JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Analysis Of Torsion Rod Used In Automobile For Different Material And Loading Condition.

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Abstract: In today's world transportation plays key role in human race, and in transportation automobile are Widely used. Torsion rod in a part of automobile suspension system which is responsible for comfort of passengers. The purpose of this study is to investigate torsion deflections and energy storage of the composite bar in torsion bar suspension system. The results reveal distinct performance characteristics for SAE5135H and S-Glass.[1] SAE5135H demonstrates higher shear strength and lower total deformation, making it suitable for applications requiring strength and stability.[3] In contrast, S-Glass exhibits higher strain energy and total deformation, indicating superior flexibility and energy absorption. The study contributes valuable insights into material selection for torsion rod applications, considering the specific requirements of strength, deformation, and energy absorption. The presented results and comparisons aid in informed decision-making for designing torsion rods based on desired performance criteria. Additionally, the study suggests potential areas for further research, such as exploring alternative materials and investigating the impact of different boundary conditions on torsional behaviour.[5]

Keywords—Torsion rod, Uniform Tapered rod, Vibration, Automobile, S-Glass, Shear stress analysis, SolidWorks simulation, ANSYS finite element analysis, Performance optimization.

I. INTRODUCTION:

In the modern era, the world heavily relies on transportation, and at the heart of this transportation network are automobiles. These vehicles have become an integral part of our daily lives, connecting people, goods, and services across the globe. To ensure a smooth and comfortable ride for passengers, the suspension system of automobiles plays a vital role. Among its various components, the torsion rod stands out as a critical element in managing vehicle dynamics and enhancing ride quality.[1]

The torsion rod, also known as a torsion bar, is a fundamental part of the automobile's suspension system. It is designed to withstand the rigors of the road, absorbing and managing the forces and vibrations that a vehicle encounters during its journey. The torsion rod is responsible for mitigating vibrations, reducing the impact of road irregularities, and providing stability, all of which contribute to a more comfortable and secure driving experience.

The purpose of this comprehensive study is to delve into the intricate aspects of torsion rods, with a particular focus on their deflection characteristics and energy storage properties within the context of a torsion bar suspension system. The research aims to provide a detailed analysis and comparison of uniform tapered torsion rods constructed from two distinct materials: SAE5135H[10], an alloy of steel, and S-Glass [2], a Fiber-reinforced plastic.[3]

Material choice is a critical factor in determining the performance of torsion rods, as it directly influences their mechanical properties and behaviour under various loads. To facilitate this analysis, the study considers two materials with distinct compositions and properties, allowing for a thorough investigation of their respective strengths and weaknesses in the context of automobile suspension.[4]

The core parameters under examination in this research include shear stress, deformation, and strain energy. These key metrics are meticulously evaluated using advanced engineering simulation tools such as ANSYS and SolidWorks. By subjecting the torsion rods to a range of loads and conditions, the study provides valuable insights into their performance and behaviour.

The comparative analysis conducted in this research is expected to yield valuable findings that can inform material selection and design optimization for torsion rods in automobile suspension systems. As the transportation industry continues to evolve and adapt to changing demands, the insights from this study are poised to contribute to the development of more efficient and comfortable vehicles for the future.[5]

II. LITERATURE REVIEW:

The various researches have been study for the performance of the torsional rod, some of them are**:**

M. Manikandan, K. Raja, V.S. Chandrasekar [1]

The research presented in the paper focuses on the "Experimental Investigation on Torsion Bar Suspension System Using E-Glass Fiber Reinforced Composite Material." The study aims to explore the torsion deflections and energy storage characteristics of a composite torsion bar used in a vehicle's suspension system. The authors conduct experiments on a solid steel bar wound with E-Glass fibre reinforced with epoxy resin to create a composite torsion bar. They use a torsion test machine to analyse the static and dynamic properties of the torsion spring bar. The paper discusses parameters like torque, modulus of resilience in torsion, and angle of twist, and provides experimental results comparing the composite torsion bar with a conventional steel torsion bar.

N. M. Cameron and C. F. Rapp [2]

The study mainly focuses on the manufacturing processes and properties of fiberglass. It covers two main types of fiberglass: continuous glass fibres and insulation wool fibres. The study provides information about the compositions, properties, and uses of these fiberglass types, as well as details about the manufacturing processes involved in their production. Additionally, the study discusses recent developments in fiberglass technology, including environmental considerations and innovative product variations. Overall, the main focus of the study is on the materials, processes, and recent advancements related to fiberglass production.

Prateek Shrivastava D, Ruchika Saini, Abhishek Kumar (2020)[3]

This research evaluates different torsional rod designs in automotive suspension systems to reduce vibrations on uneven roads and enhance driving comfort. Using software like CATIA and ANSYS, the study analyses shear stress, deformation, and strain energy for three rod types: stepped taper rods, tapered rods, and uniform stepped rods with specific length of 110mm and 130 mm. Tapered rods endure the least stress, while uniform stepped rods experience the highest. Stepped tapered rods with uniform steps deform the most. Uniform stepped rods store the highest strain energy. The study suggests employing stepped rods with particular parameters, such as L1 = 60 mm, L2 = 50 mm, D1 = 4.21 mm, and D2 = 4.02 mm, for both 110mm and 130mm length rods, in order to effectively dampen vibration in car suspension systems. Shear stress, deformation, and strain energy properties of stepped rods were favourable.

