INDIAN INSTITUTE OF TECHNOLOGY, GUWAHATI
DEPARTMENT OF MECHANICAL ENGINEERING

LABORATORY SHEET

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EXPERIMENT: UNI-AXIAL TENSION TEST.

OBJECTIVE: To obtain the stress-strain relation of mild steel using a circular cylindrical specimen and determine Young's modulus (E), proportional limit (σ_p), yield stress (σ_y), 0.2% offset yield strength, ultimate tensile stress (σ_u), true fracture stress, and nominal and true fracture strain and percentage elongation.

APPARATUS: The Universal Testing Machine (UTM) is a machine with which several tests can be performed, namely, Tension, Compression, Bending, Buckling and Hardness. The movement is controlled by rate of pumping of fluid into a hydraulic cylinder whose piston controls the movement of the moving plate. The load ranges available on the machine are 0-8 ton and 8-20 ton with resolution of 2 kgf and 5 kgf respectively. The ram must be right down before the capacity is changed or the motor is switched off.

An electronic clip on type extensometer with gauge length 25mm and 50mm is used to indicate the extension between the end points of the gauge length of the specimen to which it is attached. It must be very carefully and should be used only for yield / proof studies and not for specimen failure or breakage (i.e. it must be removed immediately after yield point to avoid damage to the extensometer).

The specimen has a larger diameter at the ends with a smooth fillet connecting to the reduced diameter of the central portion to ensure that the effect of the holding jaws is not significant on the state of stress within the gauge length. The diameter at the middle of the gauge length is reduced by about 20mm to ensure that neck forms in this region so that a meaningful value of percentage elongation is obtained.

The machine frame consists of two cross-heads and lower table. The lower cross-head is adjustable by means of geared motor. Tension test is carried out between lower and upper cross-head. Sensing of the load is done by means of precision pressure transducer of strain gauge type.

The loading unit consists of a robust base. The main hydraulic cylinder is fitted in the center of the base and piston slides in the cylinder. The lower table is connected to the main piston. This lower table is rigidly connected to the upper cross-head by two straight columns. The chain and sprocket driven by a motor fitted in the base rotates the two straight columns mounted on the base which enables movement of the lower cross-head. The jaws inserted for tensile test specimen along with the rack jaws slide in the lower and upper cross-heads. Jaw locking handle is provided to lock the jaws of the lower cross-head after the specimen is clamped. An elongation scale is kept sliding on the rod which is fixed between the lower table and upper crosshead. The elongation indicating pointer is fixed to the lower cross-head.

The control panel has two control valves to control oil flow in the hydraulic system, one at the right side and the other at the left. The right side valve is a pressure compensated flow control valve. The left side valve is a return valve, i.e. it allows the oil from the cylinder to go back to the tank. Pressure compensation of the flow control keeps a constant rate of straining regardless of the total load on the specimen.

PROCEDURE: Before testing, adjust the load range according to the capacity of the test piece. Measure the diameter of the specimen. Mark the gauge length of the specimen. Select the proper jaw inserts and complete the upper and lower chuck assemblies. Then operate the upper cross-head grip operation handle and grip fully the upper end of the test piece. Attach the extensometer to the specimen. Apply the load gradually and read the extension from the extensometer at equal increments of load till yield occurs. Remove the extensometer. Increase the displacement of the movable jaw till the specimen fractures in into two pieces. Note down the maximum load applied. Measure the minimum diameter of the necked section and final deformed lengths between the marked gauge points by assembling together the fractured pieces.

LOADING / UNLOADING: The left valve is kept in fully closed position and the right valve in normal open position. Open the right valve and close it after the lower table is slightly lifted. Now adjust the load to zero by Tare push button. (this is necessary to remove the dead weight of the lower table, upper cross-head and connecting parts from the load). Operate the lower grip operation handle and lift the lower cross-head up and grip fully the lower part of the specimen. Then lock the jaws in this position by operating the jaw locking handle then turn the right control valve solely to open position, (i.e. anticlockwise) until you get a desired loading rate. After this you will find that the specimen is under load and then unclasp the locking handle. Now the jaws will not slide down due to their own weight. Then go on increasing the load when the test piece is broken. Then open the left control valve to take the piston down.

OBSERVATION AND CALCULATION:

Diameter of specimen d_o = mm
Gauge length L_o = mm

Maximum load, P_{max} = N
Load at fracture, P_f = N
Minimum diameter of the neck, d_f = m

Undeformed Area $A_o = \dfrac{\pi d_o^2}{4} =$ m^2

The load P (N) versus extension / displacement curve is obtained from the plotter. Slope of the straight-line portion is determined from load versus extension curve as

In linear range, $E = \dfrac{\Delta P L_o}{A_o \Delta \delta} =$ N / m^2

From the computer plot, the loads P_{pl}, P_y corresponding to proportional limit and yield point are

