STM JOURNALS
International Journal of
Fracture Mechanics and Damage Science
Volume 3, Issue 1, 2025
January–June
DOI (Journal): 10.37591/IJFMDS
https://journals.stmjournals.com/ijfmds
Review
IJFMDS

Mechanical Testing Under Tensile-load

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Abstract

Mechanical testing is a technique used to establish a material's mechanical qualities by examining its strength, toughness, hardness, and other characteristics. Specimens produced of various materials whose qualities need to be examined are used to verify this property. In which a static load is applied and a dynamic load is applied, and the test is completed. Understating loads in mechanical testing is the topic of this research article. Any manufacturing business, including the casting industry, depends greatly on this process. Testing is essential prior to pouring and is crucial not just in mechanical engineering but also in civil, vehicle, and aerospace engineering. In order to determine important parameters involving ultimate tensile strength (UTS), yield strength, Young's modulus, elongation, and fracture characteristics, a standardized specimen is subjected to a uniaxial force until it fails. In structural and technical applications, these qualities are crucial for assessing a material's appropriateness. Temperature, strain rate, and specimen shape are some of the variables that affect the test and can affect the failure modes and material reaction. Extensometry and digital image correlation are examples of advanced techniques that improve measurement accuracy as offer in-depth study of strain distributed. The importance of testing for tensile strength in materials science, its real-world uses in sectors like construction, automotive, and airplanes, and new developments in method development are all covered in this paper. In order to conduct a thorough analysis of this testing material, I based some assumptions for this research article.

Keywords: Mechanical properties, ASTM standard, static load, universal testing machine

INTRODUCTION

In order to enable scientists and developers guarantee the dependability and performance of materials used in structural and industrial applications, mechanical testing is essential in evaluating the mechanical behavior of materials under various loading events. Tensile testing, one of the most basic and often used techniques among the several mechanical tests, evaluates a material's response to uniaxial tensile stress during stretching. Tensile testing determines important material aspects such as ultimate tensile strength (UTS), yield strength, elongation, decrease in area, and Young's modulus by exposing a standardized specimen to a controlled stretching force through failure. These factors assist engineers in assessing a material's viability for a range of uses, from daily consumer goods to aeronautical building.

A Universal Testing Machine (UTM) can be utilized to do tensile testing, which involves applying a steadily rising tensile force to a specimen until it breaks. The machine creates a stress-strain curve by gathering force and elongation data. This curve, which illustrates how a material deforms elastically and plastically before to failure, is a vital tool for comprehending how a solid behaves under strain. Young's modulus, a measure of stiffness, is shown by the slope in the elastic region, whereas the area under the curve shows the toughness of the material [1,2].

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Received Date: January 30, 2025
Accepted Date: March 24, 2025
Published Date: March 27, 2025

Citation: Rohit R. Raval, Rishabh D. Makwana, Darshan H. Bhalodia, Jeel H. Joshi. Mechanical Testing Under Tensile-load. International Journal of Fracture Mechanics and Damage Science. 2025; 3(1): 1–10p.

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Temperature, surface polish, strain rate, and the specimen's preparation are some of the variables that affect the precision and dependability of tensile test findings. Test results are consistent across sectors because to standardized testing protocols, such as those adopted by the International Organization for Standardization (ISO) and the American Society for Testing and Materials (ASTM). Since various materials, notably metals, polymers, and composites, have distinct stress-strain properties, tensile testing is a crucial step in the selection of materials and quality maintenance.

The concepts, procedures, and importance of tensile testing in mechanical engineering are examined in this essay. For structural integrity, failure analysis, and performance optimization in sectors including industrial, automotive, aerospace, and civil engineering, it is essential to comprehend how a material reacts to tensile loads. Engineers can improve durability of goods, optimize designs, and create novel materials for particular uses by examining tensile properties.

Universal Testing Machine

Multiple tests may be carried out with a single system using a cabled Universal Testing system, or UTM for short.