Nan, Jijun Feng (2022)[4]

The study focuses on the variables that lead to incidents involving off-road vehicles (orvs) having fractured torsion bars. The research analyses samples of fractured torsion bars and determines that the fractures occur at the junction of the spline end and take the form of a ratchet pattern with a 45-degree fracturing vector to the bar axis. All failed components exhibit the same fracture patterns and initiation sites, suggesting to a shared cause of failure. The failure reason was identified using a variety of techniques, including scanning electron microscopy (SEM), metallographic inspection, hardness testing, and spectral component analysis. Results suggested that the fractures were caused by fatigue cracking, which started from the spline junction as it was too brittle. An experiment using a tempering simulation validated the investigation's conclusion that the brittleness was caused by insufficient tempering following the quenching process.

K. Radhakrishnan, A. Godwin Antony, K. Rajaguru, B. Sureshkumar (2019)[5]

This study aims to enhance driver comfort in off-road vehicles by reducing vertical vibrations. It proposes a unique torsion bar mechanism with adjustable stiffness through a control arm system. Using ANSYS, the research analyses size, stiffness, deflection, and shearing stress. The goal is to minimize vertical vibration transmission from the driver to the wheels, improving comfort on long off-road trips. The study identifies fatigue cracking due to improper tempering as a key issue and recommends extending tempering time. It suggests specific rod specifications for automotive suspension systems to achieve effective vibration damping and performance enhancement.

Z.R. Lu, M. Huang, J.K. Liu, W.H. Chena, W.Y. Liaob (2009)[6]

The composite element method (CEM) is used in this study to analyse the free and forced vibrations of beams with various cross-sectional steps. The findings of the standard Rayleigh-Ritz approach, the receptance function, and the new method are compared. The CEM's natural frequencies and forced vibration responses are validated using data from experiments and other methodologies. Without the necessity for partitioning into uniform pieces, the approach produces precise results and can handle beams with a range of cross-sections. The study proves that the composite element method is accurate and useful for assessing the vibrations of stepped beams in engineering applications.

Rajashekhar Sardagi, Dr. Kallurkar Shrikant Panditrao (2014)[7]

The torsion bar, an essential part of the suspension system for passenger cars, is designed and optimized in this work. The major goal is to provide the best suspension system possible while also enhancing the car's comfort and stability. We examine the torsion bar as a crucial component in achieving these objectives. The study suggests using nylon instead of steel for the torsion bar in an effort to lighten the unsprang mass and, as a result, lower fuel consumption. The goals of the paper include performing torsion tests on Mild Steel (MS) and Nylon specimens, examining their characteristics, and contrasting their results. Modelling and failure analysis are done using ANSYS software. The calculations and test outcomes reveal that Nylon demonstrates promising qualities, making it a feasible material. It is emphasized that Nylon has exceptional abrasion resistance, high strength-to-weight ratio, and good flexibility. According to the study, nylon could work well as a torsion bar material, lowering suspension system weight and enhancing vehicle performance. The study supports the potential use of nylon as a substitute material for passenger automobile torsion bars, to sum up. The findings show that it has advantages over conventional mild steel, especially in terms of weight savings and potential increases in fuel economy. The study's conclusions might inspire improved suspension systems for cars, improving comfort and stability.

V. Vijayan, T. Karthikeyan. (2014)[8]

In this research, compliant mechanisms are applied to passive vibration isolation systems. To regulate displacement transmission and lessen unwanted vibrations, a compliant mechanism with an isolator is used. The mechanism's compliance is added to regulate the transfer of force at various frequencies. ANSYS software is used to do structural optimization to establish the mechanism's topology, shape, and size. It is suggested to use a library of compliant components that can be put together to lessen transmitted force and vibration. This method is contrasted in the study with a conventional coil spring isolator. Both mechanisms' displacement amplitudes and force transmission are evaluated using harmonic analysis. The findings show that the compliant mechanism offers more effective vibration isolation, with better isolation efficiency at a particular frequency as compared to the coil spring isolator.

III. MATERIAL USED:

For the analysis of torsion rod, we will use two Materials i.e., SAE5135H (Alloy of Steel) and S-Glass (Fibre-reinforced plastic).

- **SAE5135H:** SAE5135H has a nominal composition of following element

Table 1: Chemical Composition of SAE5135H Material.[10]

Element	**Composition (in%)**
Iron, Fe	97.445-98.17
Chromium, Cr	0.750-1.00
Manganese, Mn	0.600-0.800
Carbon, C	0.330-0.380
Sulphur, S	≤ 0.0400
Phosphorus, P	≤ 0.0350
Silicon, Si	0.150 - 0.300

- **S-Glass:** S-Glass has a nominal composition of following element

Table 2: Chemical composition of S-Glass Material.[2]

Element	**Composition (in%)**
Silicon oxide, SiO_2	64-66
Aluminium oxide, Al_2O_3	24-25
Boron trioxide, B_2O_3	4-6
Calcium oxide CaO	0-0.1
Magnesium oxide MgO	9.5-10
Sodium oxide, Na_2O + Potassium oxide, K_2O	0-0.2

- **Mechanical Properties of these two materials:**

Table 3: Mechanical properties of material considered for analysis (SAE5135H and S-Glass) [10][2]

Properties	**SAE5135H**	**S-Glass**
Yield Strength (MPa)	512	N/A
Tensile Strength (MPa)	958	4890
Modulus of Elasticity (MPa)	379000	89000
Young Modulus (MPa)	190000	86900
Fatigue Strength (MPa)	240	70
Shear Modulus	73000	39000
Poisson's Ratio	0.29	0.23
Density	3.11	2.46

IV. DIMENSIONAL PARAMETERS:

Dimension of rods in this study are mentioned below which has been obtained from the investigation performed by Prateek Shrivastava.

