Republic of Iraq

Ministry of Higher Education and Scientific Research

Northern Technical University

Experiments in Mechanics and Strength of Materials

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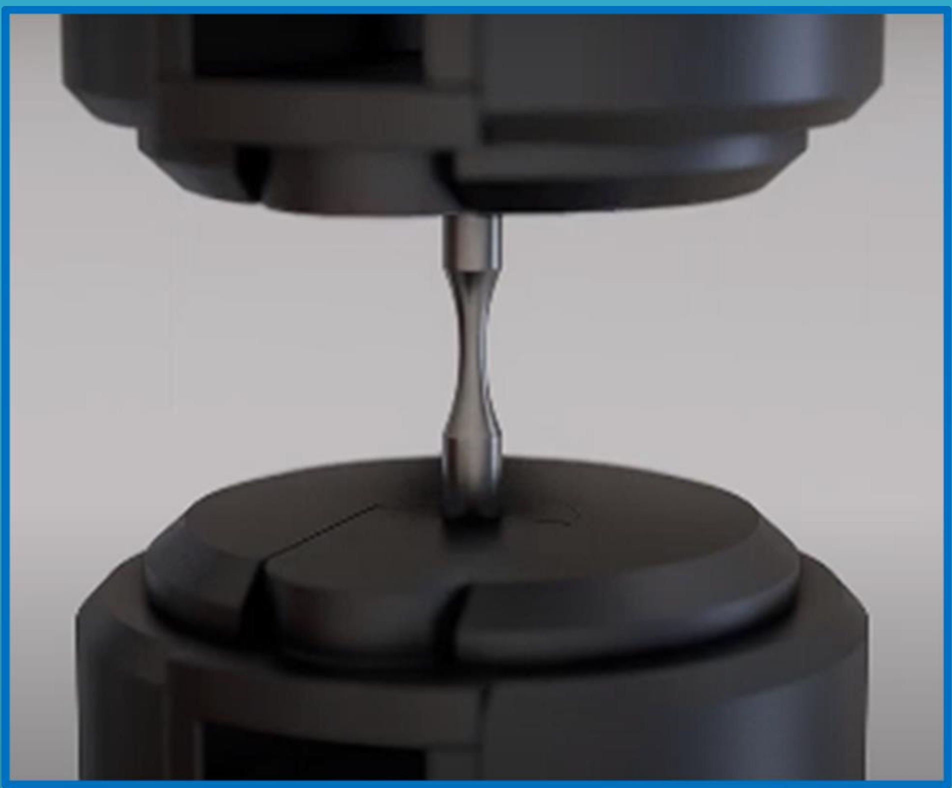

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First Experiment

Tensile Test Experiment

2024

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1. Introduction

The purpose of this experiment is to apply a tensile force to a test specimen until the specimen is pulled to failure. During the course of the tensile load application the computer will monitor properties and generate a stress/strain curve from which various values such as the Modulus of Elasticity of the material can be determined.

2. Objective

The purpose of this experiment is to measure the modulus of elasticity (Young's modulus) of an aluminum beam by loading the beam in cantilever bending.

