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INVESTIGATION OF STRENGTH OF TORSIONAL BAR WITH EPOXY REINFORCEMENT

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Abstract: A torsion bar is a type of suspension system that is usually used in vehicles such as cars, trucks and vans. A suspension system is a significant and acute element of a vehicle's design. Irrespective of the design, all suspension systems do the same functions. They keep the tires in contact with the surface of the road, upkeep the weight of a vehicle and absorb the forces produced by the movement and motion of the vehicle. This project presents an application of Finite Element Analysis (FEA) for strength improvement of torsion bar. Alsoprovides fundamental knowledge of torsion bar analysis using composite material. The existing torsion bar is modelled using CATIA and analyzed using ANSYS 19.0. First optimization is done based on fiber orientation angles of composite material. Further alternate material selection is done through study and optimization analysis is done for the same. Carbon epoxy-glass fiber selected as material. Finite element analysis of both shafts will be done under torsional loading using ANSYS 19.0. CATIA V5 will be used for CAD modeling/Design of both shafts. Experimental investigation will be done by Torque Test. Comparative analysis of FEA and Experimental will be done for validation of work. Conclusion and future scope will be suggested.

Keyword –*Torsional bar, glass fiber, UTM*

I INTRODUCTION

A torsion bar is a type of suspension system that is usually used in vehicles such as cars, trucks and vans. A suspension system is a significant and acute element of a vehicle's design. Irrespective of the design, all suspension systems do the same functions. They keep the tires in contact with the surface of the road, upkeep the weight of a vehicle and absorb the forces produced by the movement and motion of the vehicle. Torsion bars are basically metal bars that perform the role of a spring. At one end, the bar is fixed rigidly in place to the chassis of avehicle. The last end of the bar may be fastened to the axle, suspension arm, or a spindle, depending on the vehicle's design. For instance a vehicle travels alongside the road, the forces made by the motion of the vehicle produce torque on the bar, which turns it along its axis. Counteracting the torque is the fact that the torsion bar obviously wants to resist the twisting effect and return to its normal state. By doing so, the suspension supplies a level of resistance to the forces generated by the movement of the vehicle. This resistance is the basic principle behind a torsion bar suspension system.

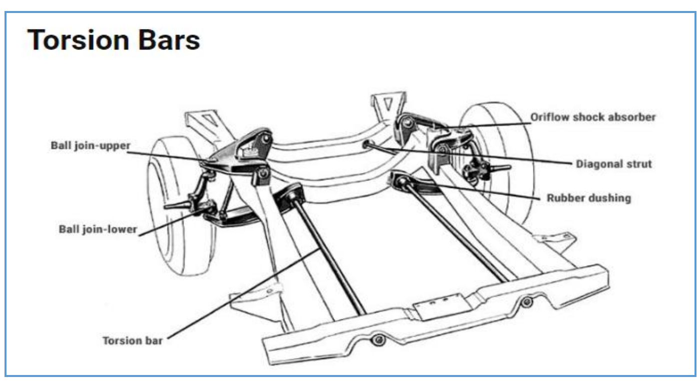


Fig. 1: Torsional bar assembly

A torsion bar suspension, also known as a torsion spring suspension, is any vehicle suspension that uses a torsion bar as its main weight-bearing spring. One end of a long metal bar is attached firmly to the vehicle chassis; the opposite end terminates in a lever, the torsion key, and mounted perpendicular to the bar that is attached to a suspension arm, a spindle, or the axle. Vertical motion of the wheel causes the bar to twist around its axis and is resisted by the bar's torsion resistance. The effective spring rate of the bar is determined by its length, cross section, shape, material, and manufacturing process.

Torsion bar, rod or bar that resists twisting and has a strong tendency to return to its original position when twisted. In automobiles a torsion bar is a long spring-steel element with one end held rigidly to the frame and the other end twisted by a lever connected to the axle. It thus provides a spring action for the vehicle.

