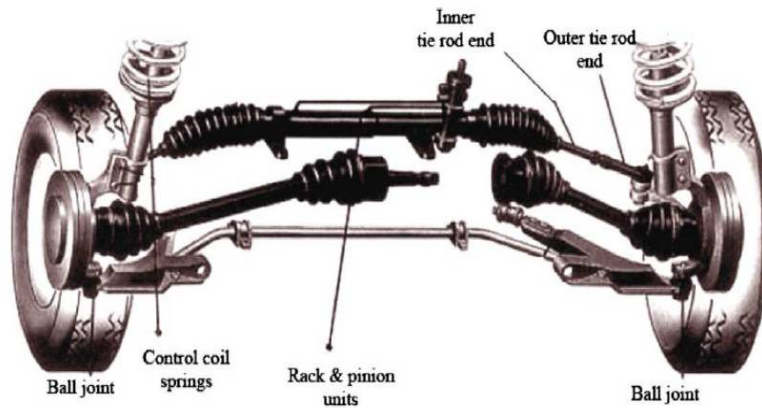


Figure 1: Steering system of a passenger car

II. STATICS ANALYSIS OF EXISTING TIE ROD

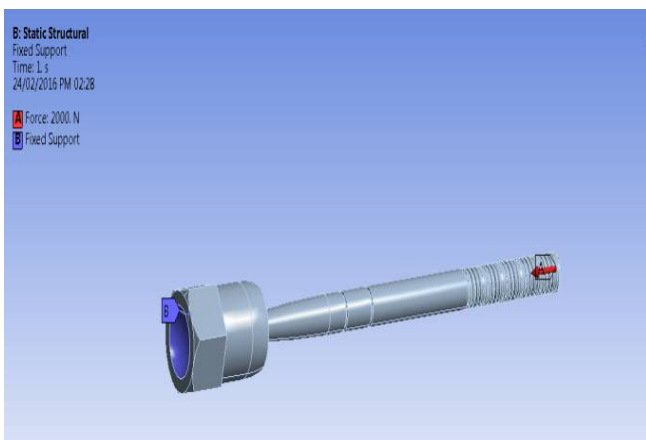


Fig 2.1: Combined Boundary Condition

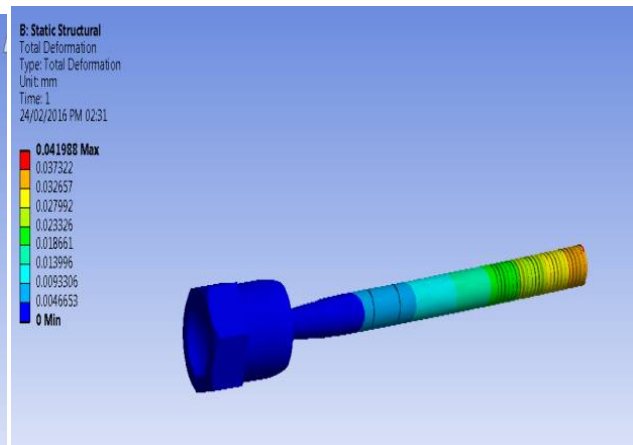


Fig 2.2: Result for Deformation

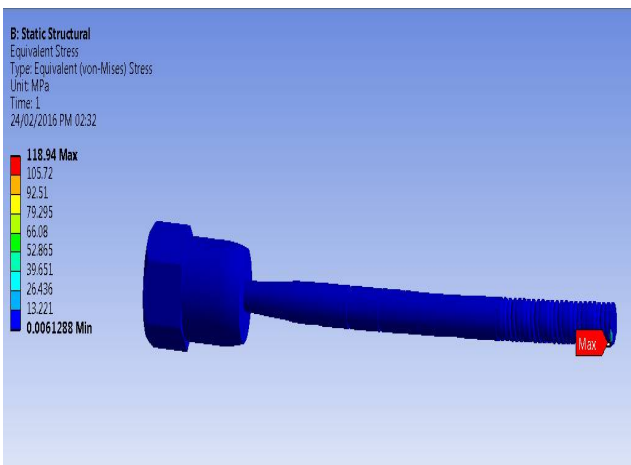


Fig 2.3: Result for Von-mises stresses

Sr. No.	Deformation (MM)	Von-mises stresses (MPa)
1	0.041988	118.94

Table 1: Result for static Analysis

III. MODAL ANALYSIS OF TIE ROD FOR FINDING NATURAL FREQUENCIES

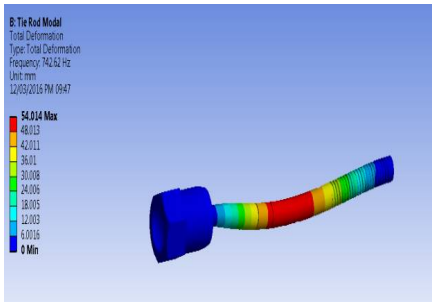


Fig 3.1: 1st Mode Shape result

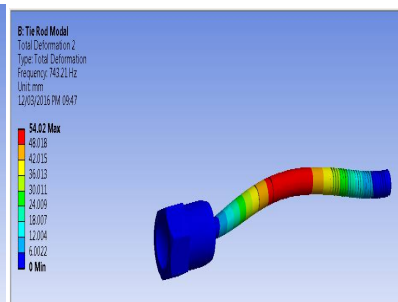


Fig 3.2: 2nd Mode Shape result

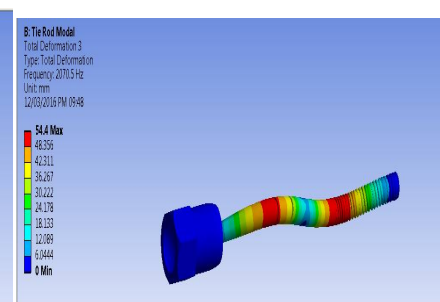


Fig 3.3: 3rd Mode Shape result