3. Apparatus

Materials and Equipment

1. Tensile testing machine, figure 1.
2. Test specimens, figure 2.
3. Micrometer
4. Calipers

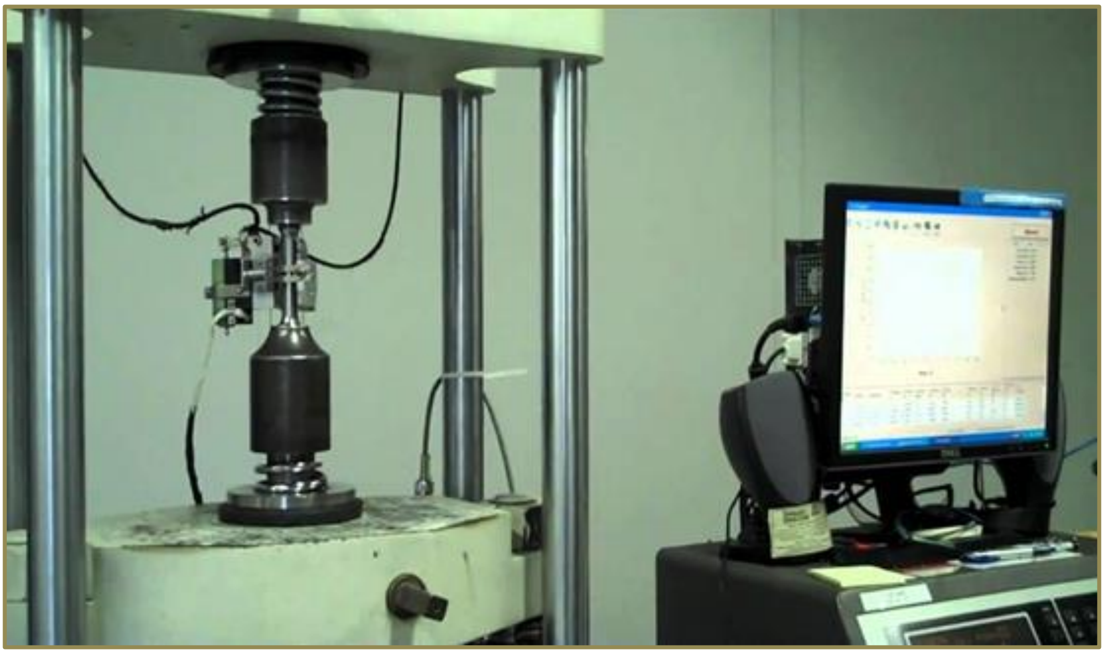
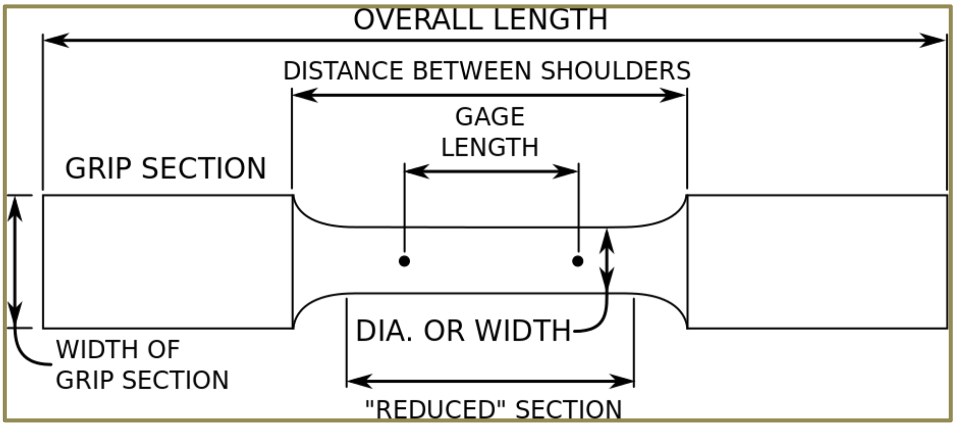