Table 4: Dimension parameter used for analysis taken for analysis.[3]

S no.	Full length of Shaft (mm)	Optimal Diameter (mm)
1	130	D1 = 4.37 D2 = 4.21
2	110	D1 = 4.37 D2 = 4.21

V. CALCULATION:

The material properties and the boundary condition are used in this study mention below has been obtained with various studies of N. M. Cameron and C. F. Rapp and M. Manikandan, K. Raja and V.S. Chandrasekar.[5][1][]

- In this study one end of the bar remains fixed during whole experiment.
- And on the other end, twisting moment of different load (15000N-mm to 20000N-mm) is applied.

The equation of Torsion is:

$$\frac{\tau}{r} = \frac{T}{J} = G\theta/L$$

The equation of Torsion Strain Energy is:

$$U = \int_0^l \frac{T^2 dx}{2GJ}$$

VI. MODELLING OF TORSION ROD:

Based on the dimension of the torsion rod we first make a drawing in AutoCAD 2021 and then make a solid model using SolidWorks 2021, the Solid Model of Torsion Rod is selected used in 4-Wheeler to control the vibration generated through engine. Then the model is imported into Ansys 2018R1.Fig 1,2 Shows the dimension of the model. In the first model the length of rod selected is 130mm with both end diameter as 4.37mm and 4.21mm respectively. And for the second rod the length selected is 110mm with both end diameter as 4.37mm and 4.21mm respectively (Shown in table 1). [3]

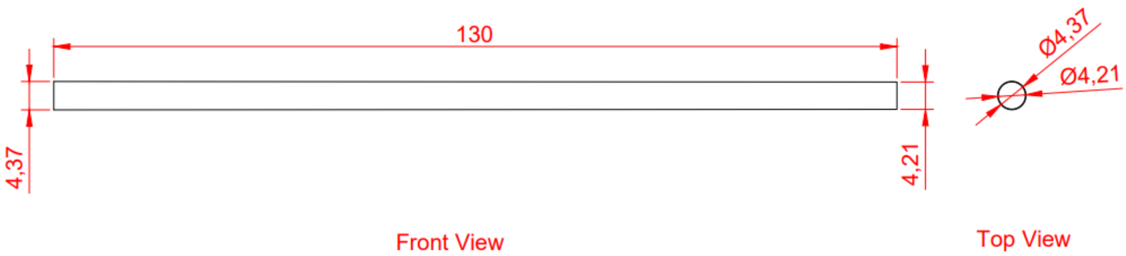


Fig. 1 Uniform Tapered Rod of 130mm Length

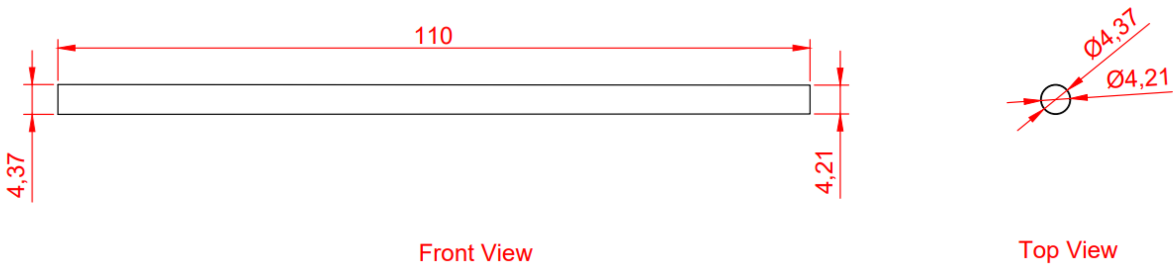


Fig. 2 Uniform Tapered Rod of 110mm Lenght

VII. ANSYS ANALYSIS:

Model Prepared using SolidWorks were imported in Ansys for analysis. Material properties as mention in table 3 were assigned to each model which were meshed (default) later. The mesh generated for the rods has been given in the table 5 and table 6 and shown the figure 4 and figure 5. Then we imported the load in the model where fixed support was applied on the large dimeter end (4.37mm) and torque (15000n-mm to 20000n-mm) was applied at the smaller diameter end.[3]

In all the cases of different load the total no of element selected varied between 245 to 290 and total no of nodes used varied between 1500to 1900.

Table 5: Meshing details of torsion rod.

