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EXPERIMENT NO.: 03(a)

NAME OF THE EXPERIMENT:

Mechanical testing of materials – (a) Tensile test of Metals and alloys and tensile test of polymer and polymer composites

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Introduction

Tensile test is the test for the materials to determine the mechanical property related to uniaxial tensile force applied to the material. This evaluation is also called ‘tension testing’. The test is conducted mainly to understand the mechanical property ‘strength’ — yield strength, ultimate tensile strength and fracture strength. Through this test, we get a stress-strain curve which helps us to understand a material's elastic region, plastic region, maximum withstandable stress etc. We also observe different materials behaving differently in the tensile tests. For example, brittle and ductile materials show contrasting behaviors in the same test. Though uniaxial (tension is created in only one axis) tensile tests are commonly used, there are also biaxial, triaxial, dynamic and other tensile tests. Moreover, tensile tests help us select materials and upgrade the quality control in the engineering applications.

Objectives

- Understand the principles of uniaxial tensile testing.
- Gain hands-on experience with the tensile testing machine.
- Calculate key tensile properties: ultimate tensile strength (UTS), yield strength, and percentage elongation.
- Analyze the stress-strain relationship graphically and understand material deformation and fracture characteristics, ductile or brittle

Equipments

- Tensile Specimens: Mild Steel
- Vernier Calipers: For precise measurement of specimen dimensions
- Universal Testing Machine (UTM): For applying uniaxial tensile force

Procedure

Preparation:

1. Recorded the initial dimensions of the specimen carefully.
2. The measurement was conducted several times in several hands for a more precise final reading.

Testing:

1. Firstly, we mounted the specimen in the Universal Testing Machine (UTM)
2. Then gradually applied force in the perpendicular axis.
3. Waited for around ten minutes for the specimen to go through elongation, necking and fracture stage.
4. Recorded the load and elongation data throughout the test for understanding the load-displacement curve.
5. The load-displacement curve was digitally created.

Results

Calculations

For Mild steel:
From the experimental preparation, we measured the dimensions of the specimen:

Width, b = 13.4 mm
Thickness, t = 0.5 mm
Gauge length, L = 50 mm
Thus, Cross sectional Area, A = width*thickness =b*t = 13.4*0.5 mm^2 = 6.7 mm^2

After testing, we got elongated length, L_1 = 74 mm
Ideal elongated length, L_2 = 75.33 mm

%Elongation (ideal) = $(L_2 - L)$*100% / L = (75.33 - 50)*100% / 50 = 50.66%
%Elongation (measured) = $(L_1 - L)$*100% / L = (74- 50)*100% / 50 = 48%

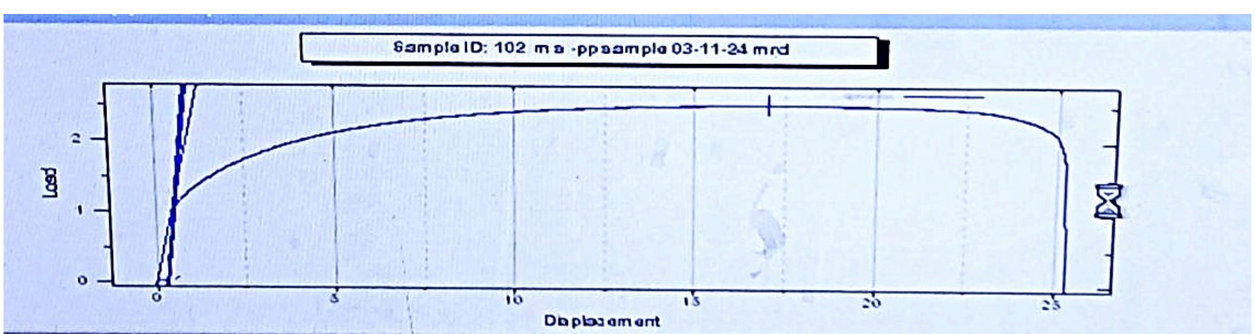

Fig: Load-Displacement Curve (mild steel)

From the graph reading, we get:

