Experiment One
Tensile Stress Testing and Modulus of Elasticity

Introduction

The purpose of this experiment is to apply a tensile force to a test specimen until the specimen is pulled to failure. During the course of the tensile load application the computer will monitor properties and generate a stress/strain curve from which various values such as the Modulus of Elasticity of the material can be determined.

Objective:

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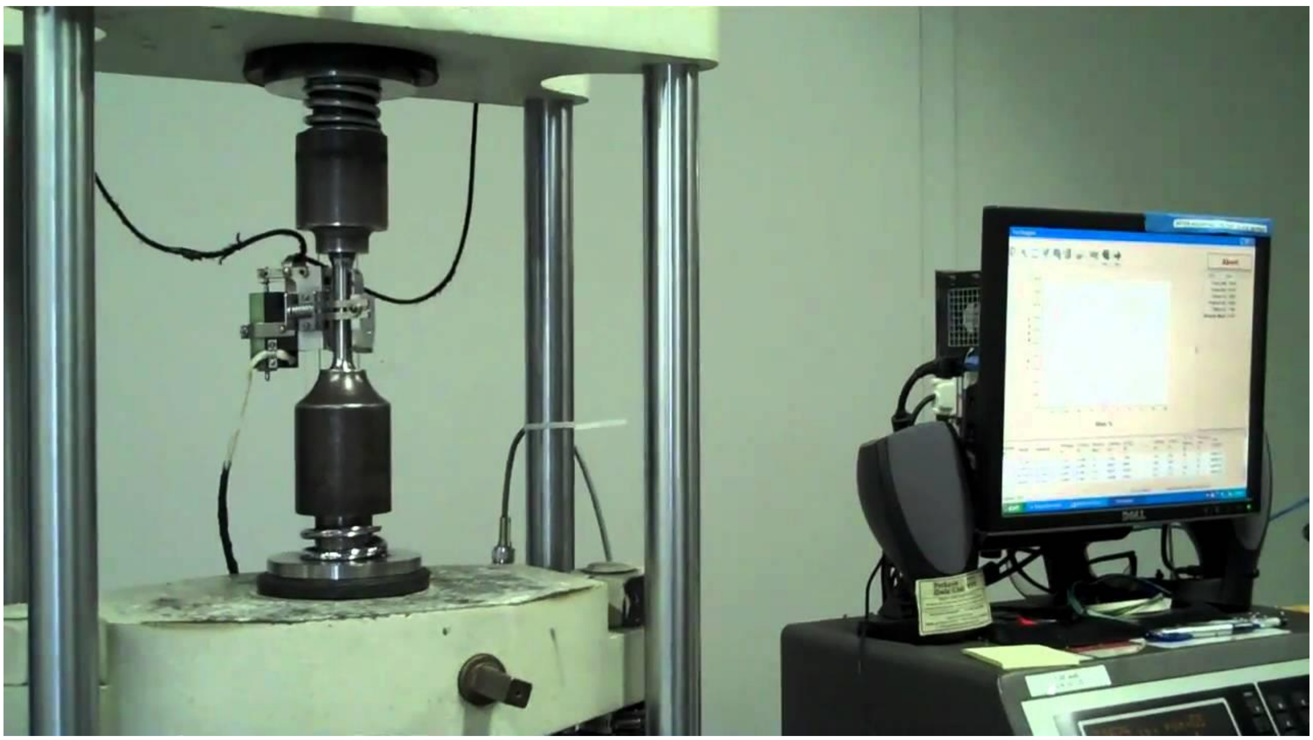
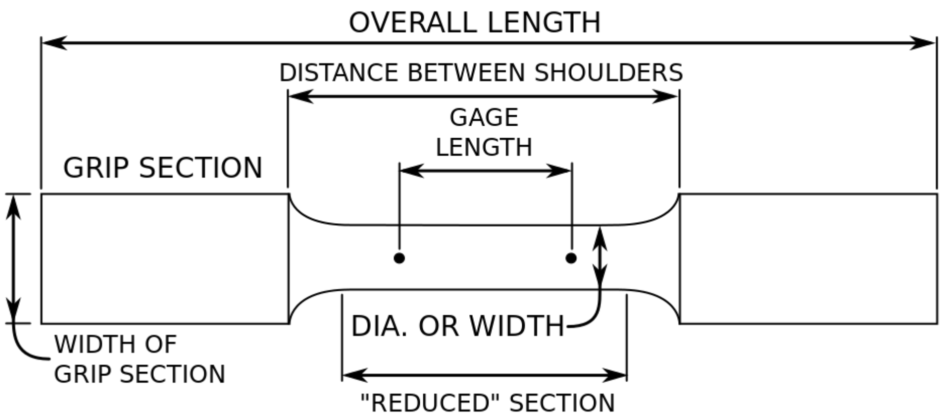