To ascertain important physical properties including tensile strength, yield strength, elongation, and flexibility of elasticity, it is frequently used in material science, quality assurance, and research applications. In mechanical and structural engineering, the Universal Testing Machine is an indispensable tool that provides vital information for product development, material selection, and monitoring of quality (Figure 1).

Figure 1. Universal Testing Machine, Lab of Atmiya University

Types of Test Testing Performing on UTM

1. *Tensile Test:* determines flexibility ductility, and elasticity.
2. *Compressive Test:* assesses the behavior of substance under pressure.
3. *Shear Test:* Assesses shear strength properties.
4. *Bend Test:* Measures a material’s resistance to bending forces.

Test Specimen

A standardized sample of an item used in mechanical testing to assess its characteristics under different load circumstances, such as tensile, compressive, or flexural forces, is called a test specimen. The accuracy and durability of test findings are greatly impacted by the specimen's size, shape, and preparation. The figure displays the material that was used for the UTM tensile test [3].

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Types of Test Specimens

1. *Tensile Test Specimen:* To guarantee even stress distribution, the sample generally looks resemble a dog bone or dumbbell and has a small cross-sectional area than normal.
    - Common standards: ASTM E8 (metals), ASTM D638 (plastics).
2. *Compression Test Specimen:*
    - A sample that is often a prismatic, cubic, or cylindrical designed to resist compressive forces.
    - *Common standards:* ASTM C39 on concrete and ASTM E9 for aluminum
3. *Flexural Test Specimen:*
    - Specimens of rectangular bars went through three- or 4-point bending tests.
    - *Common guidelines:* ASTM C78 (concrete), ASTM D790 (material).
4. *Shear Test Specimen:*
    - Usually made up of solid elements or thin sheets, it is used to test strength under shear.
    - Common criteria: ASTM D732 for plastics and Aisi B831 for metals [4].

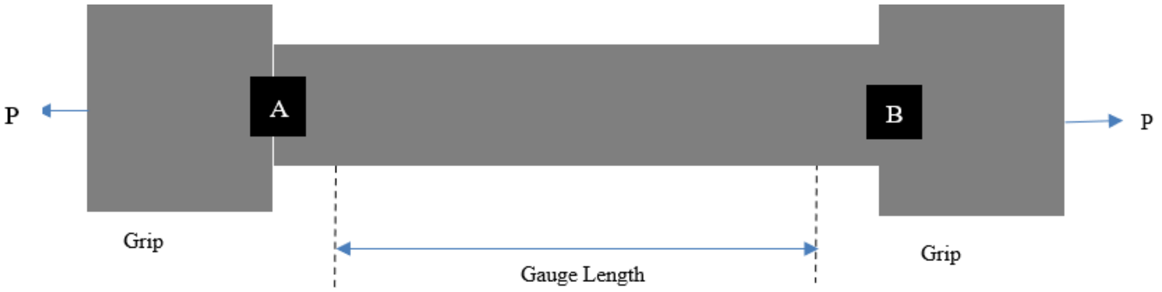

Figure 2. Test Specimen

Two Point A and B are Located Away from Ends to Avoid Local Effect of Greep and to Ensure Uniform Stress and Strain Between these Marks.

According to American Society of Testing Material (ASTM)

$L_g = 5.65\sqrt{A} \approx 5d_o$

Where,

L_g = Gauge Length

Factors Affecting Test Specimen Performance

- *Material Composition:* Under the same test settings, various materials respond slightly.
- *Specimen Geometry & Dimensions:* Uniform stress distribution is ensured by standardized shapes.
- *Surface Finish & Preparation:* Stress concentrations can be put on by flaws or surface unevenness.
- *Environmental Condition:* Test results can be impacted by temperature, humidity, even strain rate.

To achieve precise mechanical specs and guarantee dependability in engineering applications, the test specimen must be selected carefully and produced [5].