S. no.	Component Specification	Number of Nodes	Number of Element	Mesh curve
1	Rod of 130mm	1820	290	Rectangular Surface Mesh
2	Rod of 110mm	1545	245	Rectangular Surface Mesh

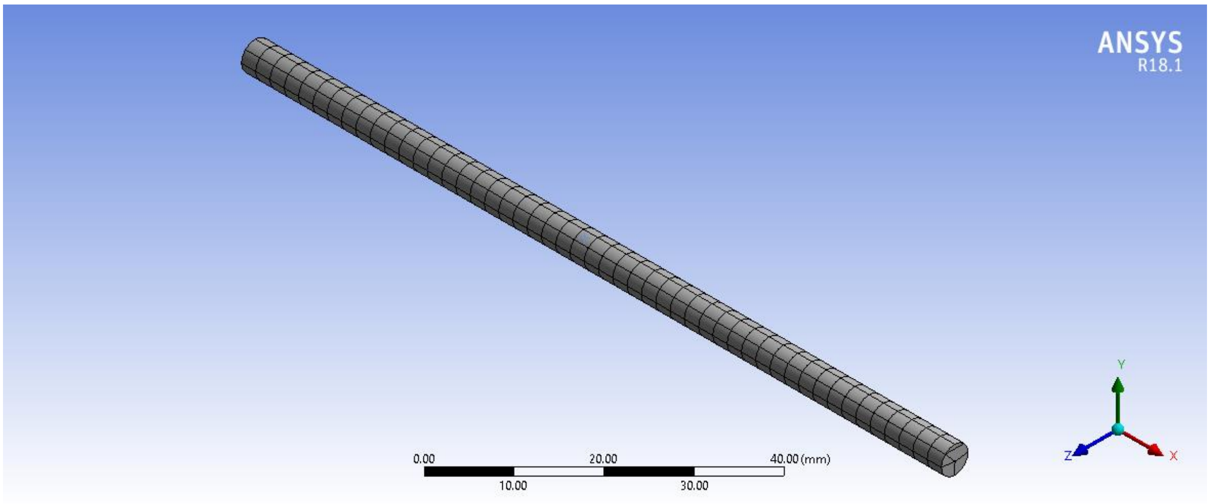


Fig.3: Meshing of 110mm length rod

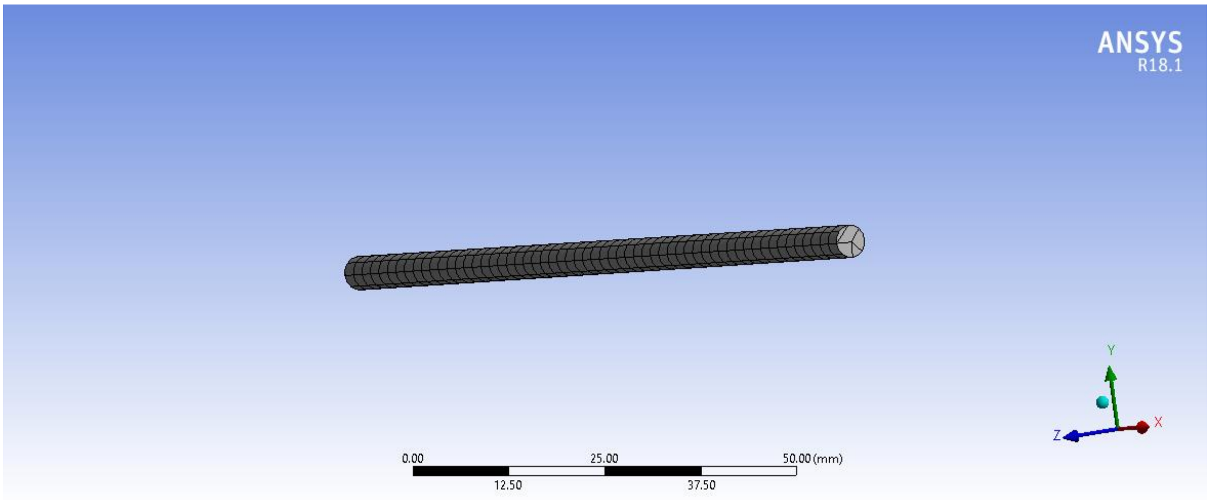


Fig.4: Meshing of 130mm length rod

VIII. RESULT AND DISCUSSION:

The various result obtained by using SolidWorks and ANSYS under different types of torsion rod have been plotted and summarized in the following tables.

Fig 3 illustrates the behaviour of shear stress (on ordinate axis) with various load range (on abscissa) for torsional load for the length of rod 130mm using both material SAE5135H and S-class. Fig 4 illustrates the behaviour of strain energy (on ordinate axis) with various load ranges (on abscissa) for the rod of length of rod 130mm using both material SAE5135H and S-Glass, Fig 5 illustrates the behaviour of total deformation (on ordinate axis) with various load ranges (on abscissa) for the rod of length of rod 130mm using both material SAE5135H and S-Glass, Fig 6 illustrate the behaviour of Equivalent stress (on ordinate axis) with various load ranges (on abscissa) for the rod of length of rod 130mm using both material SAE5135H and S-Glass.

Fig 7 illustrates the behaviour of shear stress (on ordinate axis) with various load range (on abscissa) for torsional load for the length of rod 110mm using both material SAE5135H and S-class. Fig 8 illustrates the behaviour of strain energy (on ordinate axis) with various load ranges (on abscissa) for the rod of length of rod 110mm using both material SAE5135H and S-Glass, Fig 9 illustrates the behaviour of total deformation (on ordinate axis) with various load ranges (on abscissa) for the rod of length of rod 110mm using both material SAE5135H and S-Glass, Fig 10 illustrate the behaviour of strain Equivalent stress (on ordinate axis) with various load ranges (on abscissa) for the rod of length of rod 110mm using both material SAE5135H and S-Glass.

Table 6: Ansys result for Torsion rod of 130mm length under various load using SAE5135H Material.