II LITERATURE REVIEW

Alexander R. Tusnin, Milan Prokica. [1]In this study torsional analysis of I beam is carried out. Thin-walled rods in steel structures can work in conditions of bending with torsion. Dealing with bending, conjugate withwarping torsion can be a challenging task. Researchers do the detailed study on its behavior and carrying capacity to make justified choice of construction parameters. Research of bearing capacity at such work, taking into account development of material plastic deformations, is a topical issue. To develop a methodology for the design of beams experiencing both bending and twisting a careful theoretical and numerical analysis of these structures is needed. Justification of numerical and theoretical results requires experimental evaluation. Currently in MGSU experimental studies of I beams bearing capacity considering their warping torsion are under preparation. The article considers the numerical calculations of the experiment model of I-beam under torsion with bending. Behavior of the model was analyzed, considering mesh partitioning into finite elements, diagram of the material, support conditions.

Isa Ahmadi [2]Author going to study laminated composite bar with rectangular cross-section which is subjected to torsional torque and the three dimensional stress state, specially the out of plane stresses is investigated. A reduced displacement field is obtained for the long laminated bar in which the global and local deformation response of the laminate are separated. This reduced displacement field is obtained from integration of the strain components. In order to obtain the three dimensional stress state and free edge effect, the displacement based layer wise method is employed for formulation of the problem and the governing equations are solved analytically.They compare numerical results with the predictions of multi-term extended Kantorovich method and mixed-field multi-term extended Kantorovich method and with an analytical series solution and find very good result. The twisting, extension, and bending of laminate due to torsion torque, and the out of plane and in-plane stresses are studied for various layers stacking. In order to increase the accuracy, the out of plane stresses are obtained by integrating the equilibrium equations.

Balaguru S et al. [3]In these paper researchersdiscusses the stress and deformation developed in chassis during the different load cases and identifying the failure modes bythe modal analysis. It starts from the benchmark study of different scooter frame in the aspect of material selection, mechanical properties and the sections used in it. Then Structural and modal analysis of frame are carried out under the various load considerations. It involves 3D modeling in Pro-E, meshing in HyperMesh and analysis by ANSYS. In this work they validation the Frame design i.e. stress and deformation calculation using FEA and suggest the design recommendations. Bench mark study of the frame structure, load characteristics, metallurgical and mechanical properties of the scooter frame members and identification of critical stress areas and suggest for design improvement from the Modal analysis by identifying the different mode shapes and Natural frequency of the frame.

Paolo Baldisseraet al. [4]In this study design of a composite bicycle fork is discussed. The study of a special bicycle fork needed in a Student Team prototype, so this work proposes a simplified methodology as starting point for educational and manufacturing purposes. Inorder to compare two manufacturing solutions in terms of stiffness, strength and failure mode, a numerical model was developed by author. To avoid standard destructive testing, the model validation was based on a posteriori linear stiffness comparison with the manufactured component. In order to check their origin and to assess the reliability of the model the slight discrepancies between experimental and numerical results are discussed. The overall methodology, even if complain with only a part of the safety standard requirements, shows to be reliable enough and can be the basis for further extension and refinement.

MostafaKarimi et al. [5] Author presents a formulation for a circular bar reinforced by an orthotropic coating containingmultiple arbitrarily oriented cracks and cavities subjected to Saint-Venant torsional loading. First, the stress field of a circular bar with an orthotropic coating containing a Volterratype screw dislocation is found via Fourier transform. At the next step, the problem is reduced to a set of integral equations with Cauchy singularity in the domain via distributed dislocation method. The integral equations are evaluated via a numerical approach to find the stress intensity factors of the singular crack tips, hoop stresses on cavities, and torsional rigidity of the cracked bar with its coating. Researchers use von Mises yield criterion is to find the boundary of the plastic zone via the stress filed around crack tips. There are multiple examples to indicate the efficiency and correctness of the current approach in torsion problems of cracked circular bars with an orthotropic coating.

This work presents an efficient dislocation approach for the evaluation of the stress intensity factors and hoop stresses for multiplearbitrary shaped cracks and smooth cavities in a circular cylinder with an orthotropic coating. Researchers conclude that the stress intensity factors of crack tips and torsional rigidity in the circular bar with orthotropic coating can depend on critical factors such as the distance of the crack tip from the free boundary of the domain, thickness of the coating, crack length and interaction between the cracks. Result of this study shows that the largest value of dimensionless hoop stresses was observed at the points of the cavities with minimum curvature. The orthotropic material with G < 1 had a better effect on the reduction of the stress intensity factors.

