Tensile Test

A widely used experimental test to determine plastic deformation properties is the tensile test, in which a sample is pulled apart. The reading assigned for this section, “Tension Test,” describes the test in some detail. In addition to yield stress, properties of *ultimate tensile strength*, *percent elongation*, and *percent reduction of area* are also measured with this test.

The output of the tensile test machine is the measurement of sample length at any given time and applied force at that same time. Variables of *engineering strain* and *engineering stress* are defined to be scalar multiples of length and force, and the graph plotted by the tensile machine is referred to as a *stress-strain curve*.

Engineering Strain

True strain is percent elongation defined on a differential element. It is a definition of calculus.

$$d\varepsilon_T = dL/L$$
$$\varepsilon_T = \ln (L/L_0),$$

where L is the sample length at any time during the test, L_0 is the initial length of the sample, and ln is the natural logarithm. Engineering strain is defined algebraically as:

$$\varepsilon_E = \Delta L/L_0$$
$$\varepsilon_E = (L - L_0)/L_0.$$

If you have more advanced mathematics preparation, then you can verify that:

$$\varepsilon_T = \ln (1 + \varepsilon_E),$$

so that when ε_E is small, $\varepsilon_T \approx \varepsilon_E$.

Engineering Stress

Engineering stress is defined as force per unit area, always using the initial cross-sectional area for computation, not the actual area, which decreases as the sample elongates.

Yield Strength (σ_y or YS)

Yield strength is defined as the engineering stress at which plastic deformation begins. Sometimes there is a clearly visible kink in the experimental curve. This is often called a *yield point*. Other times, our sample transitions smoothly from purely elastic to elastic plus plastic deformation. In these cases, a procedure is standardized to calculate an educated guess as to where the yield stress might be. A common standardization, the 0.2% Offset Yield Strength, is discussed in the "Tension Test" reading.

Note especially that after plastic deformation begins, the stress-strain curve is not horizontal, but slopes upwards. The sample is getting stronger. In order to continue plastic deformation, we must continue to increase the applied force. This situation is referred to as *strain hardening* or *work hardening*. We will explore in the next section how a sample's hardness is a measure of its yield stress. We will also discuss consequences of strain hardening in Unit 4 when we discuss cold forming.

Ultimate Tensile Strength (σ_u or UTS)

The stress-strain curve of a ductile material goes through a maximum. The ultimate tensile strength (sometimes called just the tensile strength) is defined as the engineering stress at the maximum.

The reason for the maximum is that the nature of the test is changing. Before the maximum, the entire sample is deforming uniformly. At the maximum, an instability develops and the sample begins to neck down. After the maximum, deformation is concentrated in the region of the neck.

Percent Elongation

Percent elongation is defined as the maximum engineering strain. The broken sample is put back together and the final length is measured.

Percent Reduction in Area

Percent reduction in area is defined similarly to percent elongation. It compares the final cross-sectional area measured at the necked-down region to the initial cross-sectional area.