S NO.	LOAD APPLIED (N-mm)	SHEAR STRESS (MPa)	STRAIN ENERGY (MJ)	TOTAL DEFROMATION(MM)	EQUIVELENT STRESS (MPa)
1	15000	1397	14.968	0.84738	2574.5
2	16000	1490.2	17.03	0.90436	2746.2
3	17000	1583.3	19.226	0.96088	2917.8
4	18000	1676.4	21.554	1.0174	3089.4
5	19000	1769.6	24.016	1.0739	3261.4
6	20000	1862.7	26.61	1.1304	3432.7

Table 7: Ansys result for Torsion Rod of 130mm length under various load using S-Glass Material.

S NO.	LOAD APPLIED (N-mm)	SHEAR STRESS (MPa)	STRAIN ENERGY (MJ)	TOTAL DEFROMATION(MM)	EQUIVELENT STRESS (MPa)
1	15000	1391.1	60.507	3.3893	2588.9
2	16000	1483.9	68.543	3.6159	2761.5
3	17000	1576.6	77.717	3.8412	2934.1
4	18000	1669.4	87.129	4.0672	3106.6
5	19000	1762.1	97.079	4.2931	3279.2
6	20000	1854.8	107.51	4.5191	3451.8

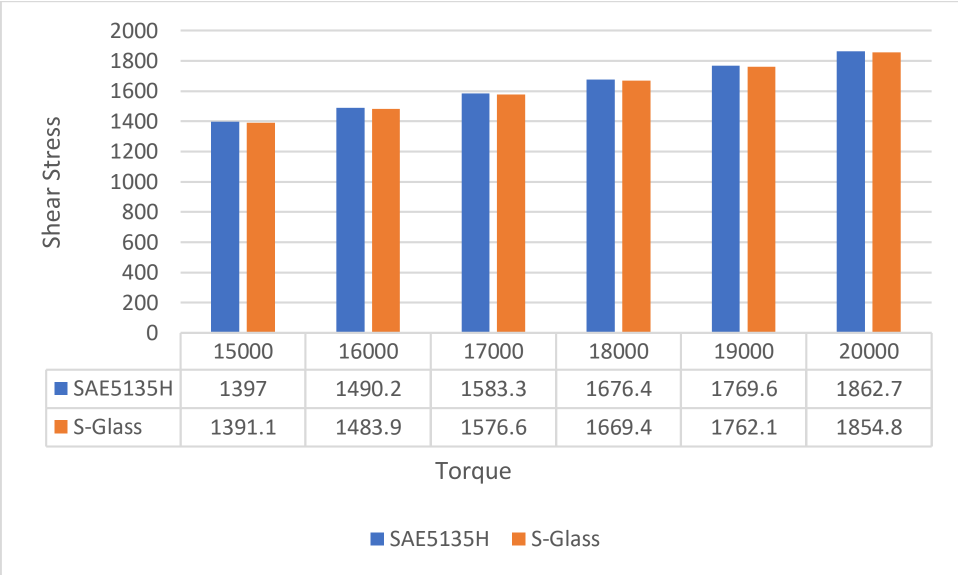


Fig.5: Shear Stress comparison in 130mm rod in different material

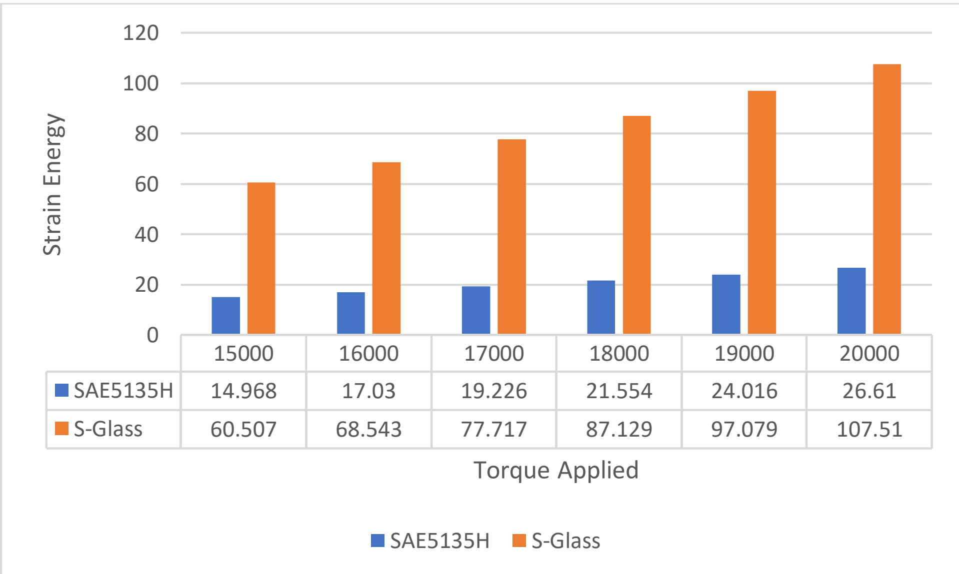
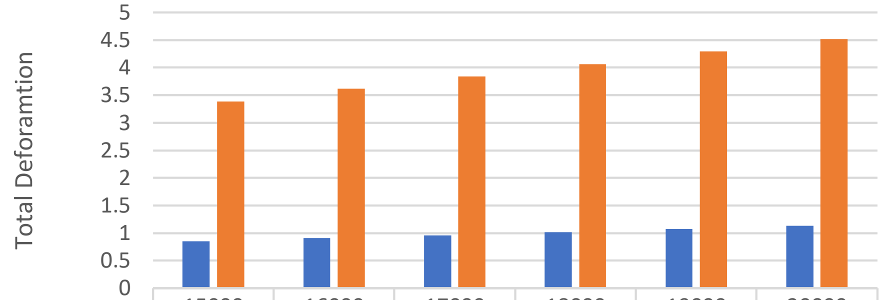
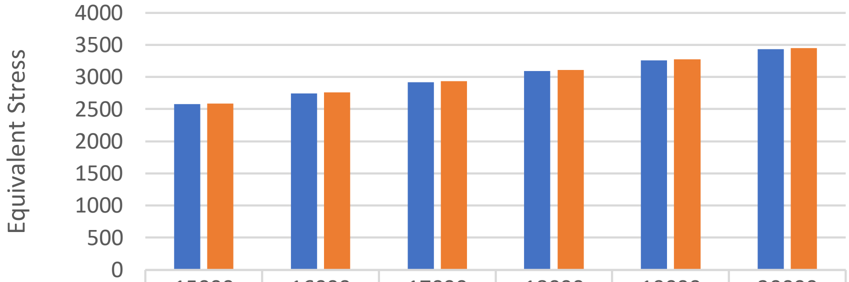