Figure 1: Tensile testing machine



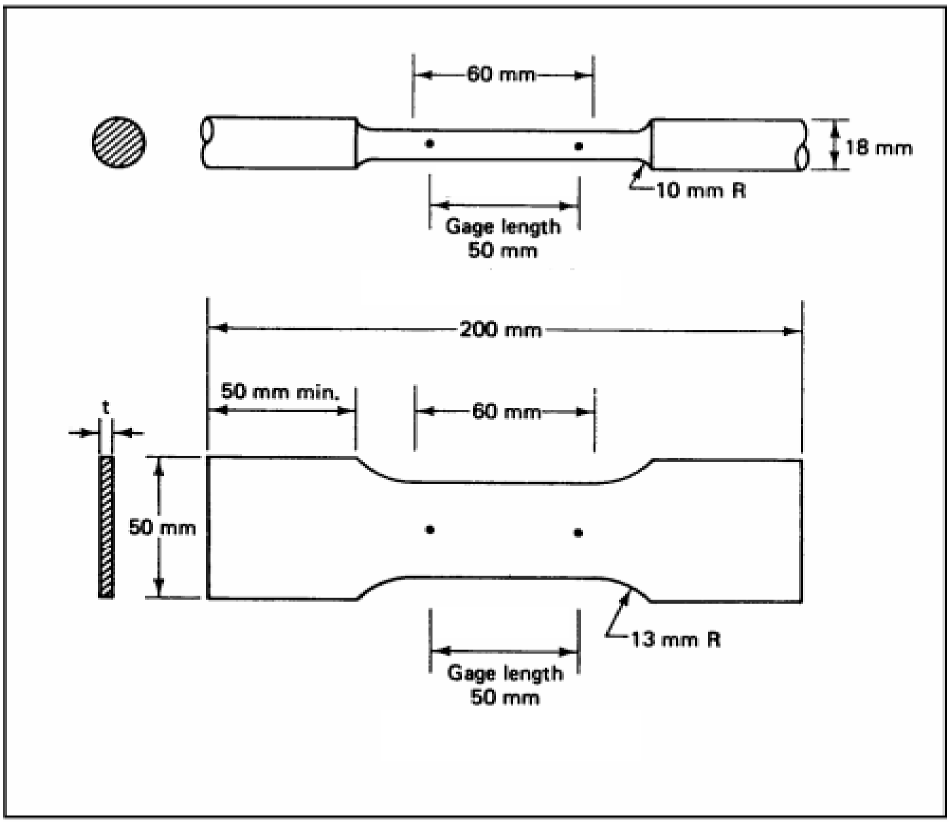


Figure 2. Test specimen

4. Test Specimens

The tensile testing machine consists of an electro-mechanical test system that applies uniaxial loading in a uniform manner to test specimens. It is general purpose in its capabilities and applications. The system performs load versus elongation (stress versus strain) tests which involve controlling forces from a few ounces to several-thousand pounds, gripping specimens ranging from delicate fibers to high strength metals or composites, and measuring the resulting forces (stresses) and deformations (strains). Measurement of the stresses and strains is accomplished by the use of highly sensitive load and strain transducers that create an electrical signal that is proportional the applied stress or strain. This electrical signal is measured, digitized and then processed for display, analysis and report of stress, strain and other computed material characteristics.

5. Theory

The modulus of elasticity (Young's modulus) is a material constant indicative of a material's stiffness. It is obtained from the stress versus strain plot of a specimen subjected to a uniaxial stress state (tension, compression, or bending). The elastic modulus is used, along with other material constants, in constitutive equations that relate stress to strain in more complex situations. Bending test is performed on beam by using the three point loading system.

A simple tensile test is the most popular means for determining the elastic modulus. Figure 1, for example, shows a cylindrical test specimen subjected to uniaxial tension. Two reference points, located at a distance Lo apart, define a gage length. Engineering stress, ó, is computed as the load is increased (based on the original cross sectional area, Ao) while engineering strain, å, is determined when the elongation experienced by the specimen, ä, is divided by the original gage.

$$\sigma = \frac{P}{A_O} \qquad (1)$$

$$\varepsilon = \frac{\Delta L}{L_O} \qquad (2)$$

$$E = \frac{\Delta \sigma}{\Delta \varepsilon} \qquad (3)$$

A plot of these quantities produces a stress-strain curve. The modulus of elasticity, E, is defined as the slope of the linear portion of this curve, and is given by **above equations** where the stress, ó, is measured in psi (N/m^2 or Pa). In Equation (1, 2, 3), å is the strain measured in in/in (m/m) in the direction of the applied load. Since strain is dimensionless, the elastic modulus is measured in units of psi (Pa).

It is important to realize that Equations above is valid only for uniaxial tension and is a special case of a generalized set of relations known as Hooke's law. Much more complex relations must be used when dealing with more complex loadings.