Apparatus:

Materials and Equipment

1. Tensile testing machine
2. Test specimens
3. Micrometer
4. Calipers



The tensile testing machine consists of an electro-mechanical test system that applies uniaxial loading in a uniform manner to test specimens. It is general purpose in its capabilities and applications. The system performs load versus elongation (stress versus strain) tests which involve controlling forces from a few ounces to several-thousand pounds, gripping specimens ranging from delicate fibers to high strength metals or composites, and measuring the resulting forces (stresses) and deformations (strains). Measurement of the stresses and strains is accomplished by the use of highly sensitive load and strain transducers that create an electrical signal that is proportional the applied stress or strain. This electrical signal is measured, digitized and then processed for display, analysis and report of stress, strain and other computed material characteristics.

Theory:

The modulus of elasticity (Young's modulus) is a material constant indicative of a material's stiffness. It is obtained from the stress versus strain plot of a specimen subjected to a uniaxial stress state (tension, compression, or bending). The elastic modulus is used, along with other material constants, in constitutive equations that relate stress to strain in more complex situations. Bending test is performed on beam by using the three point loading system.

A simple tensile test is the most popular means for determining the elastic modulus. Figure 1, for example, shows a cylindrical test specimen subjected to uniaxial tension. Two reference points, located at a distance L_o apart, define a gage length. Engineering stress, ó, is computed as the load is increased (based on the original cross sectional area, A_o) while engineering strain, å, is determined when the elongation experienced by the specimen, ä, is divided by the original gage.

$$\sigma = \frac{P}{A_o} \quad \textit{and} \quad \varepsilon = \frac{\delta}{L_o}$$

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

A plot of these quantities produces a stress-strain curve. The modulus of elasticity, E, is defined as the slope of the linear portion of this curve, and is given by **above equations** where the stress, ó, is measured in psi (N/m_2 or Pa). In Equation (3.3-2), å is the strain measured in in/in (m/m) in the direction of the applied load. Since strain is dimensionless, the elastic modulus is measured in units of psi (Pa).
It is important to realize that Equations above is valid only for uniaxial tension and is a special case of a generalized set of relations known as Hooke's law. Much more complex relations must be used when dealing with more complex loadings.

The shape of the stress-strain curve depends on the material and may change when the specimen is subjected to a temperature change or when the specimen is loaded at a different rate. It is common to classify materials as ductile or brittle. Ductile materials yield at normal temperatures while brittle materials are characterized by the fact that rupture occurs without any noticeable prior change in the rate of elongation. Figures Below typical stress-strain curves for such materials.

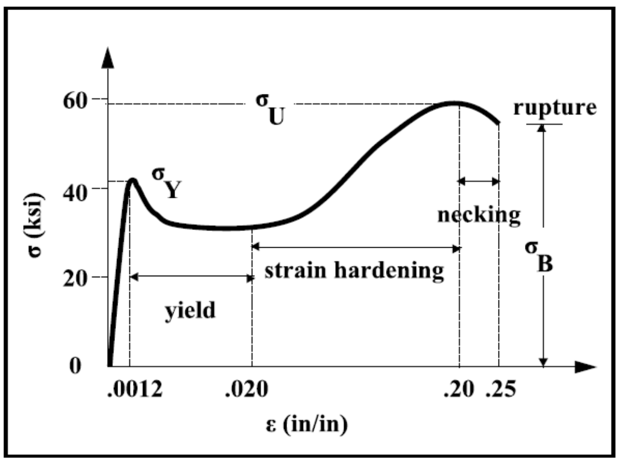


Figure 2. A stress-strain curve for a ductile material.

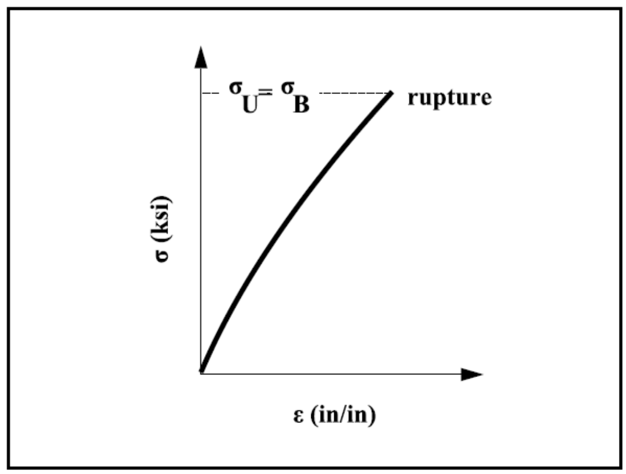


Figure 3. A stress-strain curve for a brittle material.