2% offset Yield Load = 1100 N

Ultimate Load = 2500 N

Thus, 2% Yield Strength = (2% offset Yield load / Cross-sectional Area)

= $1100/6.7*10^{-6}$ N

= 164.179 MPa

Ultimate Tensile Strength = Ultimate Load/ Cross-sectional Area

= $2500/6.7*10^{-6}$ N

= 373.134 MPa

From the machine, we directly got the Yield Strength and UTS. Which are

Yield Strength = 165.3 MPa

Ultimate Tensile Strength = 375.3 MPa

Offering an error analysis in Yield strength and UTS, we get:

%Error in UTS = (373.134 - 375.3)/ 375.3 = - 0.56%

%Error in tensile strength = (164.179 - 165) / 165 = 0.497%

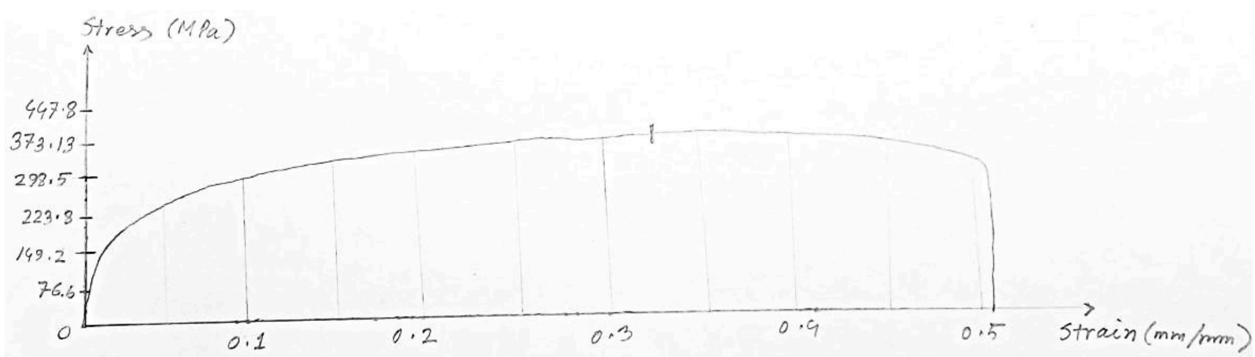

Fig: Stress-strain curve plotted from the load-displacement curve (mild steel)

For Polyethylene:
From the experimental preparation, we measured the dimensions of the specimen:

Width, b = 12.5 mm
Thickness, t = 4.9 mm
Gauge length, L = 50 mm
Thus, Cross sectional Area, A = width*thickness =b*t = 12.5*4.9 mm^2 = 61.25 mm^2