Assumption of Materials

Homogenous Material

- The body of this figure takes into consideration three points. It takes all three axes, or directions.
  The term "homogeneous" refers to bearing the same attribute in a certain direction as provided by E in the X direction.

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A property is said to be homogeneous if it is the same in one direction as provided E' in the other.
When a property is homogeneous, it means that it is the same in one direction as it is in another.

- The body of this figure taken into account three points. It must take into account three axes, or dimensions (Figure 3).

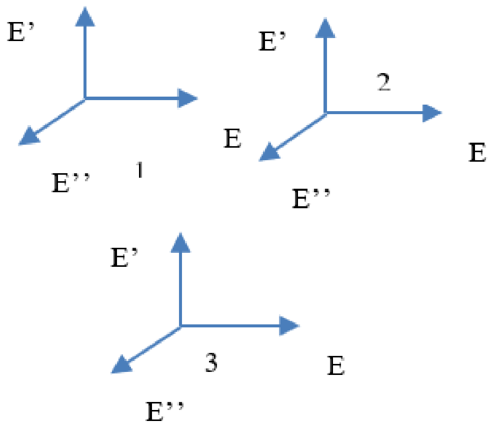

Figure 3. Homogenous Material.

Isotropic Material

- An isotopic point is one that possesses the same qualities in any of the three dimensions, or in the E-X direction [6].
- An isotopic point was one that has the same qualities in all three dimensions, or in the E-Y line.
- An isotopic point constitutes a single point that has the same qualities in each of the three dimensions or in the E-Z direction (Figure 4).

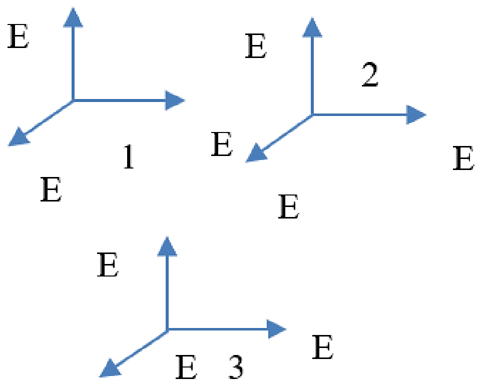

Figure 4. Isotropic Material.

SIMPLE TENSILE TEST ON MILD STEEL UNDER STATIC LOADING

Proportional Limit

- This limit is known as the equal limit since the amount of stress placed on the steel material matches up to the quantity of strain.
- Up to this moment, the motion of tension and strain is linear.
- While applying axial load to the test piece Longitudinal strain and lateral stress occur by this load.
- According to Hooke's law, strain on the are identical up to the proportional limit or the threshold of elasticity (Figure 5, Figure 6).

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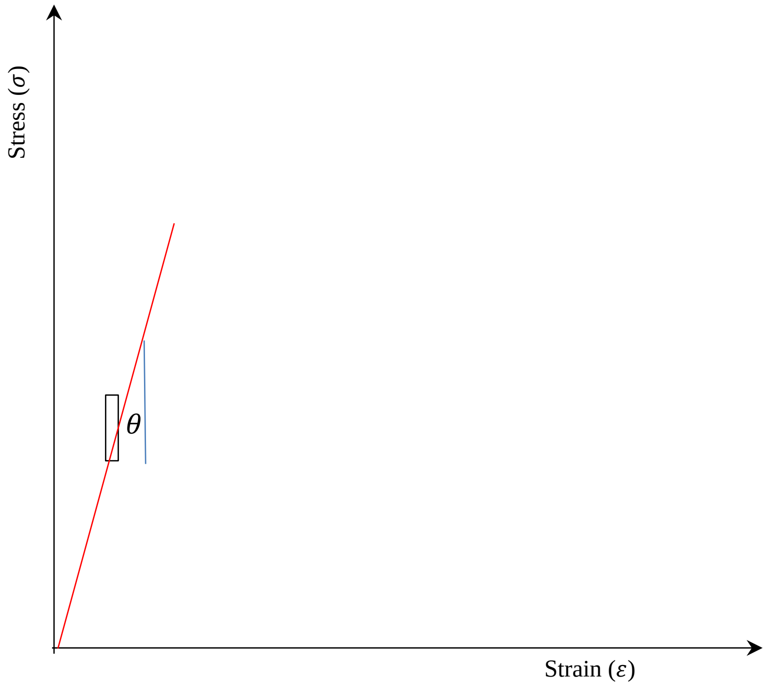

