Tensile Testing of Materials

PURPOSE

To determine the Ultimate Tensile Strength, Yield Strength, Modulus of Elasticity (Stiffness), Modulus of Resilience.

INTRODUCTION

Mechanical strength is a basic property of all solid materials. Every engineering structures or device imposes certain requirements of mechanical strength on the material to be used: structures designed to sustain loads must have the necessary mechanical strength before they can serve any other function. The members are subjected to loads, which are often a critical factor. In its broadest sense mechanical strength may be defined as the ability to sustain loads without undue distortion or failure.

In the idealized state of static tension it is assumed that:

a) The stress is uniformly distributed across each cross-section of the member.
b) The stress is constant from cross-section to cross-section along the length of the member.
c) The load changes are so slow that no dynamic effects are present.

In a standard test these conditions are approached as closely as possible within the practical limitations of the equipment available. To conduct a static tension test according to ASTM E8-22, the specimen is loaded slowly with an axial load and a series of observatories of load and deformation are made. These observations are later transformed into what is commonly termed Conventional Stress-Strain diagrams and true Stress-Strain diagrams as shown in Figure 1. Both conventional stress-strain and true stress-strain have applications in engineering and research. Conventional Stress-Strain diagrams are based on the change in load with respect to the original cross-sectional area of the specimen and true Stress-Strain diagrams are based on the change in load with respect to actual cross-sectional area of the specimen recorded when the observations are made. The true stress-strain tension test is more involved since the lateral contraction must be measured, and sometimes the elongation as well. This is the main reason for the widespread use of the conventional stress and strain. In fact all standardized tension tests are for conventional stress and strain.

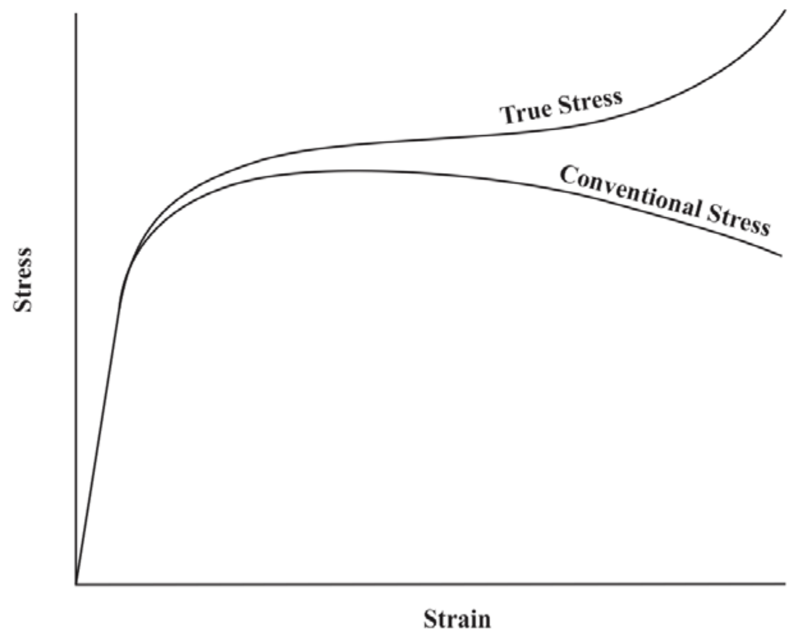

Figure 1. Comparison of true and conventional stress

In the static tension test a universal testing machine is used to obtain Stress-Strain diagrams. Typical Stress-Strain diagrams for brittle and ductile materials are shown in Figure 2. For materials which behave elastically the initial portion of the stress-strain diagram will be a near straight line. These materials obey Hooke's law and the material stiffness (E) (Young's modulus) is obtained by dividing the stress at any point on the curve by the corresponding strain.

$$E = \frac{\sigma}{\varepsilon} \quad \text{(MPa)} \qquad (1)$$

Where

σ = Normal Stress (MPa)

ε = Normal Strain (m/m)

From the stress-strain diagram the point from which the first deviation from linearity is noticeable is determined and that point is called the yield stress and in terms of strength of the material, the Yield strength. In ductile materials where the linear portion of the stress-strain curve is not a straight line and the actual yield point is not clearly noticeable, the yield offset method is used to determine the yield strength. The breaking load gives the ultimate tensile strength and from knowing the strength the modulus of resilience can be found.