Gerald R. Kress, Paolo A. Ermanni [6] Carbon fibre torsion bar is to be made to outperform steel bars. But problem is to introduce the torsion moment into the fiber bar. The search for an answer to the question of how to introduce the load into the composite bar has led to a design principle where a CFRP body is wound around a multi-functional steel mandrel which increases its radius towards the end which holds a spike annulus and also serves as adapter to connect with external parts

III PROBLEM STATEMENT

Torsion bars are long metal springs that are used in low-cost car suspension. As more load is placed on a torsion bar, the more the bar twists. The amount of the twist will differ depending on the material used in the bar. Torsion bar suspension is used because it is cheap and durable, but it can still go bad. Most often torsion bars are damaged through impacts on the undercarriage or through rust.

IV OBJECTIVES

1. Modeling of actual torsion bar in CATIA V5 software
2. Analyzing for stresses, deformation and reaction moments actual torsion bar using ANSYS 19.0.
3. Preparing Carbon epoxy-glass fiber reinforced torsion bar.
4. Analyzing for stresses, deformation and reaction moments on composite torsion bar.
5. Experimental testing on Torsion Testing Machine and correlating results.

V METHODOLOGY

Step 1: - We started the work of this project with literature survey. We gathered many research papers which are relevant to this topic. After going through these papers, we learnt about Reinforcement & Analysis of torsion bar.

Step2: - After that the components which are required for our project are decided.

Step 3: - After deciding the components, the 3 D Model and drafting will be done with the help of CATIA software.

Step 4: - The Analysis of the components will be done with the help of ANSYS using FEA.

Step 5: - The experimental observations will be taken on Torsion testing machine.

Step 6: - Comparative analysis of Reaction forces will be made between simulation and experimental results and then Results and conclusions will be drawn.

VI CATIA MODEL

Three-dimensionalmodel of existing wheel hub was making in Catia V5 R20 software.