Figure 5. Simple Tensile Test on Mild Steel Under Static Loading

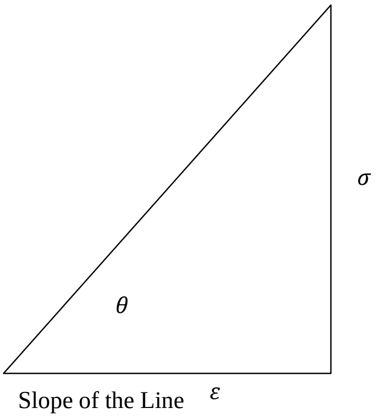

Figure 6. Hooke's law.

$$\tan\theta = \frac{\sigma}{\varepsilon}$$

For Very Small Angle $\tan\theta \approx 0$,

$$E = \frac{\sigma}{\varepsilon}$$

$\sigma = E\varepsilon$

$\sigma \propto \varepsilon$ (Hooke’s Law)

Elastic Limit

- Despite being in the stretch zone, the stress and strain history is not linear between the proportional threshold and the elastic limit.
- The point that occurs when the material starts yielding.

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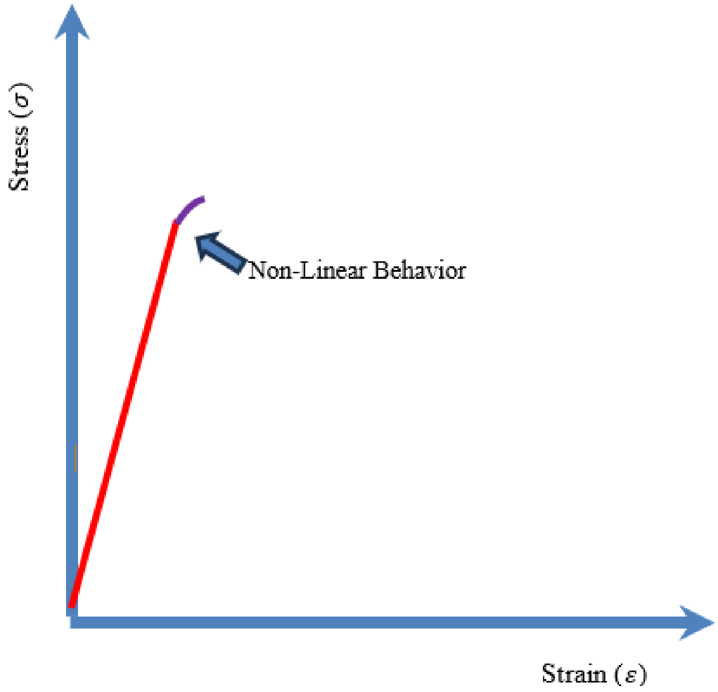

Figure 7. Elastic Limit

- The specimen exhibits some little deformation once the load has been put up to the elastic limits [7,8].
- If the load is removed after it has reached the elastic limit of the material, it is done so in the same direction as it was originally applied (Figure 7).
- Hooke's Law isn't really applicable.

Upper Yield Point
- The material beginning to yield at that point.
- Hooke's Law isn't really applicable.
- The specimen experiences some serious deformation upon stress up to the Upper Yield Level.
- Stress and strain go up to this Upper Yield Point because ionic flow starts to happen in the loading component (Figure 8).