The shape of the stress-strain curve depends on the material and may change when the specimen is subjected to a temperature change or when the specimen is loaded at a different rate. It is common to classify materials as ductile or brittle. Ductile materials yield at normal temperatures while brittle materials are characterized by the fact that rupture occurs without any noticeable prior change in the rate of elongation. Figures Below typical stress-strain curves for such materials.

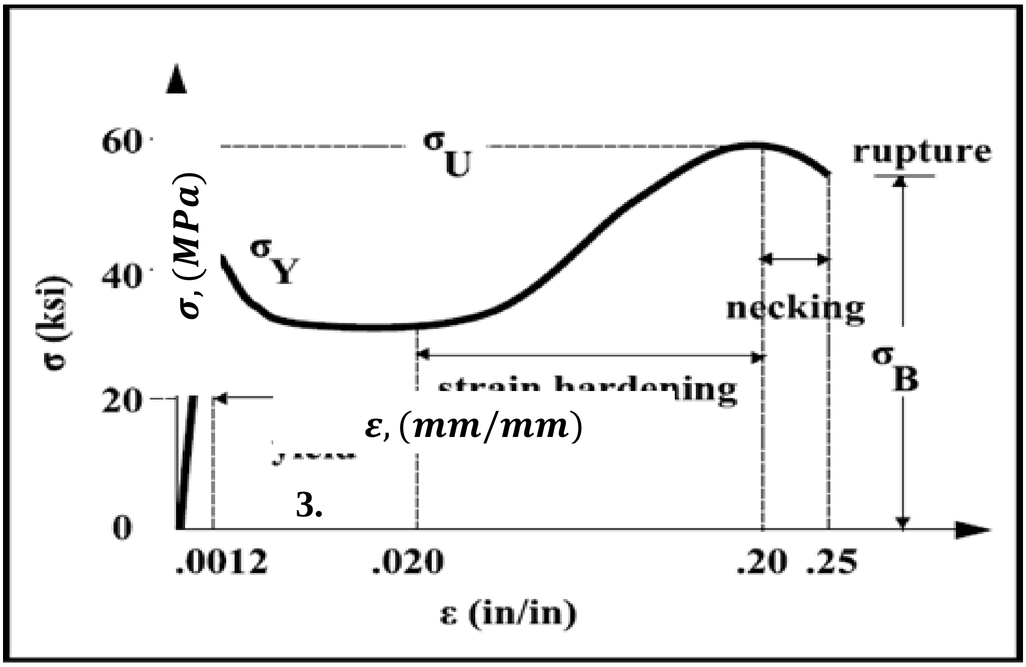


Figure 2. A stress-strain curve for a ductile material.

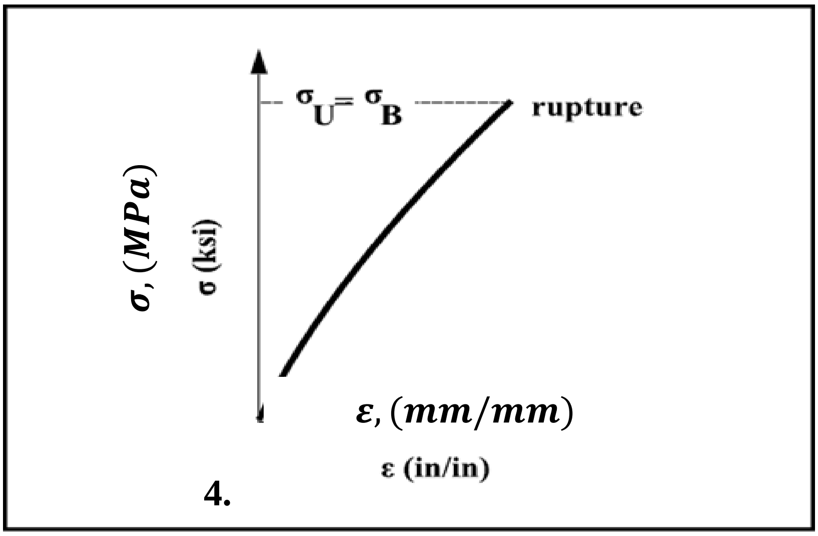


Figure 3. A stress-strain curve for a brittle material.