Fig.6: Strain energy comparison in 130mm rod in different material



	15000	16000	17000	18000	19000	20000
SAE5135H	0.84738	0.90436	0.96088	1.0174	1.0739	1.1304
S-Glass	3.3893	3.6159	3.8412	4.0672	4.2931	4.5191

Fig.7: Total Deformation comparison in 130mm rod in different material.



	15000	16000	17000	18000	19000	20000
SAE5135H	2574.5	2746.2	2917.8	3089.4	3261.4	3432.7
S-Glass	2588.9	2761.5	2934.1	3106.6	3279.2	3451.8

Fig.8: Equivalent Stress comparison in 130mm rod in different material.

Fig 5 illustrates the shear stress for the rod of 130mm full length for the application of torque ranges from 15000 n-mm to 20000 n-mm with the shear stress on ordinate axis and various types of loads on the abscissa. There is a little difference on shear stress both materials were S-Glass material observed higher shear stress as compare to SAE5135H.

Fig 6 shown the strain energy for each type of material having the length of 130mm length for the application of torque ranges from 15000 N-mm to 20000 N-mm using two material S-Glass and SAE5135H increase trend is observed with increasing torque in both the material. There is a big difference in strain energy between SAE5135H and S-Glass, which means that SAE5135H is suitable material for the strain energy prospective.

Fig 7 shows the deformation in the rod having length of 130mm applied under torque ranges from 15000 N-mm to 16000 N-mm in both materials. Fig represents that the deformation in the S-Glass is high as compare to SAE1535H, which make it suitable for long term use.

Fig 8 represents the Equivalent stresses for rod of length 130mm in both material under the torque ranges from 15000 N-mm to 16000 N-mm. Which shows that Equivalent stress is less in S-Glass material as compare to SAE5135H.

Table 8: Ansys result for Torsion Rod of 110mm length under various load using SAE51355H Material.

S NO.	LOAD APPLIED (N-mm)	SHEAR STRESS (MPa)	STRAIN ENERGY (MJ)	TOTAL DEFROMATION(MM)	EQUIVELENT STRESS (MPa)
1	15000	1092.4	14.864	0.71801	2504.4
2	16000	1238.1	19.092	0.81375	2838.3
3	17000	1165.3	16.912	0.76588	2671.3
4	18000	1310.9	21.404	0.86161	3005.3
6	19000	1383.7	23.849	0.90948	3172.2
6	20000	1456.6	26.425	0.95735	3339.2

Table 9: Ansys result for Torsion Rod of 110mm length under various load using S-Glass Material.

S NO.	LOAD APPLIED (N-mm)	SHEAR STRESS (MPa)	STRAIN ENERGY (MJ)	TOTAL DEFROMATION(MM)	EQUIVELENT STRESS (MPa)
1	15000	1080.8	59.94	2.8707	2514.7
2	16000	1152.8	68.198	3.0621	2682.4
3	17000	1224.9	76.989	3.2534	2850
4	18000	1297	86.313	3.4448	3017.7
6	19000	1369	96.17	3.6362	3185.3
6	20000	1441.1	106.56	3.8276	3353