Primary length L_1 = 50mm
Secondary length L_2 = 305mm

%Elongation = (305-50)*100%/50 = 510%

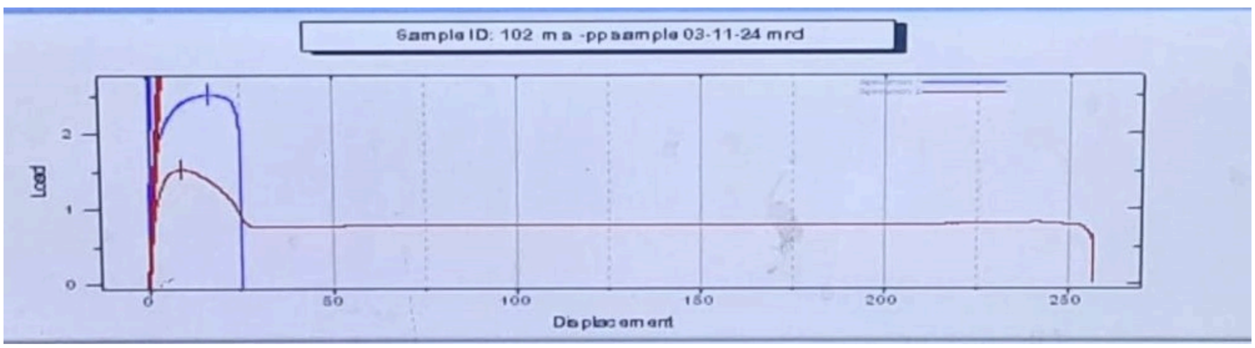

Fig: Load-displacement curve for Polyethylene

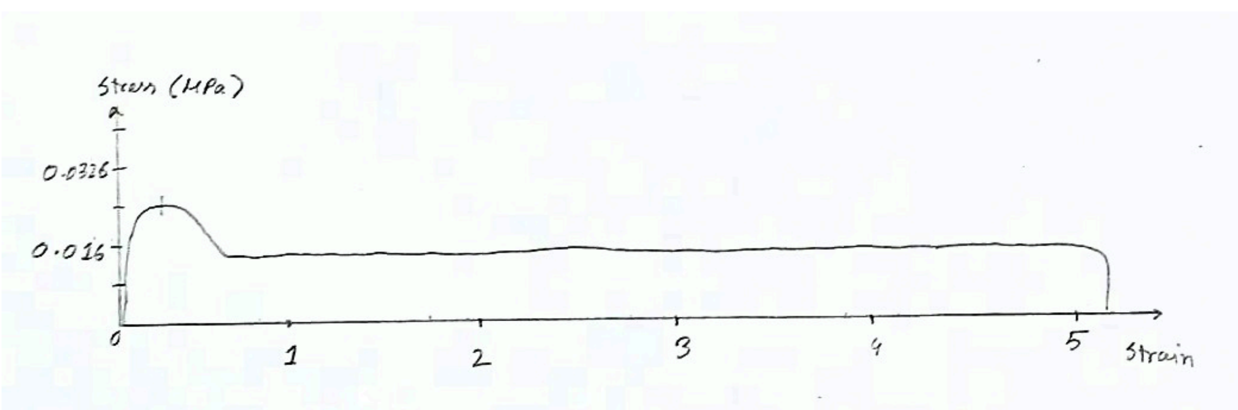

Fig: Stress-strain curve for Polyethylene

Table: Data from the tensile test

Material Type	Mild Steel (ASTM A36)	Polyethylene
Width (mm)	13.4	12.5
Thickness (mm)	0.5	4.9
Cross Sectional Area (mm^2)	6.7	61.25
Gauge Length (mm)	50	50
Load at Yield Point (N)	2515	673.75
2% Yield Strength (MPa)	165.3	11
Maximum Load (N)	2515	1532
Ultimate Tensile Strength (MPa)	375.3	25
%Elongation (ideal)	50.66%	N/A
%Elongation (measured)	48%	510%
%Area Reduction	N/A	N/A

Discussion

We conducted our experiment divided in two groups where one did mild steel tensile testing and the other group did the test with polyethylene. We conducted our experiment using the Universal Testing Machine or UTM. The specimen (both for the case of PE and mild steel) was clipped in the UTM and then pulled uniaxial (in this case, vertically). We observed the experiment carefully. In the case of mild steel, it took around ten minutes to finish the experiment (more specifically– to break the specimen). The most significant part of the visual observation of the entire experiment was necking of the specimen. Necking occurs when the stress reaches the tensile stress when a large local decrease in the cross section occurs and the overall body narrows down thin. Later on, it breaks.