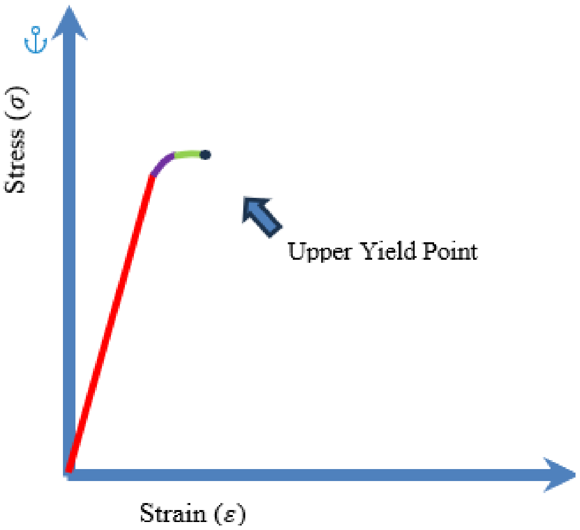

Figure 8. Upper Yield Point.

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Lower Yield Point

- The material's molecules have a tendency to become stuck at one spot when a load is applied up to this lower yield range.
- The material's stress reduces and its strain rises when the load is moved to the lower location.
- At this lower yield point of view, the material's yield strength is evaluated.
- Hooke's Law isn't really applicable (Figure 9, Figure 10).

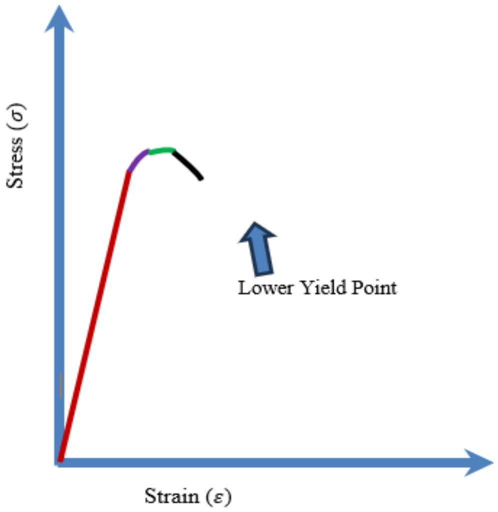

Figure 9. Lower Yield Point.

Figure 10. Stuck Molecules of the Material.

Yield Plateau

Applying loads The molecules of what is inside travel ahead and start to stretch over the lower point; the substance does not attempt to return to its basic size [9].

- Up to this moment, once the load is applied, both the stress or the strain vary.
- It happens while steel's molecular structure contain a little amounts of silicon.
- More strain but less anxiety (Figure 10).

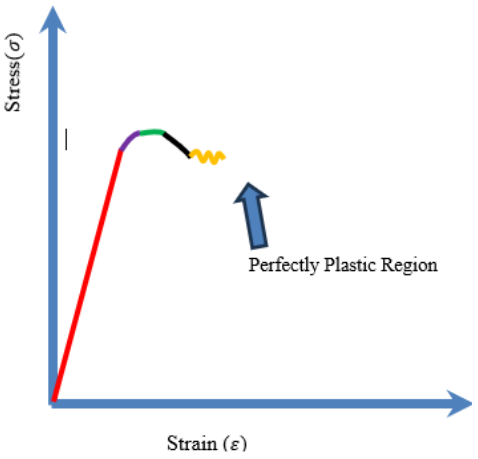

Figure 10. Yield Plateau.

Strain Hardening Region

- Steel's structure in molecules is random, which is why it happened.

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- This region's last point is also referred to as the Ultimate Stress Point.
- Following this yield slow down, the material's molecules get stuck and cannot be moved or stretched, even with energy applied [10].
- The material has its full strength at that moment. It is said to as the crowning glory (Figure 11).

