To: Professor Qi Lu

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Subject: ME1042 Lab 07 Uniaxial Tension Test of Materials

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On 11$^{\text{th}}$ November, Gordon Lou, Owen Chen, Frederic Liu, Yanjun He, and I conducted our seventh experiment in the course Mechanical Measurements 2, from which we have applied uniaxial tensile test on two kinds of materials, brittle material and ductile material, to test their performances under uniaxial tension and their behaviors at fracture.

Tensile test is a fundamental materials science and engineering test in which a sample is subjected to a controlled tension until failure (Wattrisse et al., 2001). Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials.

From the first test curve of the aluminum sample, we found that the range of 0 to about 0.19% strain are linear region where the stress and the strain are approximately proportional. The slope of this region (or Young's modulus) is around $69\ \text{GPa}$. With the aid of the figure as shown in Figure 3 which shows the intersection between the test curve and the offset curve, the yield point is obtain where the strain is around 0.39% and the yield strength is around $338\ \text{MPa}$. Then, the boundary between the elastic region and the plastic region is somewhere between 0.19% and 0.39% strain. The curve between 0.19% strain and 0.585% strain is relatively flat since it is perfect plasticity region or yielding region. After that, the slope of the curve increased, and the ultimate stress (around $360\ \text{MPa}$) is approached when strain is around 3%. This region that the curve goes up is strain hardening region. After that, the curve goes down (neck region) and finally approaches fracture point.

As for the second test curve of the aluminum sample, we found that the range of 0 to about 0.18% strain are linear region where the stress and the strain are approximately proportional.

The slope of this region or (Young's modulus) is around 68 GPa. With the aid of the figure as shown in Figure 3 which shows the intersection between the test curve and the offset curve, the yield point is obtain where the strain is around 0.38% and the yield strength is around 326 MPa. Then, the boundary between the elastic region and the plastic region is somewhere between 0.18% and 0.38% strain. The curve between 0.18% strain and 0.50% strain is relatively flat since it is perfect plasticity region or yielding region. After that, the slope of the curve increased, and the ultimate stress (around 347 MPa) is approached when strain is around 2.1%. This region that the curve goes up is strain hardening region. After that, the curve goes down (neck region) and finally approaches fracture point.

As for the third test curve of the aluminum sample, we found that the range of 0 to about 0.17% strain are linear region where the stress and the strain are approximately proportional. The slope of this region or (Young's modulus) is around 69 GPa. With the aid of the figure as shown in Figure 3 which shows the intersection between the test curve and the offset curve, the yield point is obtain where the strain is around 0.38% and the yield strength is around 322 MPa. Then, the boundary between the elastic region and the plastic region is somewhere between 0.17% and 0.38% strain. The curve between 0.17% strain and 0.54% strain is relatively flat since it is perfect plasticity region or yielding region. After that, the slope of the curve increased, and the ultimate stress (around 345 MPa) is approached when strain is around 3%. This region that the curve goes up is strain hardening region. After that, the curve goes down (neck region) and finally approaches fracture point.

The above three curves of aluminum samples show the basic characteristics of ductile material. The three curves are relatively close in the early linear region, but the difference becomes larger after the yield point. This kind of error is reasonable and acceptable, since different samples contain different internal cracks which will affect the results of the tensile test.

Compared with the curves of aluminum, the curves for cast iron have a relatively simpler shape with fewer characteristic regions or characteristic points. First, unlike the curves of aluminum samples, the curves for cast iron have no distinct linear region and yield point since cast iron is a kind of brittle material. Besides, the curves of cast iron samples have the same problem as the curves of aluminum samples, that is, three curves are close to each other in the early stage, but differences become larger in the later stage. We still believe that this phenomenon is reasonable and acceptable, since different cast iron samples can also contain different internal cracks which affects the results of the tensile test.

Next, we will conduct t-test to determine whether our uniaxial tensile test perform well. Using a 95% confidence t distribution and combined with Equation 3, we can get the probability interval for your calculated values of yield stregth is $[67.4, 70.4]$ GPa and the probability interval for your calculated values of yield stregth is $[103, 379]$ MPa.

After this experiment, with observing and comparing the elongation, reduction in area and fracture surface for the three heat-treated samples, we have learned a lot about the properties for the ductile and brittle material, and have a better glimpse of how these materials would fracture under the uniaxial tension, which promotes the theories we have learned in class. In the future, if we have the opportunity to study in the materials science, even in specialty materials field, today's experiment will provide us with tremendous help regarding to this usefulness and significance.