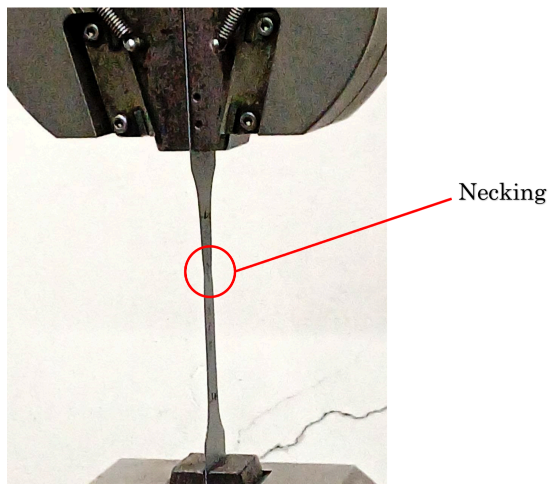

Fig: Necking in the tensile test of mild steel

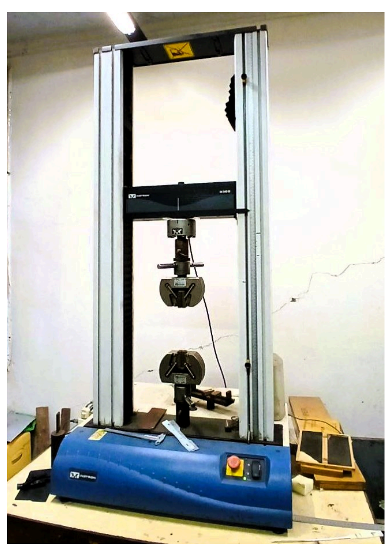

Fig: Universal Testing Machine

**What information does a tensile test provide regarding material properties?*

A successful tensile test provides different mechanical properties of a material. We get some straightforward mechanical properties, which are– yield strength of the material, ultimate tensile strength (UTS), fracture strength, elongation and reduction in area of the material. On the other hand, we can derive different properties from the test outputs, for example: Young's modulus and Poisson's ratio. Finally, an overall characteristic of a material's stress-strain can be derived from a tensile test.

**Which material showed higher ductility? Provide its elongation percentage.*

Polyethylene samples showed higher ductility than mild steel. In the mild steel tensile test, we saw an elongation percentage of 50.33%. On the other hand, in the PE tensile test, the elongation percentage is 510%, which means the specimen extended its length 5.1 times than its original length. Thus, we can say PE has a higher ductility than mild steel.

**Describe the type of fracture observed and explain the cause.*

There was a slice-like fracture in the tensile test of mild steel. Though, from the theoretical perspective, mild steel is ductile enough to demonstrate a cup-cone fracture instead of a crack. But from the load–displacement curve, we see that mild steel is not brittle but ductile.

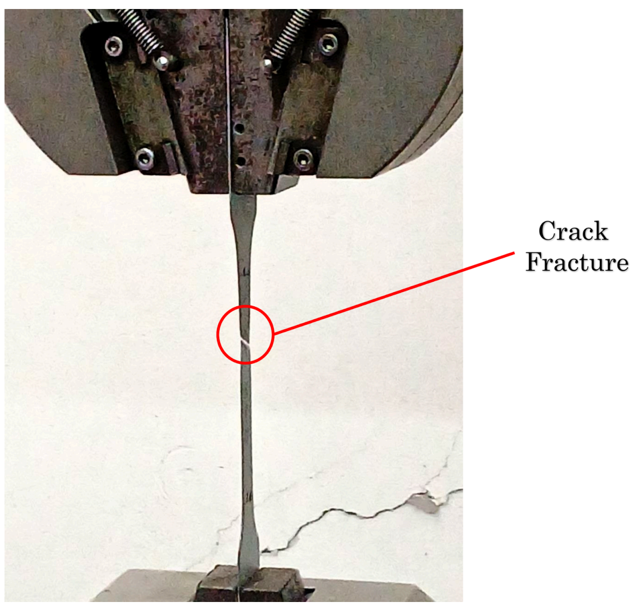

Fig: Fracture after elongation of the mild steel specimen

The reason for a crack fracture is the shape of the specimen. The specimen was not in a dog-bone shape. Thus the gauge space was not cylindrical, as a result, it was not possible for the material to make a cup-cone shape. That is why it formed a crack.

**Between yield strength and UTS, which parameter would you prefer for material selection in structural applications? Justify your answer.*

I would prefer yield strength as the main parameter while designing structural applications. The main reason is safety. While using yield strength as a parameter, we extend our structure's deformation limit only to the yield point, where the material shows elastic behavior. If we use the ultimate tensile strength as a parameter, we are letting the structure deform till its breaking point, because, after the ultimate tensile point, it takes less load to fracture or break a material. While using UTS as a parameter, the structural damage causes more harm as the preparation against the damage is null. That is why, I would prefer yield strength as the main parameter than the UTS in the structural application.