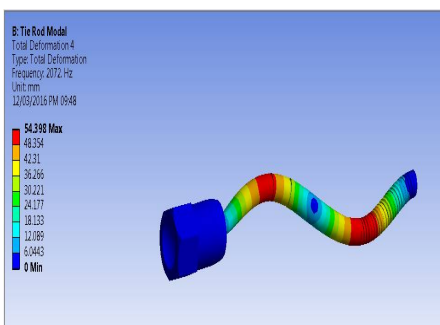


Fig 3.4: 4th Mode Shape result

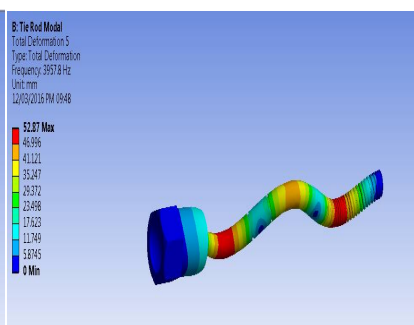


Fig 3.5 : 5th Mode Shape result

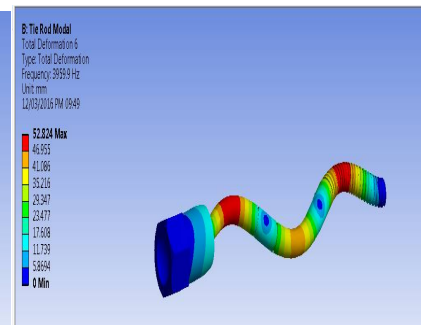


Fig 3.6: 6th Mode Shape result

IV. OPTIMIZATION ANALYSIS FOR TIE ROD AT DIFFERENT THICKNESSES (HOLLOW TIE ROD)

Solid Tie rod is over safe and further can be considering for Hollow shape (for weight reduction). For the same, dimension of hollow shaft is to be determined. Considering various thicknesses and further Analysis of the same. Starting from $d_i/d_o = 0.5$

So $d_o = 20.5$ mm, hence $d_i = 10.25$ mm

Trial	ID (mm)	Thickness (mm)
1	8.5	6
2	9.0	5.75
3	9.50	5.5
4	10.0	5.25
5	10.25	5.125
6	10.50	5.0
7	11.0	4.75
8	11.50	4.5
9	12.0	4.25