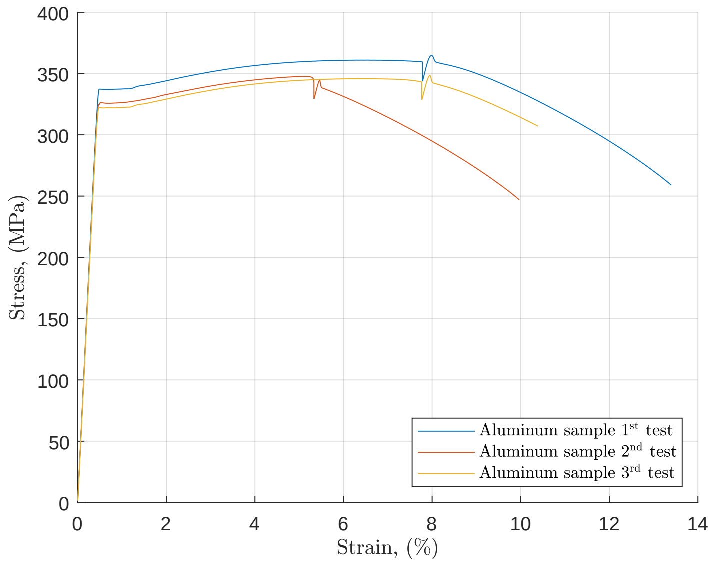

Figure 1: Stress-strain curve for aluminum alloy bar.

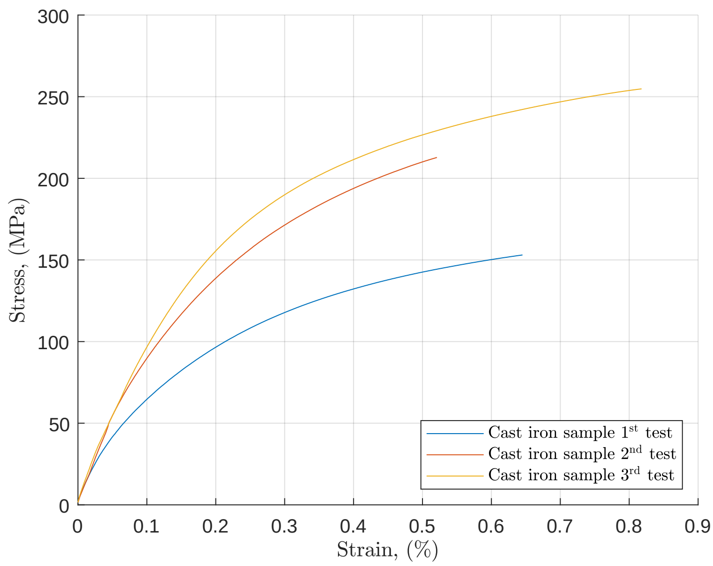

Figure 2: Stress-strain curve for steel bar.

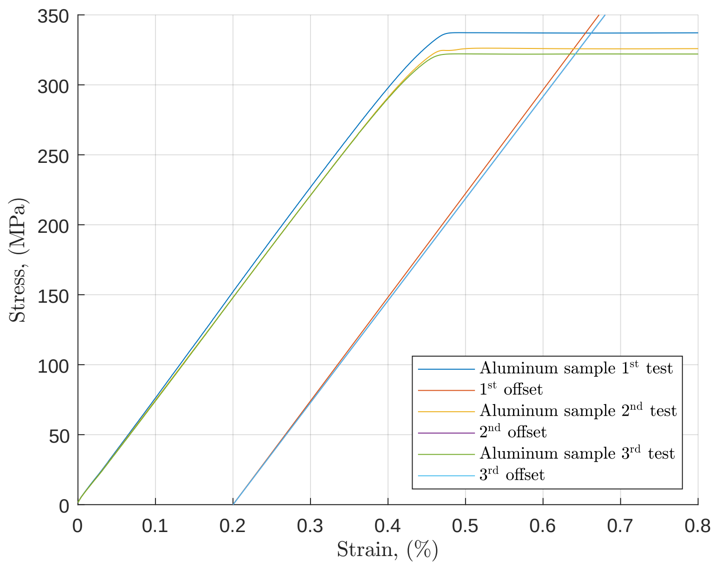

Figure 3: Approach to determine yield strength of aluminum alloy.