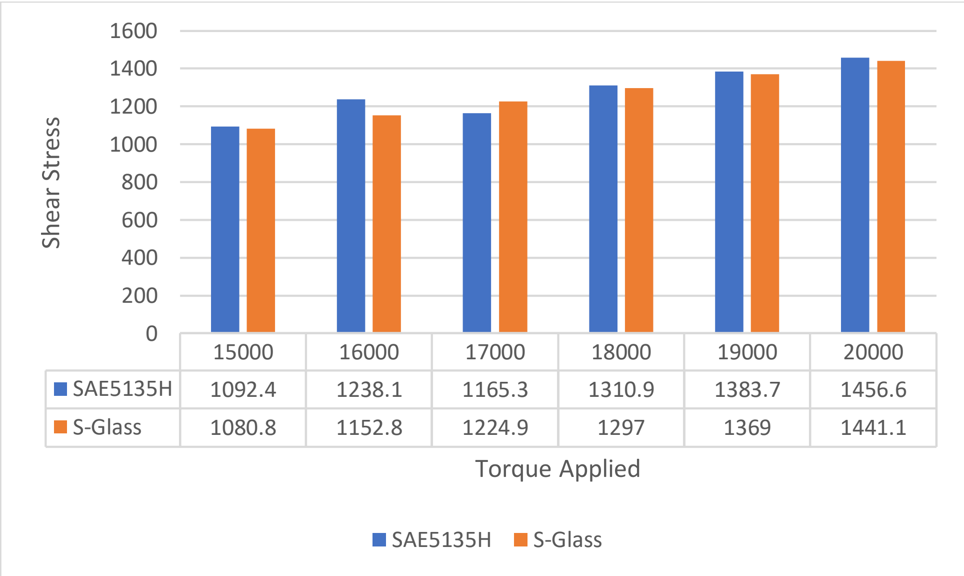


Fig.9: Shear Stress comparison in 110mm rod in different material

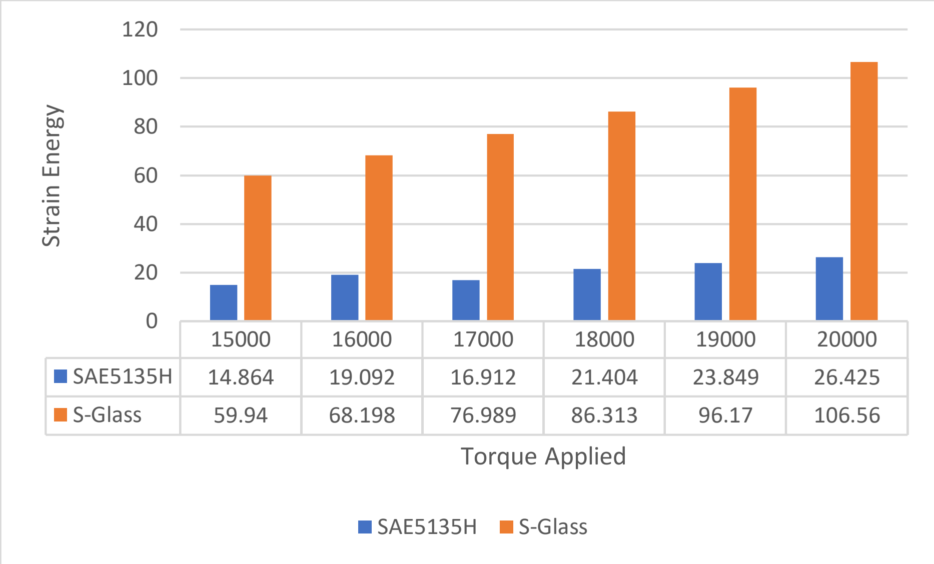


Fig.10: Strain energy comparison in 110mm rod in different material

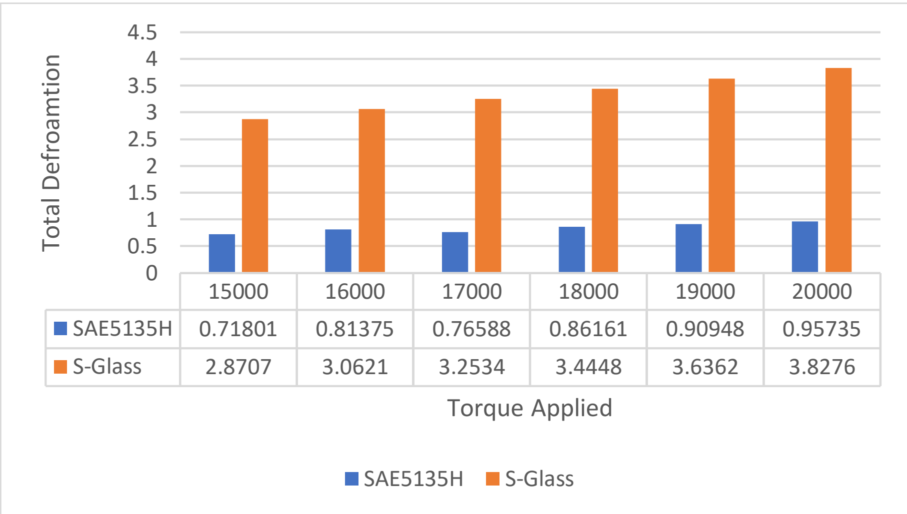


Fig.11: Total Deformation comparison in 110mm rod in different material.