Table 2: Tie rod at Different Thicknesses

Trial	ID, mm	Thickness, mm	Stress, MPa	Deformation, mm	Weight, kg
0	Solid	--	118.94	0.041988	1.96
1	8.5	6	144.86	0.052593	1.82
2	9.0	5.75	149.36	0.054226	1.803
3	9.50	5.5	154.44	0.0566062	1.785
4	10.0	5.25	160.18	0.058128	1.766
5	10.25	5.125	163.28	0.059246	1.756
6	10.50	5.0	166.6	0.06045	1.746
7	11.0	4.75	173.89	0.063084	1.725
8	11.50	4.5	182.14	0.066089	1.703

Table 3: Static Analysis Of Hallow Tie Rod

V. OPTIMIZATION ANALYSIS FOR TIE ROD AT DIFFERENT MATERIALS

Steel- SM45C (Existing)

The material properties are:

Young's Modulus 'E'	210 x 10 ³ MPa
Poisson's ratio	0.3
Density	7860 kg/m ³
Tensile strength, yield	343 MPa
Ultimate tensile strength	569 MPa

$$\begin{aligned} \text{Allowable Stress} &= \text{Yield} / \text{FOS} \\ &= 343/2.0 \\ &= 171.5 \text{ MPa} \end{aligned}$$

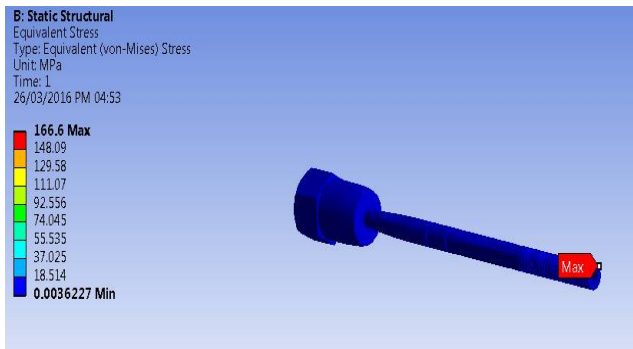


Fig 5.1: Stress in Tie Rod (ID=10.5 mm)

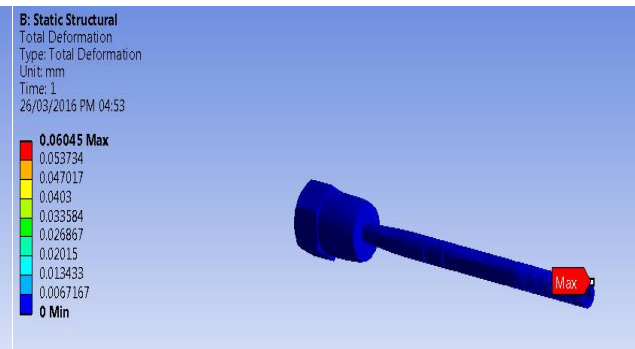


Fig 5.2: Deformation in Tie Rod (ID=10.5 mm)

Aluminium Alloy 6082

The material properties for AL 6082 are:

Young's Modulus 'E'	72 x 10 ³ MPa
Poisson's ratio	0.33
Density	2710 kg/m ³
Tensile strength, yield	340 MPa
Ultimate tensile strength	380 Mpa

Cast Iron – FG 350

The material properties are:

Young's Modulus 'E'	110 x 10 ³ MPa
Poisson's ratio	0.29
Density	7200 kg/m ³
Ultimate tensile strength	350 MPa

Results for Aluminium Alloy:

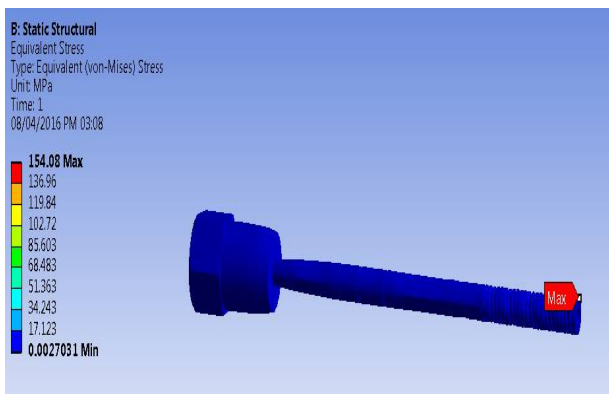


Fig 5.3: Stress in Aluminium Tie Rod

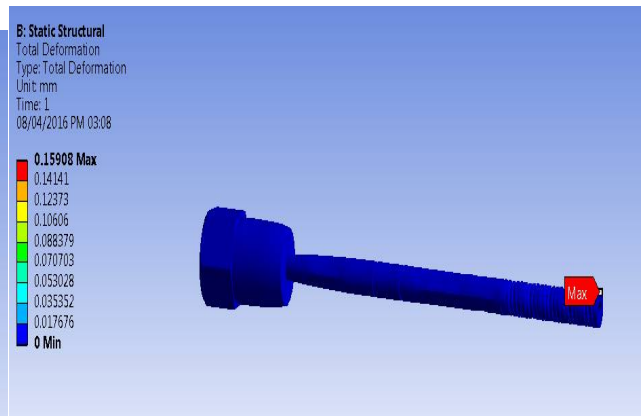


Fig 5.4: Deformation in Aluminium Tie Rod

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Results for Cast Iron:

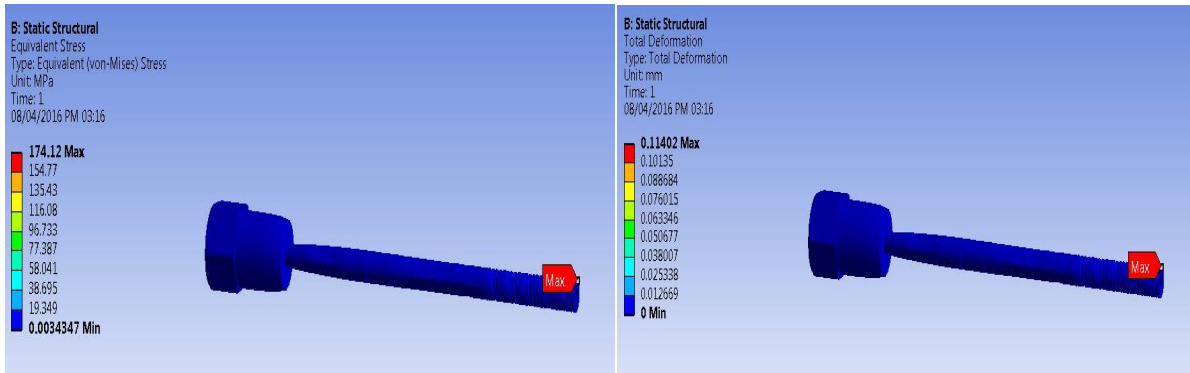


Fig 5.5: Stress in CI Tie Rod

Fig 5.6: Deformation in CI Tie Rod

Material	Stress, MPa	Deformation, mm	Weight, kg	Allowable Stress, MPa
Steel SM45C	166.6	0.06045	1.746	171.5
Aluminium Alloy 6082	154.08	0.15908	0.6145	170.0
Cast Iron – FG 350	174.12	0.11402	1.5993	175

Table 4: Results for various materials

- From the above result it can be seen that for weight condition Aluminium gives us better result without failure, hence can be used for alternative to existing material. Cost of material is less compare to Steel and Cast Iron.
- For case of Reliability and life, Steel is better (Weight on higher side).
- Cast Iron (CI) is good in strength, higher in weight compare to Aluminium. Cost of CI is on higher side.
- Depending on requirement material can be selected. So we select Steel SM45C (Existing material) for further work because it gives better results as compare to other materials.