In the case of a ductile material, the specimen experiences elastic deformation, yields, and strain-hardens until maximum load is reached. Necking occurs prior to rupture and failure takes place along the planes of maximum shear stress. Referring to Figure 3, the stress, óy, at which yield is initiated is called the *yield stress*. The stress, óu, corresponding to the maximum load applied to the specimen is known as the *ultimate strength*. The stress, óB, corresponding to rupture is defined as the *breaking strength*.

In the case of the brittle material characterized by Figure 4, there is no difference between the ultimate strength and the breaking strength. Necking is negligible and failure takes place along the principal planes perpendicular to the maximum normal stress. Since the slope of the elastic portion of the stress versus strain curve often varies, different methods, such as secant and tangent methods, have been developed to obtain the elastic modulus. When the yield point is not well defined, a 0.2% offset method is often used to determine the yield stress. As illustrated in Figure 5, óy is obtained by drawing a line parallel to the initial straight-line portion of the stress-strain diagram starting from a strain value of ε = 0.2 % (or ε = 0.002). The yield stress is defined as the point where this line intersects the stress versus strain curve.

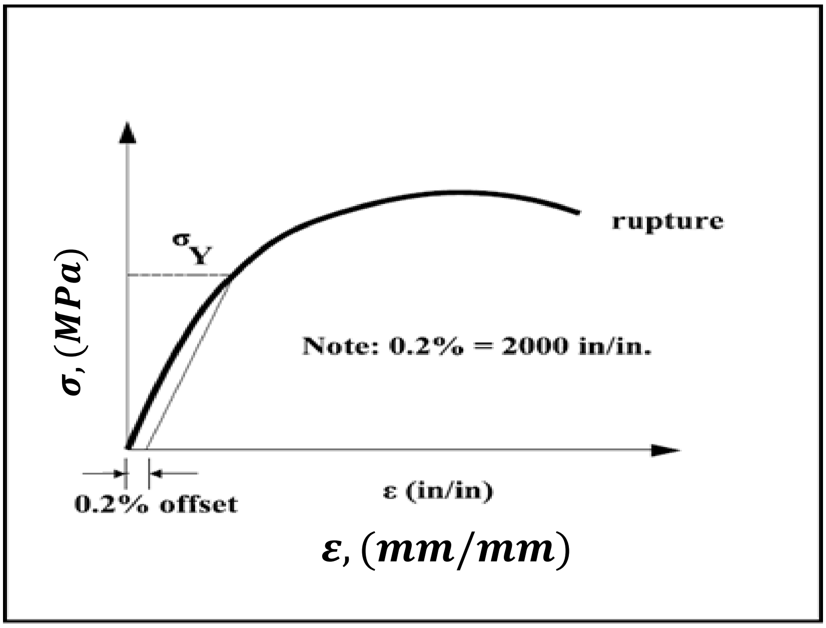


Figure 5. An offset method may be used to determine the yield stress of a material.

6. Preparation for the Lab

1. What is the Modulus of Elasticity?
2. Is the Modulus of Elasticity a material property?
3. What are the various regions on a stress/strain curve?
4. What is Hooke's Law?

7. Procedure

The computerized tensile testing machine will be used to produce stress versus strain plots for several different specimens having rectangular cross sections. The data is used to determine the modulus of elasticity while the specimens are examined for failure characteristics. Information should be entered on the attached work sheet. The steps to be followed are:

1. Measure and record the beam width (b), beam thickness (t), and length (L) of the test section.
2. Mark a section of specimen and measure the effective length.
3. Start the computer and select AUTOMATIC application Icon.
4. In main Menu select specimen preparation.
5. Select Tensile Test for Rectangular bar.