$P_{pl} =$ N, $P_y =$ N

Proportional limit, $\sigma_{pl} = \dfrac{P_{pl}}{A_o} =$ Pa

Yield stress, $\sigma_y = \dfrac{P_y}{A_o} =$ Pa

A permanent strain of 0.002 corresponds to the following displacement between the jaws

$\Delta \delta_p = 0.002L$

Take the origin in the computer plot (load-displacement curve) at the point of intersection of the straight line fitted to the data with displacement axis. From the point $(\Delta \delta_{p,} 0)$ (where permanent displacement corresponding to 0.2% strain0 w.r.t. this origin, a line is drawn parallel to the fitted line which intersects the curve at a load P_1

$P_1 =$ N

0.2% offset yield strength = P_1/A_o = Pa

Ultimate stress, $\sigma_u = P_{max} / A_o$ = Pa

True fracture stress, $\sigma_f = P_f / A_f$ = Pa

Final deformed gauge length, L_f= m

Nominal average strain at fracture = $(L_f - L_o) / L_o$=

True strain at fracture = $2 \ln\left(\dfrac{d_o}{d_f}\right) =$

For L_o = m, and d_o= m, we have for mild steel,

Percentage elongation = $\dfrac{(L_f - L_o)}{L_o} 100 =$ %

Percentage reduction in area = $100\frac{(A_o - A_f)}{A_o} = \left[1 - \left(\frac{d_f}{d_o}\right)^2\right]100 =$ %

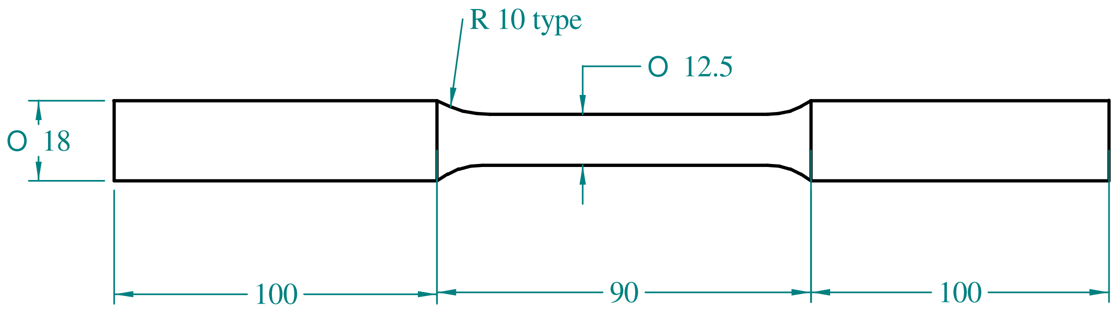
Draw the sketch of the final deformed specimen.

DISCUSSION OF RESULTS AND SOURCES OF ERROR:

Lack of calibration of machine, improper alignment, initial curvature of specimen, error in measurement of extension, etc., are the sources of error.

EXERCISE:

1. Draw nominal $\sigma - \varepsilon$ relation for a ductile material and indicate properly in the diagram E, proportional limit, yield stress, ultimate tensile strength σ_u, normal fracture stress σ_f, 0.2% offset yield strength (0.2% proof stress), modulus of resilience. For a stress level σ such that $\sigma_y < \sigma < \sigma_u$, show that the elastic part ε_o and plastic part ε_p of strain.
2. Draw σ-ε relation for cast iron and mild steel in the same figure.
3. Classify the following into brittle and ductile: mild steel, C.I, rock, concrete, Al, copper, Perspex, brass, brick wood, chalk.
4. Draw the tensile flow curve (True stress vs, True strain) from the load-elongation curve during the tension test. Assume the displacement values from the load-displacement plot that was obtained using a 2” extensometer. Determine the work hardening exponent for the sample tested.
5. What are the types of test that can be conducted on U.T.M.
6. What is the Bauschinger effect? Illustrate by σ-ε graph.
7. Why is the state of stress in the local neck formed in a uni-axial tension test of cylindrical specimen of ductile metal neither uni-axial nor uniform?
8. Ductile metals in a uni-axial tension test have a cup cone fracture whereas brittle ones have flat fracture surface. Why?
9. Percentage elongation of material has been quoted as 17%. What is wrong with this statement?
10. Sketch on the same graph, σ-ε curves for uni-axial test of ductile metal for rate of strain ε- very small, intermediate value, very large.
11. Sketch on the same graph, σ-ε curves for uni-axial test of mild steel at room temperature and at temperature below the brittle-ductile transition temperature.
12. a) Define true strain ε_t (logarithmic strain) and obtain its expression in terms :- (i)L_o & L (ii) Nominal strain ε.
    b) Assuming volume constancy, relate nominal and true strains ε, ε_t to areas A_o and A.
    c) Which expression should be used to obtain ε_t before necking and after necking?



Tensile Specimen (Plain)

Material: 1) MS
2) Al

(Tensile test sample of MS was heated to 730^{0}C and held for 45 minutes and allowed to cooled in the furnace)

All dimensions are in mm.