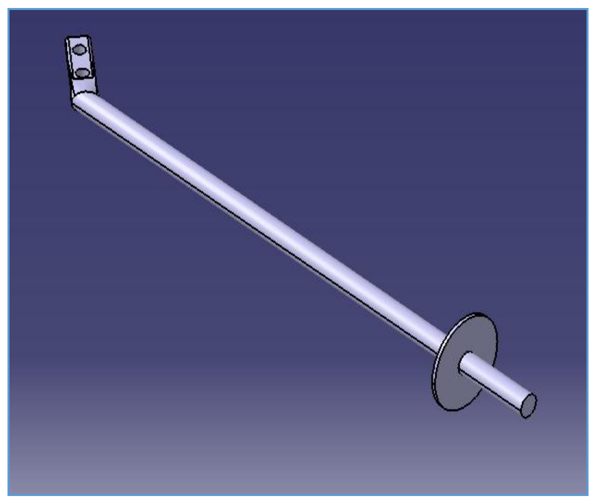


Fig. 2: CATIA model of torsional bar

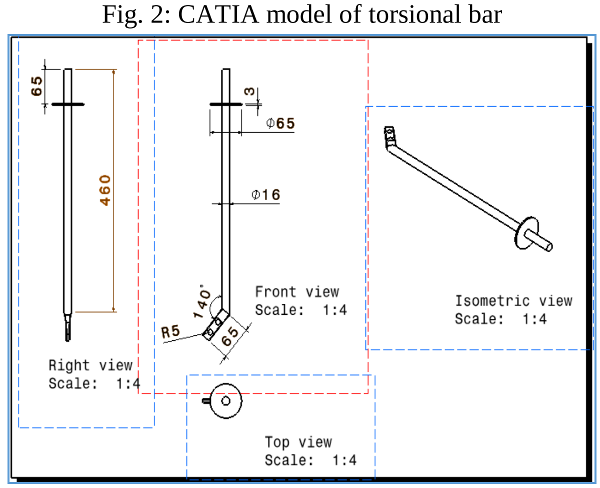


Fig. 3: Drafting of torsional bar

VI FEA ANALYSIS OF WHEEL HUB INANSYS

Material Selection – Structural Steel

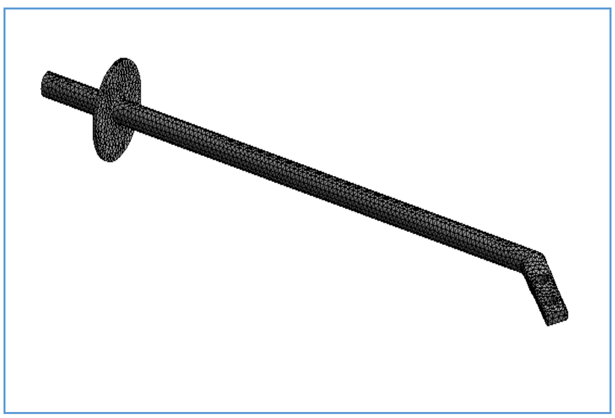
Properties of Outline Row 3: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	⊞ Isotropic Secant Coefficient of Thermal Expansion		
6	⊟ Isotropic Elasticity		
7	Derive from	Young's Modulu...	
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa

Fig.4Material properties

Mesh

ANSYS Meshing may be a general-purpose, intelligent, automated high-performance product. It produces the foremost appropriate mesh for accurate, efficient Multiphysics solutions. A mesh compatible for a selected analysis are often generated with one click for all parts during a model. Full controls over the choices want to generate the mesh are available for the expert user who wants to fine-tune it. the facility of multiprocessing is automatically wont to reduce thetime you've got to attend for mesh generation.



Details of "Body Sizing" - Sizing	
⊟ Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
⊟ Definition	
Suppressed	No
Type	Element Size
Element Size	4.0 mm

Statistics	
Nodes	26824
Elements	16027

Fig.5Mesh of torsion bar

After meshing of steering uprightnodes are 26824 and elements 16027.

Boundary Condition

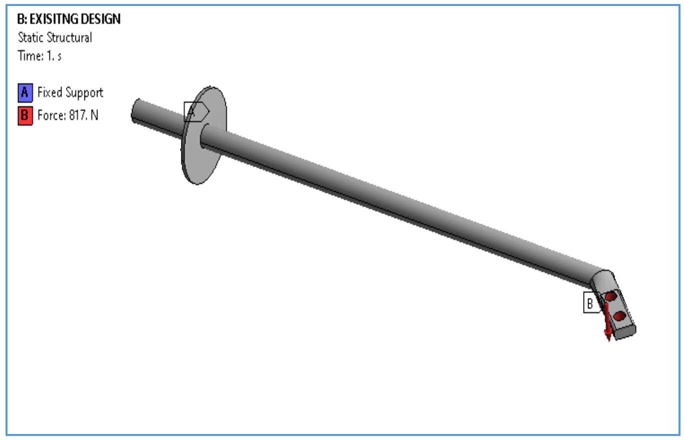


Fig. 6: Details of boundary conditions for static analysis

Results of existing design

Vehicle name – Maruti Omni van

Weight – 785 kg

Front axle weight shared is 30 % of overall weight that is 235.5 kg

Weight on each wheel is 235.5/2

That is 117.75 kg = 1177 N

But as per shoch absorber absorbs 30 % of shock so 30% is absorbed now remaining force is 817 N

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So we apply a load of 817 N.