6. Provide measured gauge and other data for specimen.
7. Mount the specimen in the machine using the grips provided. Make sure it is fixed and rigidly positioned, and centered the testing area as much as possible.
8. Go to main menu and Run Test. (it will be switched to an interactive screen). MAKE SURE TO FOLLOW EVERY INSTRUCTIONS ON SCREEN.
9. Run test and follow instructions.
10. It is extremely important to follow instruction on screen and place the strain measurement gauge and remove when it is asked to do so.
11. If Asked, take the rupture specimen out and measure the new length between the original marked area and report the number as input to program.
12. Upon completion return to main menus and get all reports.
13. Print reports onto your USB.

8. Required

From graph and data collected find:

1. elastic modulus (E) by using the tangent method
2. elastic modulus (E) by using the secant method
3. yield stress (óy) by using the 0.2% offset method
4. ultimate strength (óu)
5. breaking strength (ób)
6. Plastic deformation region
7. Proportional limits
8. Examine each specimen after it has failed and note the degree of necking an orientation of the fracture surface.

9. Calculations

From your text or another material handbook find the standard value for the modulus of elasticity of the specimens tested. Calculate the percentage error with the value determined by using the tangent method.

10. Discussion

1. What are possible sources of error?
2. Were your errors within reasonable limits (< 10 %)?
3. Why are the failed specimens shaped as they are?

11. Examples

Examples - 1

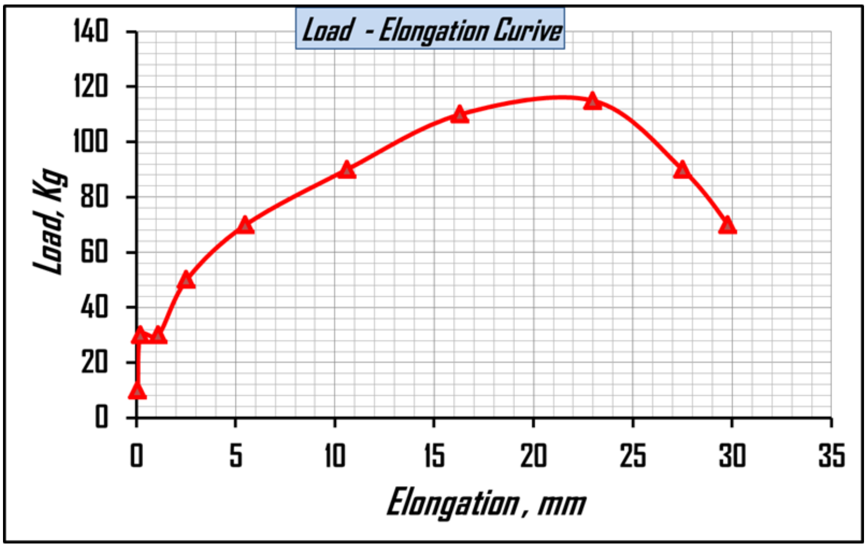
The tensile test was performed on a standard high carbon steel specimen, which has a length (100 mm) and a circular cross-section (20 mm) . The load readings in kilonewtons and the corresponding elongation in mm were in the table below?

Load, (KN)	10	30	30	50	70	90	110	115	90	70
Elongation, mm	0.07	0.21	1.11	2.53	5.51	10.6	16.3	23	27.5	29.8

Draw the load and elongation curves, then determine the following:

1. Yield stress
2. Tensile strength
3. Percentage of elongation
4. Modulus of elasticity
5. Reversibility coefficient
6. Durability coefficient