VI. MODAL ANALYSIS OF OPTIMIZED TIE ROD

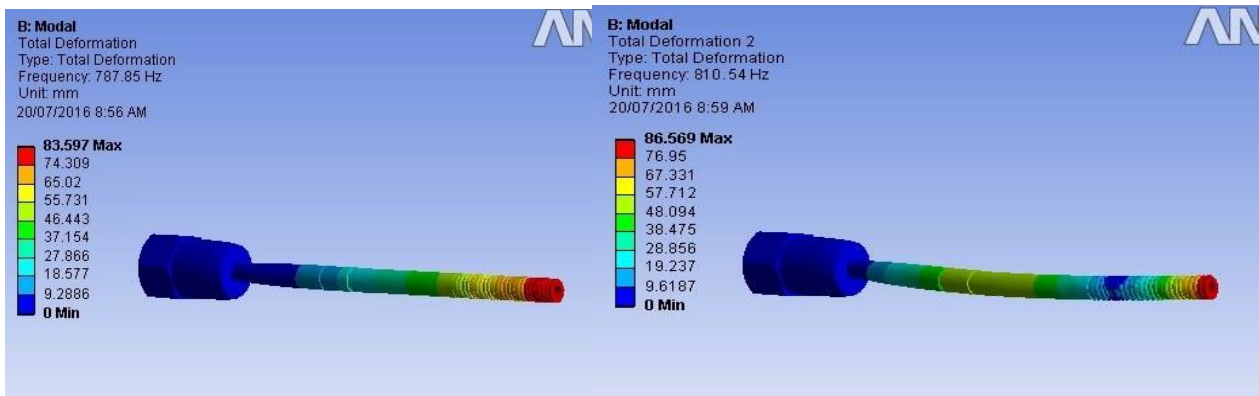


Fig 6.1: 1st Mode Shape result Optimized Tie rod

Fig 6.2: 2nd Mode Shape result

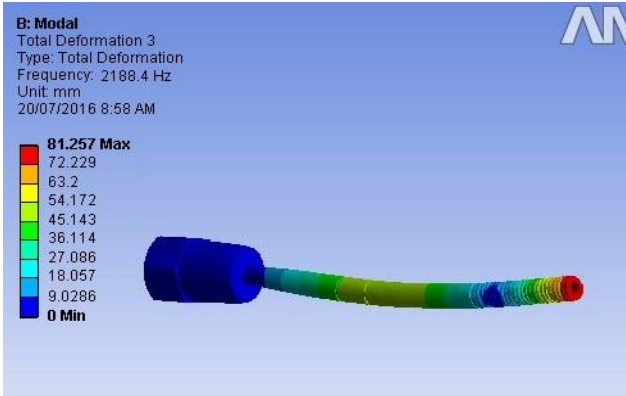


Fig 6.3: 3rd Mode Shape result

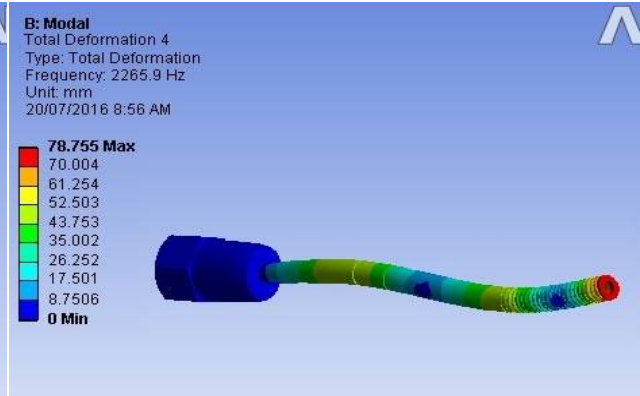


Fig 6.4: 4th Mode Shape result

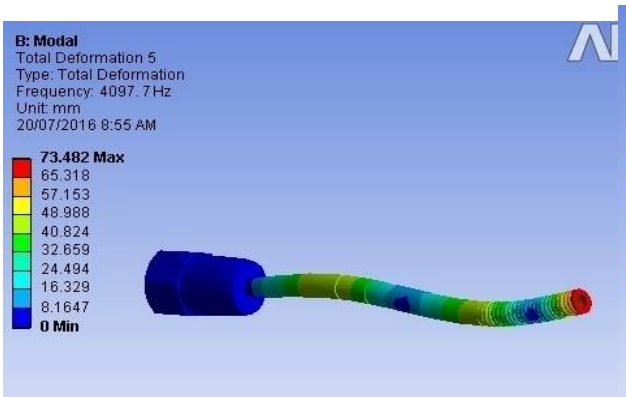


Fig 6.5: 5th Mode Shape result

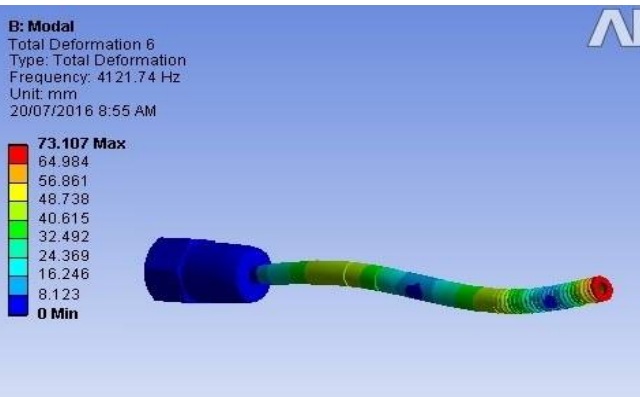
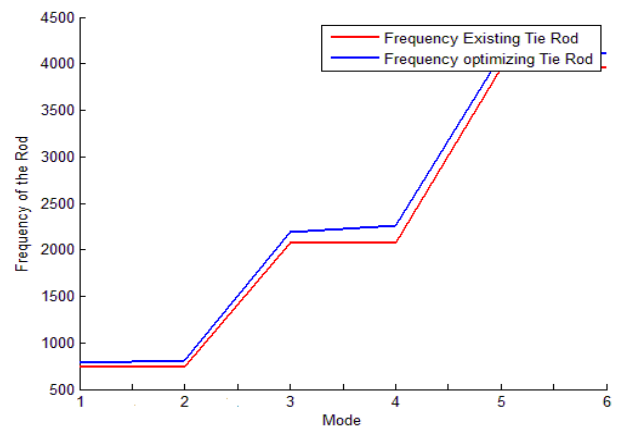


Fig 6.6: 6th Mode Shape result

Mode	Frequency [Hz] Existing Tie Rod	Frequency [Hz] Optimized Tie Rod
1.	742.62	787.85
2.	743.21	810.54
3.	2070.5	2188.4
4.	2072.	2265.9
5.	3957.8	4097.7
6.	3959.9	4121.74

Table 6: Result for Modal Analysis (Existing and Optimized)



Graph 1: Mode Shapes Vs Natural

From results of normal mode analysis, it is seen that the natural frequency of existing design is 742.62 Hz and proposed design is 787.85 Hz. So there is rise in natural frequency of proposed design. Further the second and onwards the frequencies of proposed design are increased compared to existing design. So overall the dynamic performance of tie rod is being improved.