Total deformation

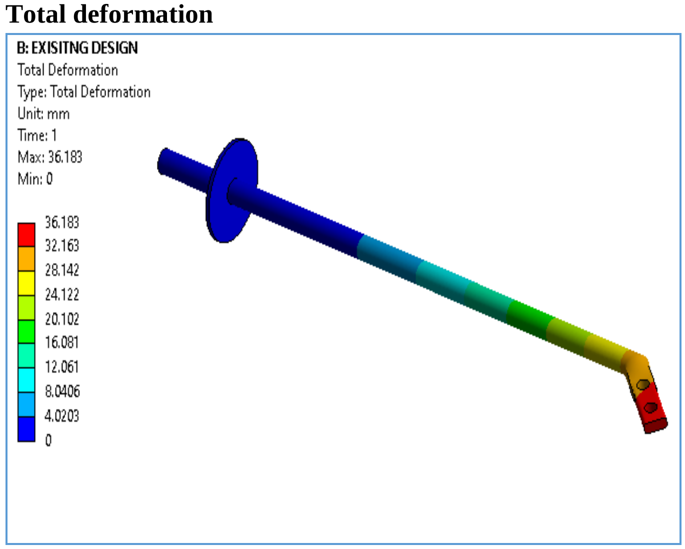


Fig. 7: Total deformation results

- Maximum deformation under static condition of steering upright 36.183 mm is observed.

Equivalent stress

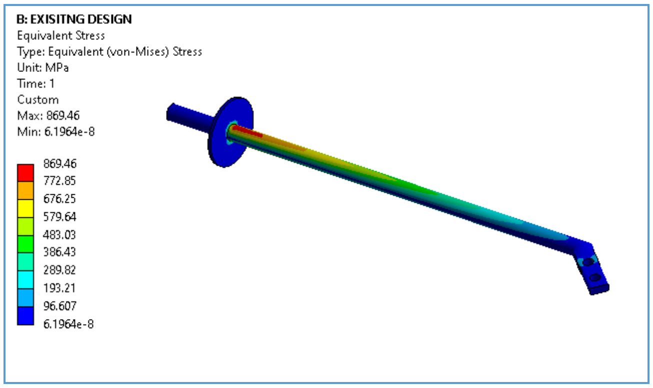


Fig 8 Equivalentstress **of**torsional bar

Maximum stress is observed around 95 MPa at lower cross section (bottom indicated as MAX) but average stress induced is about 44 MPa in green color. So, design is safe compared to yield strength of material.

VII REINFORCED TORSIONAL BAR

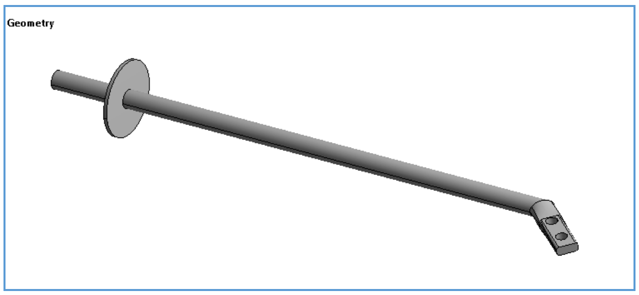


Fig.9CAD model of torsional bar with reinforcement

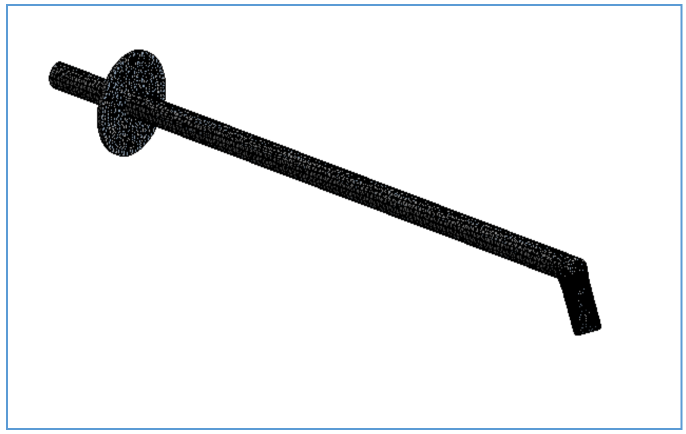
Properties of Outline Row 3: Epoxy E-Glass UD