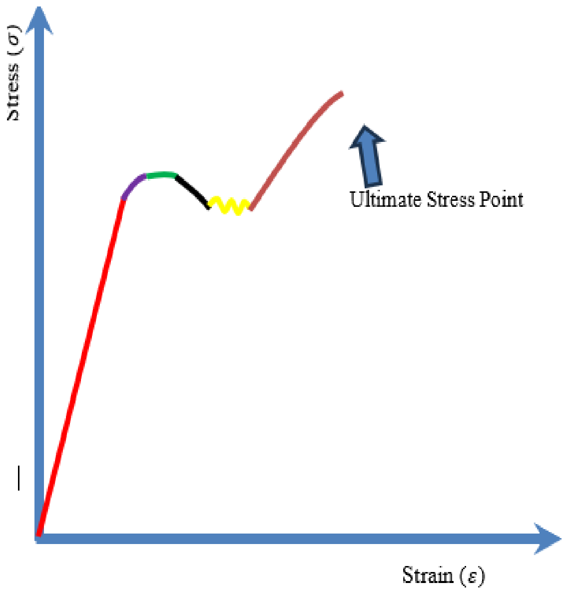

Figure 11. Strain Hardening Region.

Necking Zone

- The Cross Section Area Partly Declined
- The Cross Section Area Substantially Declined (Figure 12, Figure 13)
- Fracture Tip is the region's last tip. A graph of different materials have also been shown in Figure 14.

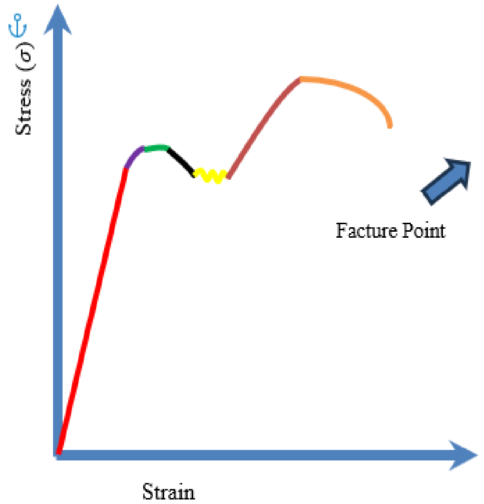

Figure 12. Necking Zone.

$$\sigma_{\text{Engineering}} = \frac{Load}{Orignal\ Area}$$

$$\sigma_{\text{True}} = \frac{Load}{Instantaneous\ Area}$$

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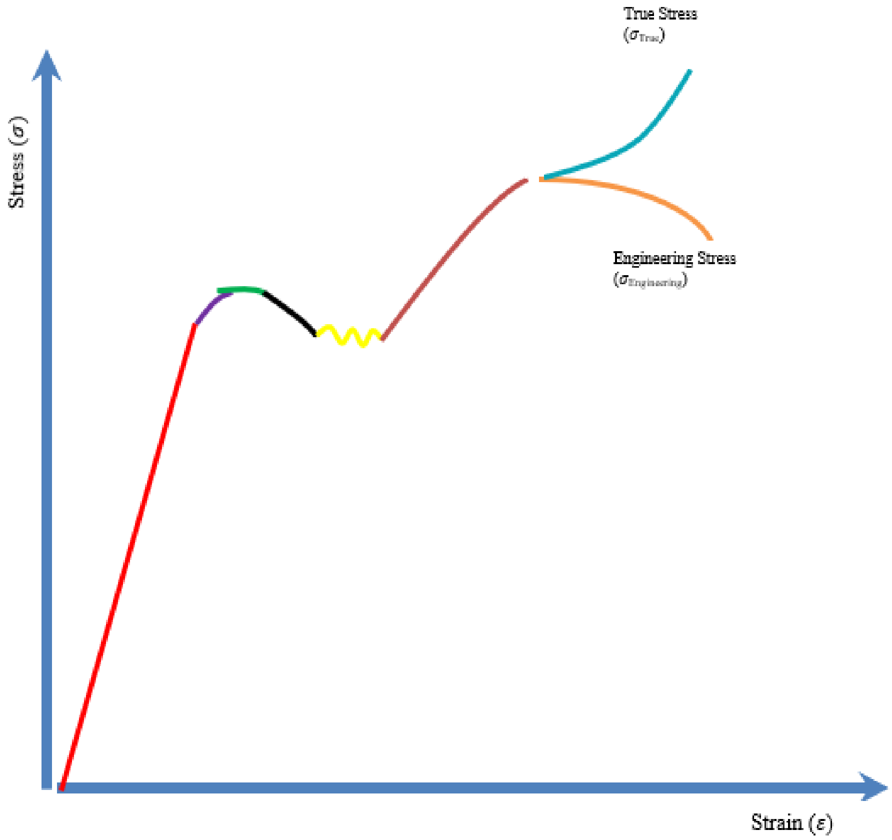