In the case of a ductile material, the specimen experiences elastic deformation, yields, and strain-hardens until maximum load is reached. Necking occurs prior to rupture and failure takes place along the planes of maximum shear stress. Referring to Figure 2, the stress, $ó_y$, at which yield is initiated is called the *yield stress*. The stress, $ó_u$, corresponding to the maximum load applied to the specimen is known as the *ultimate strength*. The stress, $ó_B$, corresponding to rupture is defined as the *breaking strength*.

In the case of the brittle material characterized by Figure 3, there is no difference between the ultimate strength and the breaking strength. Necking is negligible and failure takes place along the principal planes perpendicular to the maximum normal stress. Since the slope of the elastic portion of the stress versus strain curve often varies, different methods, such as secant and tangent methods, have been developed to obtain the elastic modulus. When the yield point is not well defined, a 0.2% offset method is often used to determine the yield stress. As illustrated in Figure 4, σ_y is obtained by drawing a line parallel to the initial straight-line portion of the stress-strain diagram starting from a strain value of ε = 0.2% (or ε = 0.002). The yield stress is defined as the point where this line intersects the stress versus strain curve.

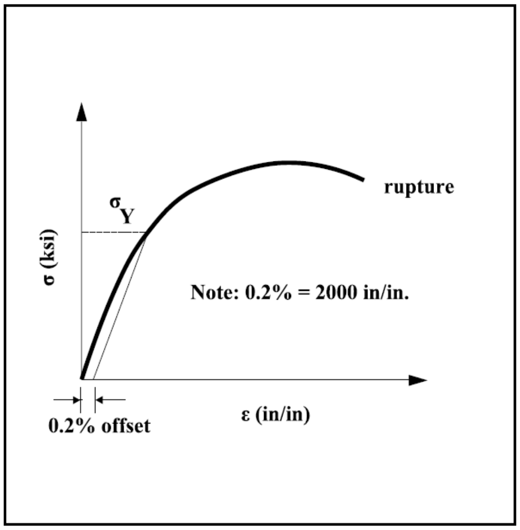


Figure 4. An offset method may be used to determine the yield stress of a material.

Preparation for the lab:

1. What is the Modulus of Elasticity?
2. Is the Modulus of Elasticity a material property?
3. What are the various regions on a stress/strain curve?
4. What is Hooke's Law?

Procedure

The computerized tensile testing machine will be used to produce stress versus strain plots for several different specimens having rectangular cross sections. The data is used to determine the modulus of elasticity while the specimens are examined for failure characteristics. Information should be entered on the attached work sheet. The steps to be followed are:

1. Measure and record the beam width (b), beam thickness (t), and length (L) of the test section.
2. Mark a section of specimen and measure the effective length.
3. Start the computer and select AUTOMATIC application Icon.
4. In main Menu select specimen preparation.
5. Select Tensile Test for Rectangular bar.
6. Provide measured gauge and other data for specimen.
7. Mount the specimen in the machine using the grips provided. Make sure it is fixed and rigidly positioned, and centered the testing area as much as possible.

8. Go to main menu and Run Test. (it will be switched to an interactive screen). MAKE SURE TO FOLLOW EVERY INSTRUCTIONS ON SCREEN.
9. Run test and follow instructions.

   It is extremely important to follow instruction on screen and place the strain measurement gauge and remove when it is asked to do so.

10. If Asked, take the rupture specimen out and measure the new length between the original marked area and report the number as input to program.
11. Upon completion return to main menus and get all reports.
12. Print reports onto your USB.

Required:

From graph and data collected find:

1. elastic modulus (E) by using the tangent method
2. elastic modulus (E) by using the secant method
3. yield stress (ó$_y$) by using the 0.2% offset method
4. ultimate strength (ó$_u$)
5. breaking strength (ó$_b$)
6. Plastic deformation region
7. Proportional limits
8. Examine each specimen after it has failed and note the degree of necking an orientation of the fracture surface.

CALCULATIONS:

1 From your text or another material handbook find the standard value for the modulus of elasticity of the specimens tested. Calculate the percentage error with the value determined by using the tangent method.

DISCUSSION:

1. What are possible sources of error?
2. Were your errors within reasonable limits (< 10%)?
3. Why are the failed specimens shaped as they are?