Note: This lab is performed at the MTIL facility in Talbot. Detailed procedures can be found on that website

Mechanical Properties

Objective

The objective of this laboratory is to explore the mechanical properties of a material by conducting mechanical tests on common engineering materials.

Preparation

Read the reference materials on tensile stress-strain, impact strength, and hardness found on the Compass website.

Equipment and samples

- Universal testing machine (Instron tensile tester), extensometer, Rockwell hardness tester.
- Instrumented impact tester, servo-hydraulic testing machine.
- Samples of carbon steel, aluminum alloy, brass, cast iron, and engineering plastics.

Introduction

The mechanical properties of a material are typically determined by applying a mechanical load to a testing sample and observing the mechanical response from the sample. To simplify the interpretation of the testing results, we often apply simple loads, such as tension and compression, and use sample geometries which lead to well-defined stress states in our samples. From such experiments, we measure basic mechanical properties such as hardness, yield strength, ultimate tensile strength, tensile elongation and ductility. We can extend these simple tests to including more complex loading conditions, such as those around a crack tip by conducting a fracture toughness test, or dynamic loading conditions where the load changes rapidly with time.

Session 1: Tensile tests of engineering alloys

- Use tensile testing machine to measure the tensile properties of a carbon steel (under several different processing conditions) and an aluminum alloy. Obtain the load-displacement curves from tensile samples and convert them into stress-strain curves. From the stress-stress curves, find basic mechanical properties such as yield strength, ultimate tensile strength, working hardening exponent, tensile elongation, fracture strength, and tensile ductility.
- Use Rockwell hardness tester to measure the hardness of engineering alloys and find out how the hardness may be related to tensile behavior of a materials.
- A sample of cast iron and brass will also be run as a demonstration.

Session 2: Impact testing of engineering polymers and alloys

- Use the impact testers to measure the dynamic impact resistance of common engineering materials, including steel, aluminum, and two different plastics. Conduct the impact tests at different temperatures to explore the ductile-brittle transition (or glass transition) in engineering materials.
- Observe a demonstration experiment on the fracture toughness test of an aluminum sample. Use the data collected to determine K_I.

Requirements for Report

Tensile testing

1. Plot both engineering and true stress-strain curves for the steel and aluminum samples. Comment on the shapes of the curves, and explain the different behavior observed.
2. From your data, calculate the following quantities. You may want to summarize them in a table.
   a. Elastic modulus (E)
   b. 0.2% offset yield stress ($\sigma_{0.2\%y}$)
   c. Ultimate tensile strength (UTS)
   d. Percent elongation (%EL)
   e. Percent reduction in area (%RA)
   f. Fracture stress (σ_f)
   g. Fracture strain (ε_f)
   h. Strain hardening exponent (n)
   i. Strength coefficient (K)
   j. Rockwell B Hardness (use cylindrical correction) (RHB)
3. How well do your calculated strengths and moduli compare to values from the literature? Possible sources of error?
4. Is there a relationship between strength, hardness, and ductility?
5. What do the fracture surfaces look like for each of the samples, and what do they tell you about the type of failure that occurred?

Impact testing

1. Plot the change in impact energy as a function of temperature for each of the materials tested. (May want to include on the same plot for best comparison.)
2. Discuss the impact behavior of the materials. Is there a ductile-to-brittle or glass transition temperature in the regime we tested? If so, can you approximate its value? Is one expected?
3. Compare the fracture surfaces of the hottest and coldest test temperatures for each of the materials. What type of failure was observed? How do you know if it is ductile or brittle from the fracture surface?
4. Compare the room temperature impact strengths of the steel and aluminum samples. Do the same for the two plastic samples.

Fracture toughness

1. Based on the load-displacement curve, identify what type of behavior was observed for our fracture toughness specimen. What are P_Q and P_{max}?
2. Determine if all four criteria were met for the ASTM standard method to be valid.
3. Calculate the value of K_Q. Is this value also K_{IC}?
4. What is the expected value of K_{IC} from the literature?