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VII. VALIDATION

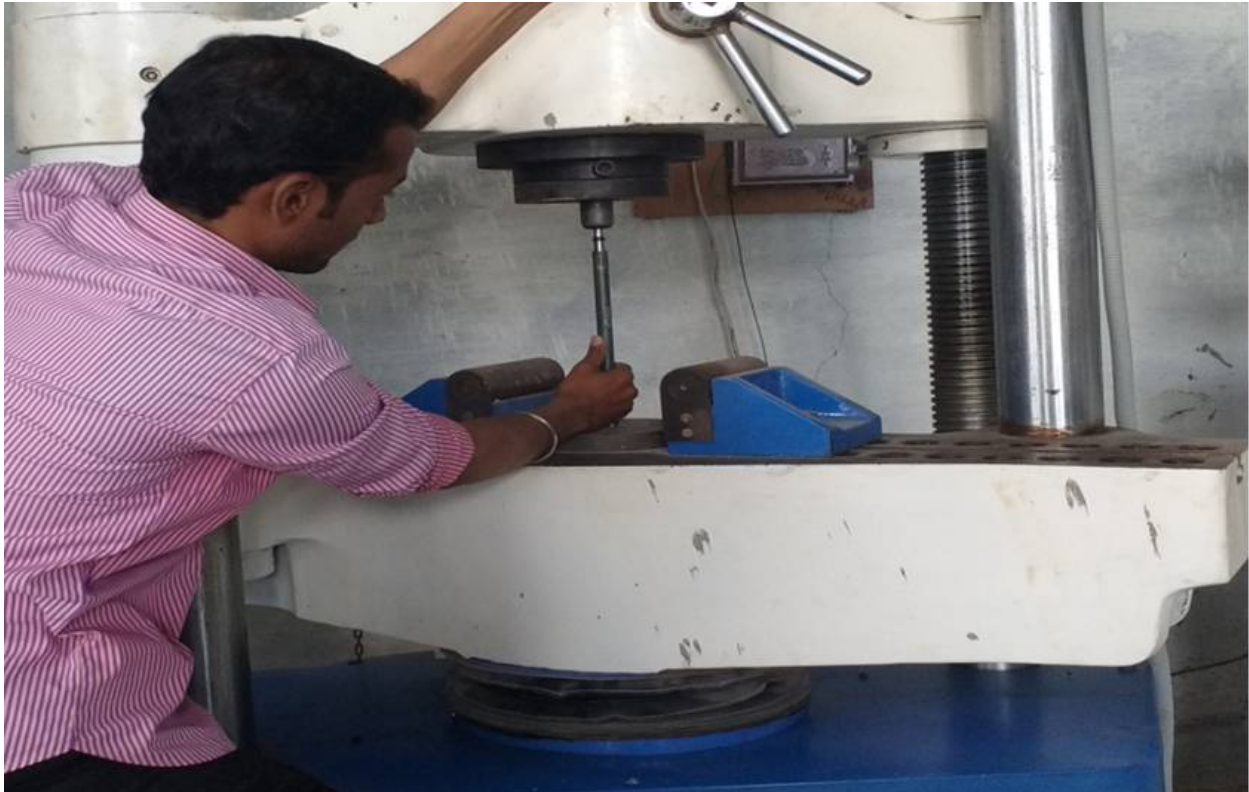


Fig 7.1: Test on UTM

Above figure shows the test set up of UTM. A compression test can be performed on UTM by keeping the Tie rod on base block and moving down the central grip to apply load. A compression testing machine shown in figure. it has two compression heads. The upper head moveable while the lower head is stationary. Load is applied from the top end of UTM vertically in Z-direction in pure axial direction. Initial load applied is 40N. The load is applied (its acts as compressive force) gradually to avoid any slippage of the rod during testing. Recorded change in length is tabulated. Test is carried out three times and average change in length is considered for finalized deformation.

Sr. No.	Load (N)	Recorded change in length (mm)
1	40	0.01002
2	400	0.01435
3	800	0.02564
4	1200	0.03827
5	1500	0.03996
6	2000	0.041880

Table 7: Test Result of Load and Deformation of Existing tie rod

Sr. No.	Load (N)	Recorded change in length (mm)
1	40	0.01221
2	400	0.01504
3	800	0.02564
4	1200	0.03827
5	1500	0.04982
6	2000	0.06010

Table 8: Test Result of Load and Deformation of Optimized tie rod

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Condition	ID, mm	Material	Deformation, mm
New Design	10.50	Steel- SM45C (Hollow)	0.06010

Table 9: Results(Test results)

VIII. RESULT COMPARISON FOR EXISTING AND OPTIMIZED TIE RODS

Parameters	Existing Tie Rod	Optimized Tie Rod
Material	Steel- SM45C (Solid)	Steel- SM45C (Hollow- ID – 10.50 mm)
Weight	1.96 kg	1.746 kg
% Change in Weight	Hollow Tie rod is 12.25 % lighter than Steel	
Stress	118.94 MPa	166.6 MPa
% Change in Stress	Hollow tie rod has 28.60 % more Stress than Steel but its within allowable limit	
Deformation	0.041988 mm	0.06045 mm
% Change in Deformation	Hollow tie rod has 30.54 % More deformation than Steel but it's not big issue	

IX. CONCLUSION

- Tie rod fillet radius plays important role in rod failure and should be carefully selected.
- The results we got for Tie rod are showing good improvement compare to allowable stresses.
- Tie rod with hollow ID- 10.50 mm shows safe results and is selected for further work.
- Hollow tie rod at 10.50 mm ID shows very less weight (12.25 %) compare to solid and hence finally suggested for Tie rod improvement for weight reduction application.
- Hollow tie rod at 10.50 mm ID shows high Stress (28.60 %) and deflection (30.54 %) values compare to steel but those are within limit while considering.

X. FUTURE SCOPE

- Dynamic Analysis can be done.
- Composite materials can be tested for less weight applications.
- Effect of Vibrations can be consider

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