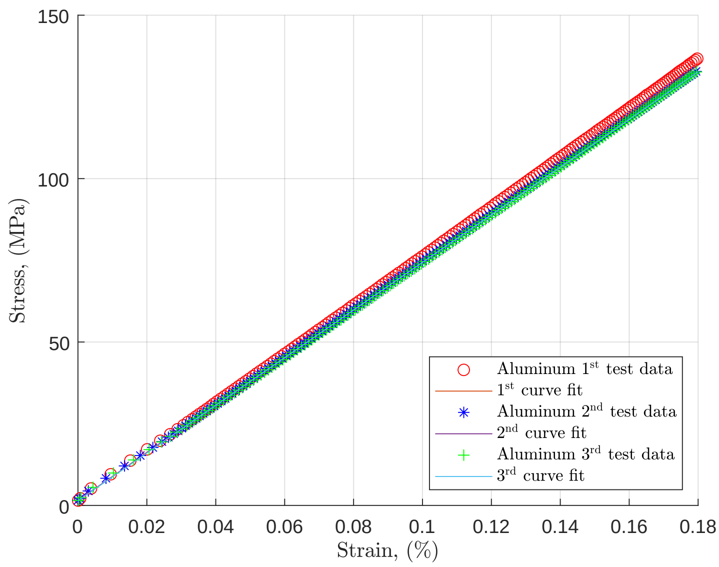

Figure 4: Curve fit for the elastic region of stress-strain curve of aluminum alloy.

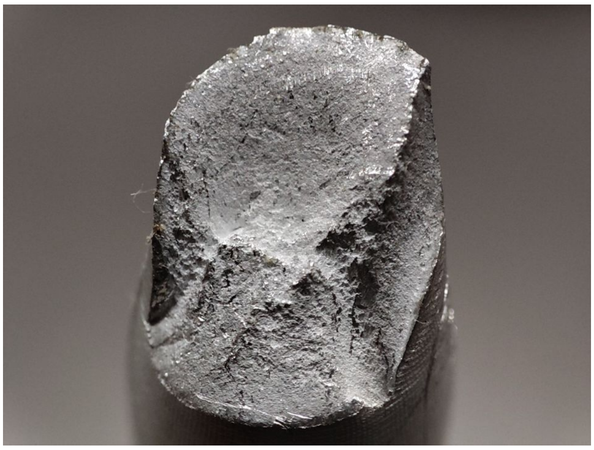

Figure 5: Fracture surface of aluminum alloy.

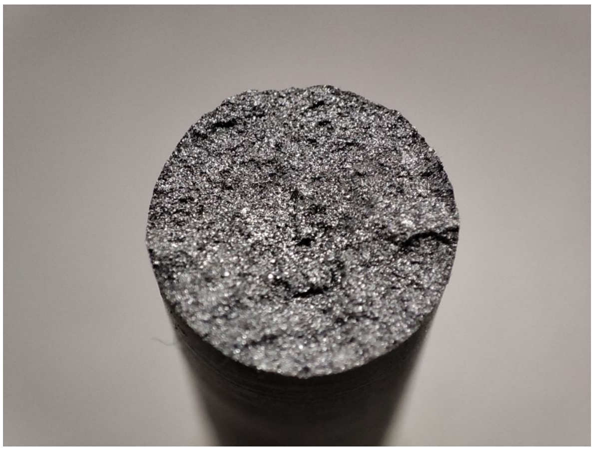

Figure 6: Fracture surface of carbon steel.

Figure 7: Aluminum alloy rod after fracture.

Figure 8: Carbon steel rod after fracture.

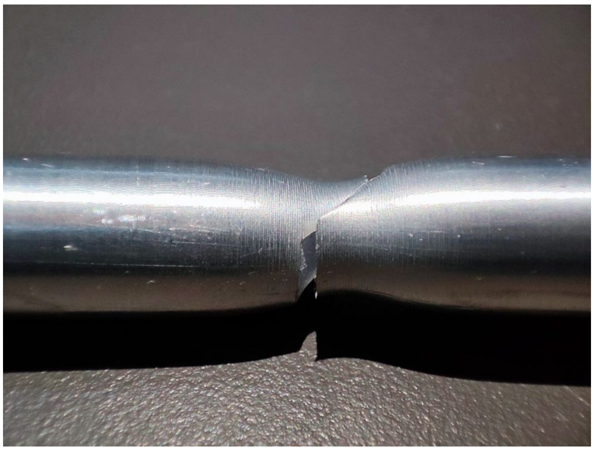

Figure 9: The appearance of the fracture of the aluminum alloy rod.

Equation for stress and strain:

$$\sigma = E\epsilon \tag{1}$$

$$\sigma = \frac{F}{A} \tag{2}$$

Equation for t test:

$$t_0 = \frac{\bar{x} - x_0}{s_x/\sqrt{N}} \tag{3}$$

$$x = \bar{x} \pm t_{2,95} s_{\bar{x}} \tag{4}$$

$$t_{2,95} = 4.303 \tag{5}$$

References

Wattrisse, B., Chrysochoos, A., Muracciole, J.-M., & Némoz-Gaillard, M. (2001). Analysis of strain localization during tensile tests by digital image correlation. *Experimental Mechanics*, 41(1), 29–39.