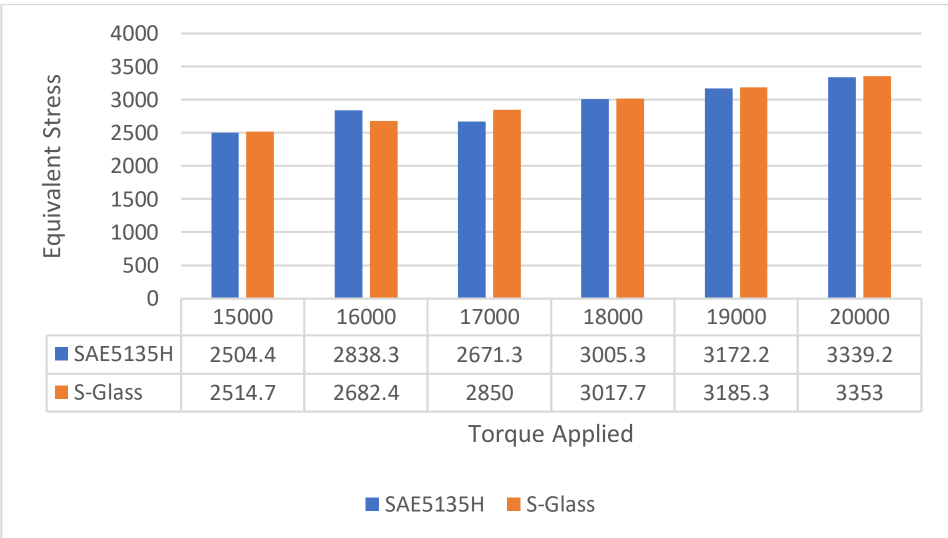


Fig12: Equivalent Stress comparison in 110mm rod in different material.

Fig 9 illustrates the shear stress for the rod of 110mm full length for the application of torque ranges from 15000 n-mm to 20000 n-mm with the shear stress on ordinate axis and various types of loads on the abscissa. There is a little difference on shear stress both materials were S-Glass material observed higher shear stress as compare to SAE5135H.

Fig 10 shown the strain energy for each type of material having the length of 110mm length for the application of torque ranges from 15000 N-mm to 20000 N-mm using two material S-Glass and SAE5135H increase trend is observed with increasing torque in both the material. There is a big difference in strain energy between SAE5135H and S-Glass, which means that SAE5135H is suitable material for the strain energy prospective.

Fig 11 shows the deformation in the rod having length of 110mm applied under torque ranges from 15000 N-mm to 16000 N-mm in both materials. Fig represents that the deformation in the S-Glass is high as compare to SAE1535H, which make it suitable for long term use.

Fig 12 represents the Equivalent stresses for rod of length 110mm in both material under the torque ranges from 15000 N-mm to 16000 N-mm. Which shows that Equivalent stress is less in S-Glass material as compare to SAE5135H.

Torsion Rod of 130mm Length:

Using SAE5135H Material:

At a load of 15000 N-mm, shear stress is 1397 MPa, strain energy is 14.968 MJ, total deformation is 0.84738 mm, and equivalent stress is 2574.5 MPa.

As the load increases to 20000 N-mm, shear stress, strain energy, total deformation, and equivalent stress also increase.

Using S-Glass Material:

At a load of 15000 N-mm, shear stress is 1391.1 MPa, strain energy is 60.507 MJ, total deformation is 3.3893 mm, and equivalent stress is 2588.9 MPa.

As the load increases to 20000 N-mm, shear stress, strain energy, total deformation, and equivalent stress also increase. The S-Glass material exhibits significantly higher strain energy compared to SAE5135H.

Torsion Rod of 110mm Length:

Using SAE5135H Material:

At a load of 15000 N-mm, shear stress is 1092.4 MPa, strain energy is 14.864 MJ, total deformation is 0.71801 mm, and equivalent stress is 2504.4 MPa.

As the load increases to 20000 N-mm, shear stress, strain energy, total deformation, and equivalent stress also increase.

Using S-Glass Material:

At a load of 15000 N-mm, shear stress is 1080.8 MPa, strain energy is 59.94 MJ, total deformation is 2.8707 mm, and equivalent stress is 2514.7 MPa.

As the load increases to 20000 N-mm, shear stress, strain energy, total deformation, and equivalent stress also increase. S-Glass material again shows higher strain energy compared to SAE5135H.

IX. CONCLUSION:

Material Comparison:

For the torsion rods of both 130mm and 110mm lengths, two materials were considered: SAE5135H (steel alloy) and S-Glass (fibre-reinforced plastic).

SAE5135H exhibits higher shear strength and equivalent stress compared to S-Glass, making it more suitable for applications where strength is crucial.

S-Glass, on the other hand, shows significantly higher strain energy, suggesting better performance in terms of deformation and energy absorption.

Load-Deformation Characteristics:

As the applied torque increases from 15000 N-mm to 20000 N-mm, the shear stress, strain energy, total deformation, and equivalent stress for both materials also increase.

The length of the rod (130mm or 110mm) influences the deformation and stress characteristics, with longer rods generally exhibiting higher values.

Performance of SAE5135H:

SAE5135H, being a steel alloy, demonstrates high shear stress, making it suitable for applications where strength and resistance to deformation are critical.

The total deformation in SAE5135H is comparatively lower, indicating better stiffness and stability under torsional loads.

Performance of S-Glass:

S-Glass exhibits significantly higher strain energy, suggesting better energy absorption capabilities and potential suitability for applications where flexibility and damping properties are desired.

S-Glass, however, shows higher total deformation, indicating more significant elastic deformation under torsional loads.

Dimensional Influence:

The analysis considers two different rod lengths (130mm and 110mm). The choice of rod length influences the deformation and stress characteristics, with longer rods generally showing higher values.

Recommendations:

The choice between SAE5135H and S-Glass should be based on the specific requirements of the application.

If strength and stiffness are crucial, SAE5135H may be preferred.

If energy absorption and flexibility are priorities, S-Glass might be a more suitable choice.

Limitations:

The analysis is based on specific material properties, and real-world variations may exist.

Boundary conditions, such as the fixed support at one end, may influence the results.

X. REFERENCE:

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