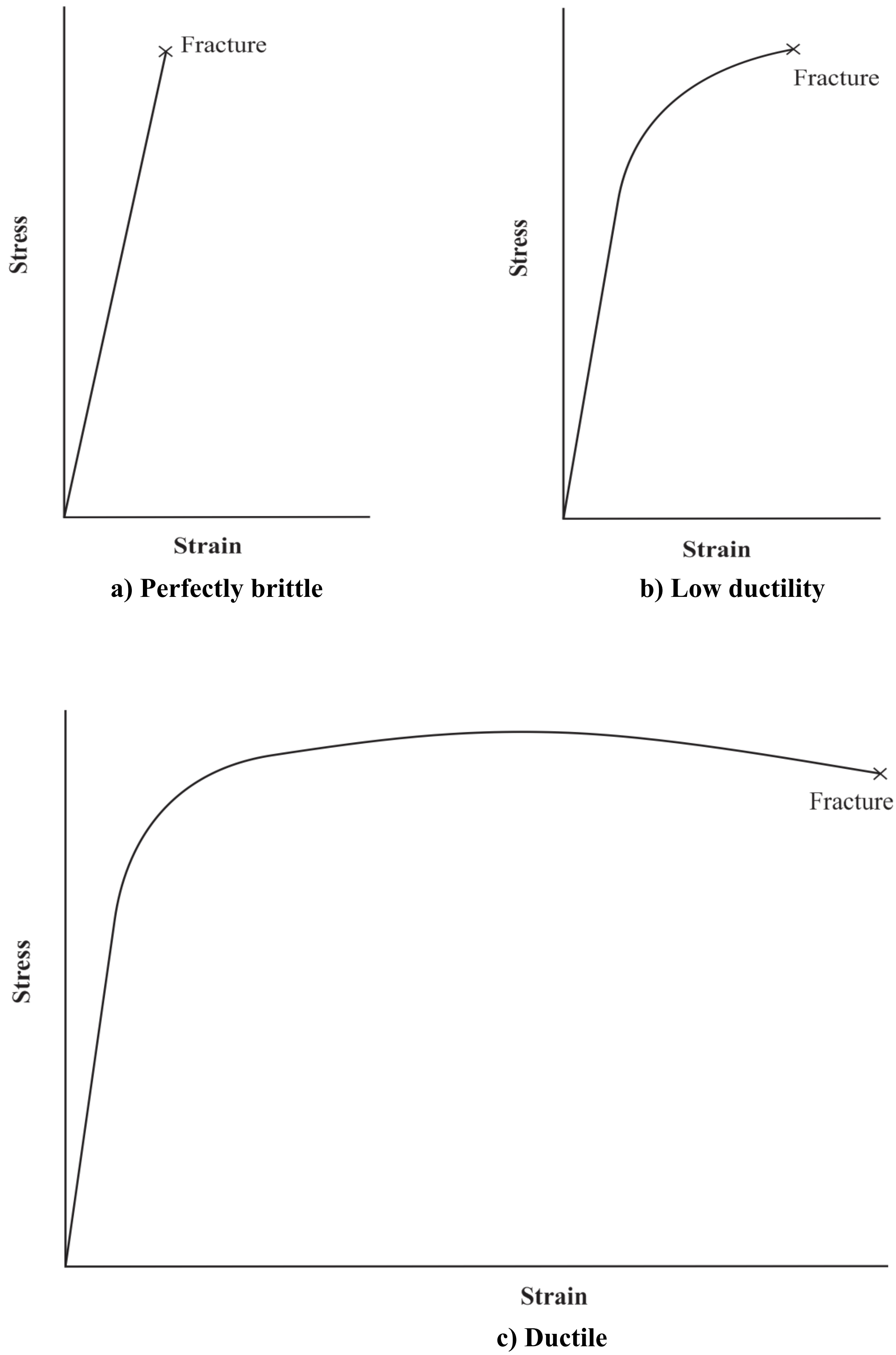

Figure 2. Typical Stress-Strain diagrams.

EQUIPMENT:

1. **Universal Testing Machine:**
MTS 810 Material Testing Machine. The MTS 810 is a versatile, multipurpose, servo-hydraulic testing system for static and dynamic mechanical tests. Figure 3. The 810 Material Testing System delivers a broad array of testing capabilities for both low and high force static and dynamic testing. By selecting from a variety of force capacities, servovalve flow ratings, pump capacities, software, and accessories, the floor-standing 810 system can easily be configured to meet your specific material or component testing needs. The versatile 810 system features:
   - Force ranges from 25 kN (5.5 kip) to 500 kN (110 kip)
   - A wide performance range
   - The ability to test materials ranging in strength from plastics to aluminum, composites and steel
   - A large test space to accommodate standard, medium and large size specimens, grips, fixtures and environmental subsystem
   - The capability to perform a wide variety of test types from tensile to high cycle fatigue, fracture mechanics, and durability of components

2. **Vernier Calipers and Steel Scale**

PROCEDURE:

REQUIRED RESULTS:

1. Measure the test length L_o and the test diameter d_o
2. Tabulate your results as shown in Table 1.
3. Draw the Stress-Strain Graph

   Note:

   $$\text{Stress, } \sigma = \frac{Load}{Area} \text{ MPa}$$

   $$\text{Strain, } \varepsilon = \frac{\Delta L}{L_o} \text{ m/m}$$

Also, explain what type of behavior the curve represents (e.g. Brittle, Low ductile, Ductile etc.)

4. Explain "Yield Strength" and determine it using the stress-strain curve from step 3 (using 0.2 % offset method if required) and report it as following.

   Yield strength = σ_y MPa

5. Calculate the following properties using stress-strain curve from step 2.

   a. Modulus of Elasticity (E) (MPa)

   b. Percent elongation at the time of rupture ($\frac{L_f - L_o}{L_o}$)

   Where

   L_f is the final length of the elongated specimen. (mm)

   L_o is the initial length of the specimen. (mm)

   c. Ultimate Tensile strength (Breaking load divided by the original cross-sectional area of the specimen) (MPa).

   d. Modulus of Resilience (MPa)

   $$Ur = \frac{\sigma^2{}_y}{2E}$$

   Where

   Ur = Modules of Resilience

6. Using the information provided to you (in step 3), show in your plot the elastic limits, maximum stress, elastic strain, and maximum strain.

Table 1. Stress – Strain Data for the Tension Test

Data Points	Load (N)	Elongation (m)	Stress (MPa)	Strain (m/m)
1				
2				
3				