Figure 13. True Stress and Engineering Stress Diagram

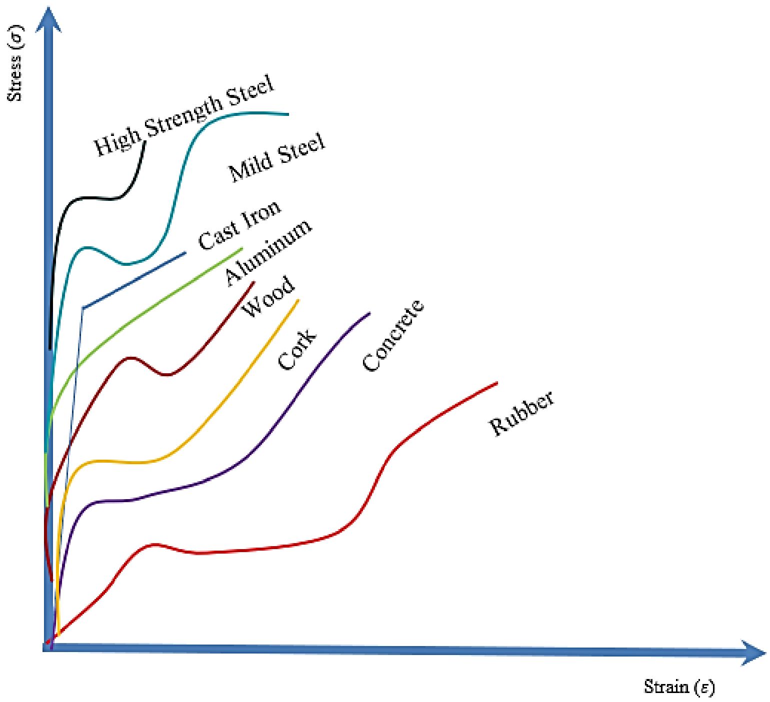

Figure 14. Graph of Different Materials

CONCLUSION

A basic mechanical testing technique offering essential details about a material's strength, ductility, and elasticity is tensile testing. Engineers and researchers can ascertain fundamental properties of steel

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including ultimate tensile strength, yield strength, Young's modulus, and elongation—all of which are essential for material selection and structural design—by applying a uniaxial tensile load to a standardized piece. Tensile test results aid in evaluating material performance in practical settings, guaranteeing dependability and security in engineering applications.

The precision and accuracy of test results are guaranteed by the use of Universal Testing Machines (UTM) and standardized testing protocols, such as ASTM and ISO guidelines. However, a number of variables, comprising specimen geometry, strain rate, surface finish, and environmental conditions, can have a substantial impact on test results, stressing the significance of meticulous test planning and management.

In sectors including manufacturing, the automotive, aerospace, and construction where material performance under load plays a role for product efficiency and safety, tensile testing is essential. High-precision extensometry and digital image correlation are both instances of testing technology advancements that keep enhancing the precision and breadth of mechanical property analyses.

To sum up, mechanical testing under strain is still a crucial component of engineering design, quality assurance, and material definition. Engineers can create stronger, more dependable materials and structures with a full grasp of tensile characteristics, guaranteeing superior durability and lifespan in a range of use in industry.

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