	A	B	C
1	Property	Value	Unit
2	Density	2000	kg m^-3
3	Orthotropic Elasticity		
4	Young's Modulus X direction	4.5E+10	Pa
5	Young's Modulus Y direction	1E+10	Pa
6	Young's Modulus Z direction	1E+10	Pa
7	Poisson's Ratio XY	0.3	
8	Poisson's Ratio YZ	0.4	
9	Poisson's Ratio XZ	0.3	
10	Shear Modulus XY	5E+09	Pa
11	Shear Modulus YZ	3.8462E+09	Pa
12	Shear Modulus XZ	5E+09	Pa
13	Orthotropic Stress Limits		
14	Tensile X direction	1.1E+09	Pa
15	Tensile Y direction	3.5E+07	Pa
16	Tensile Z direction	3.5E+07	Pa
17	Compressive X direction	-6.75E+08	Pa
18	Compressive Y direction	-1.2E+08	Pa
19	Compressive Z direction	-1.2E+08	Pa
20	Shear XY	8E+07	Pa
21	Shear YZ	4.6154E+07	Pa
22	Shear XZ	8E+07	Pa

Fig.10Material properties for reinforcement

Layer	Material	Thickness (mm)	Angle (°)
(+Z)			
4	Epoxy E-Glass UD	1	0
3	Epoxy E-Glass UD	1	0
2	Epoxy E-Glass UD	1	0

Fig.11Layer for torsional bar



Statistics	
Nodes	79327
Elements	53354

Fig.12Meshing

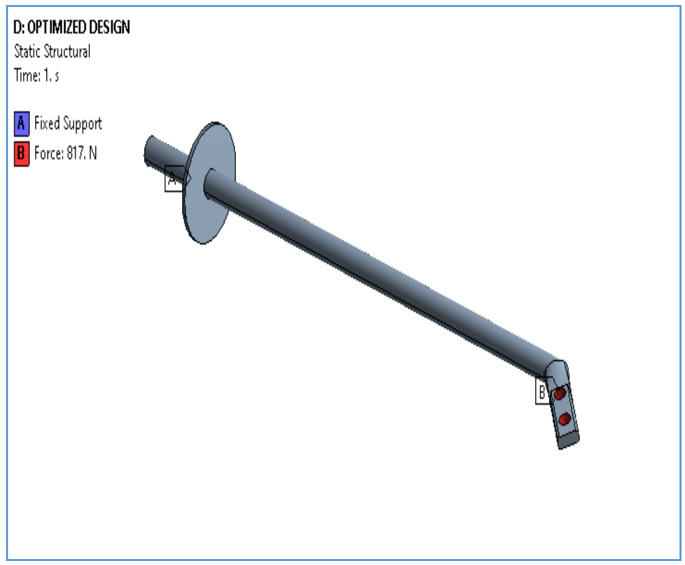


Fig.13Boundary condition

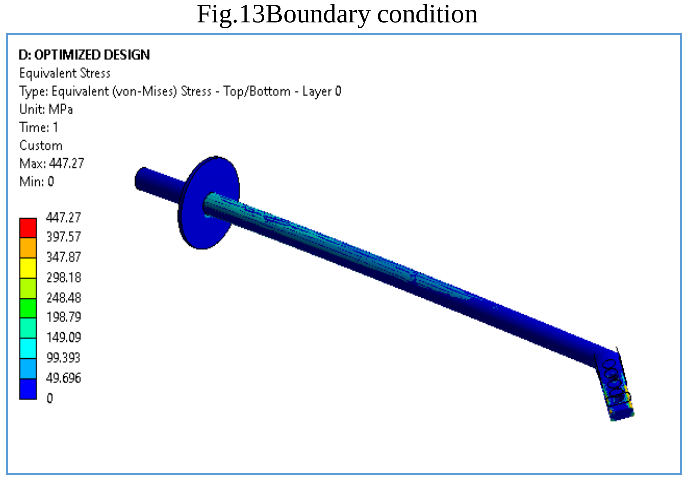


Fig.14Equivalent stress

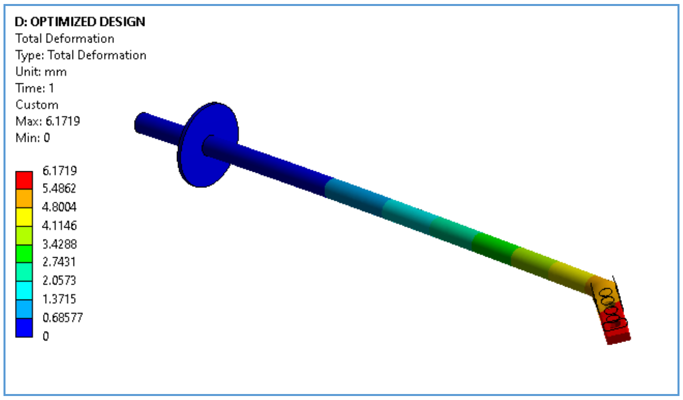


Fig.15Total deformation

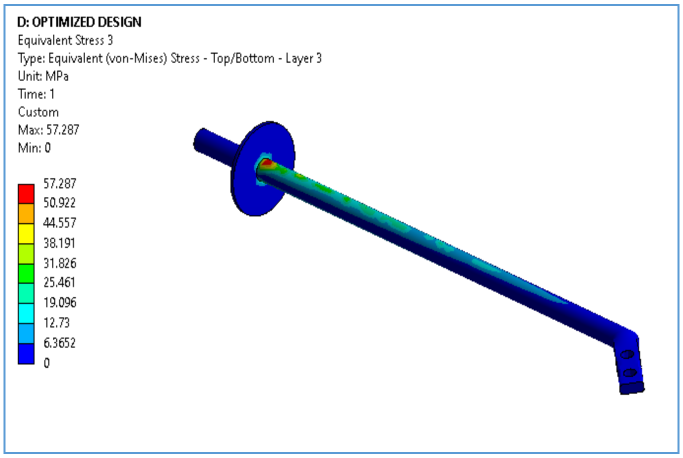


Fig.16Equivalent stress with layer 3

VIII EXPERIMENTAL SETUP

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 (in other words, that it is versatile). The set-up and usage are detailed in a test method, often published by a standards organization. This specifies the sample preparation, fixturing, gauge length (the length which is under study or observation), analysis, etc.The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips.Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen.

Specification of UTM

1	Max Capacity	400KN
2	Measuring range	0-400KN
3	Least Count	0.04KN
4	Clearance for Tensile Test	50-700 mm
5	Clearance for Compression Test	0- 700 mm
6	Clearance Between column	500 mm
7	Ram stroke	200 mm
8	Power supply	3 Phase , 440Volts , 50 cycle. A.C
9	Overall dimension of machine (L*W*H)	2100*800*2060
10	Weight	2300Kg

IX EXPERIMENTAL TESTING FEA

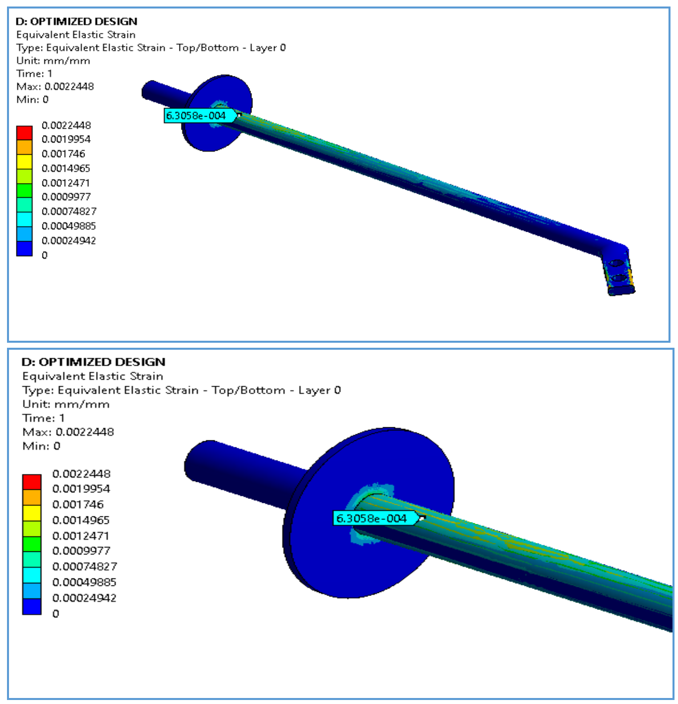


Fig.17 Experimental testing strain results

By FEA analysis strain is observed around 630microns.

Experimental procedure

- Fixture is manufactured according to component designed.
- Single force is applied as per FEA analysis and reanalysis is performed to determine strain by numerical and experimental testing.
- Strain guage is applied as per FEA results to maximum strained region and during experimental testing force is applied as per numerical analysis to check the strain obtained by numerical and experimental results.

- During strain gage experiment two wires connected to strain gage is connected to micro controller through the data acquisition system and DAQ is connected to laptop. Strain gage value are displayed on laptop using DEWESOFT software.

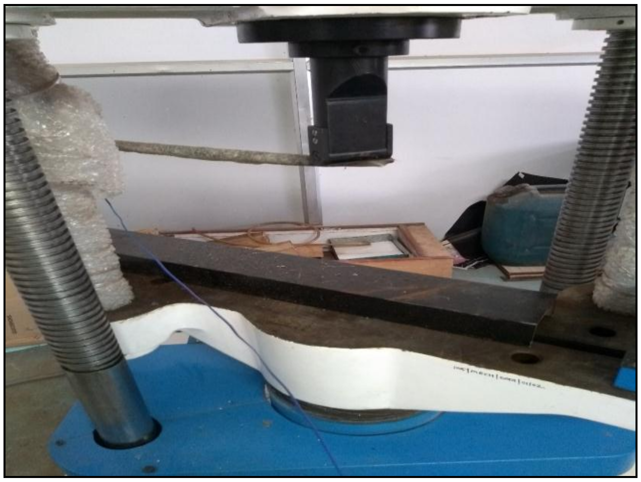


Fig.18 Experimental testing setup

Fig.19 Experimental testing setup

Fig.20 Experimental testing setup

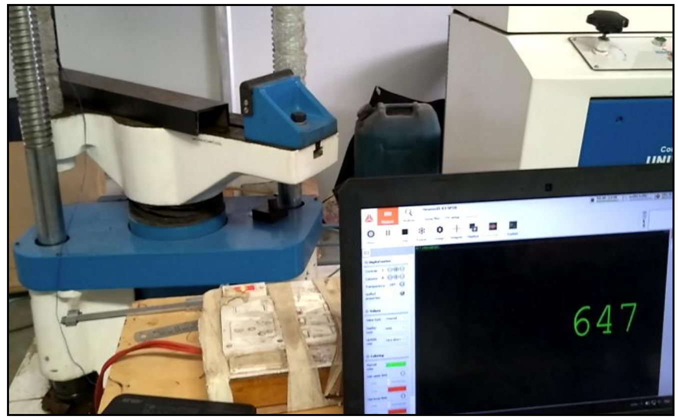
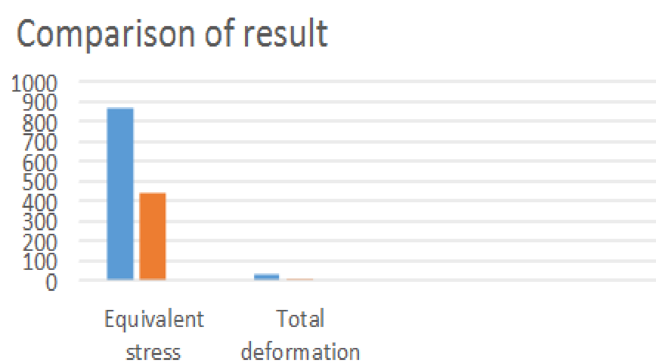


Fig.21Experimental result

X CONCLUSION

- Static structural analysis of torsional bar is performed to determine deformation and equivalent stress. It is observed that around maximum deformation is 36.18 mm and equivalent stress is 869.46 MPa.
- After reinforcing the glass fiber on torsional bar, the strength was increased. Static structural analysis of torsional bar after reinforcement determine total deformation 6.17 mm and equivalent stress 447.27 mpa
- Strain measurement of 630 microns and 647 microns by numerical and experimental testing respectively.
- Thus we can conclude that the stress and strain capacity of the torsion bar is largely enhaced after reinforcement of epoxy E glass layers.



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