Solution:



$$A = \frac{\pi\, d^2}{4} = \frac{3.143 \times 25^2}{4} = 491.094\, mm^2$$

1. **Yield stress (σ_y):**

$$\sigma_y = \frac{F}{A} = \frac{30000}{491.094} = 61.088\, MPa$$

2. **Ultimate Tensile strength (σ_{UTS}):**

$$\sigma_{UTS} = \frac{F_{max}}{A} = \frac{115000}{491.094} = 234.171\, MPa$$

3. **Percentage of elongation (e %):**

$$e\,\% = \frac{\Delta L}{L} = \frac{29.8}{100} \times 100\,\% = 29.8\,\%$$

4. **Modulus of elasticity (E):**

$$E = \frac{\sigma_P}{\varepsilon_P} = \frac{\frac{F}{A}}{\frac{\Delta L}{L}} = \frac{F\,.\,L}{\Delta L\,.\,A} = \frac{10000 \times 100}{0.07 \times 491.094}$$

$$= 29089.572\, MPa \approx 290.9\, GPa$$

5. **Reversibility coefficient (U_r)**

$$U_r = \frac{1}{2}\,\sigma_P\,.\,\varepsilon_P = \frac{1}{2} \times \frac{30000}{491.094} \times \frac{0.21}{100} = 0.064\, N/mm^2$$

6. **Durability coefficient (T)**

$$T = \frac{1}{2}\left[\frac{(Yield\ Load + Ulimate\ Load) \times Total\ Elongation}{Sample\ Volume}\right]$$

$$T = \frac{1}{2}\left[\frac{(30000 + 115000) \times 29.8}{491.094 \times 100}\right] = 4.339\, N/mm^2$$

Examples - 2

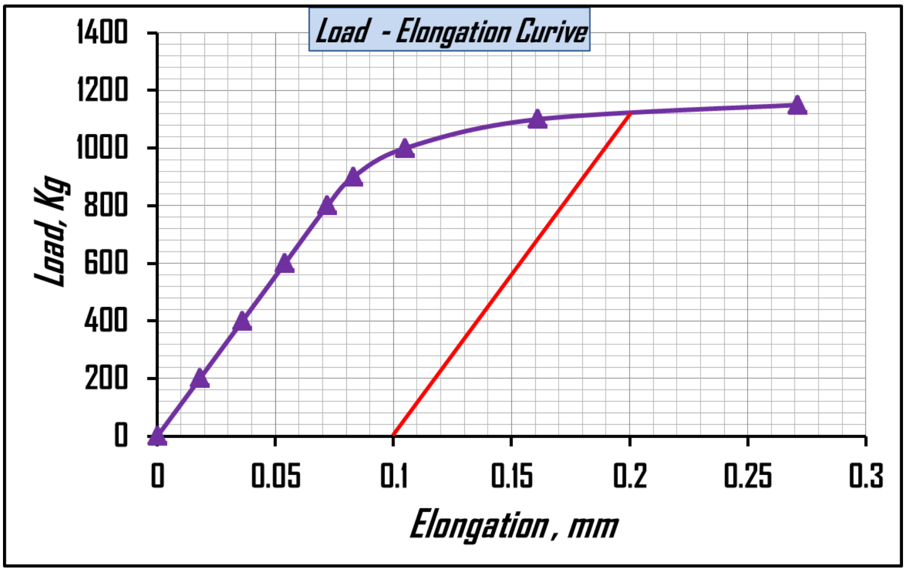
The tensile test was performed on a standard aluminum alloy specimen, which has a length (50 mm) and a circular cross-section (10 mm) . The load readings in kilonewtons and the corresponding elongation in mm were in the table below?

Load, (Kg)	0	200	400	600	800	900	1000	1100	1150
Elongation, mm	0	0.018	0.036	0.054	0.072	0.083	0.105	0.161	0.271

Draw the load and elongation curves, then determine the following:

1. Yield stress (0.2 %)
2. Tensile strength
3. Percentage of elongation
4. Modulus of elasticity
5. Reversibility coefficient
6. Durability coefficient

Solution:



$$A = \frac{\pi\, d^2}{4} = \frac{3.143 \times 10^2}{4} = 78.575\, mm^2$$

1. Proof stress (σ_{Proof}):

Permanent elongation at yield stress Here, the proof stress is considered to be:

$$\Delta L_{Proof} = 0.2\ \%\ L = \left(\frac{0.2}{100}\right) \times 50 = 0.1\ mm$$

From the load and elongation curves, we find that the proof load is:

$$F_{Proof} = 1130\ Kg$$

$$\therefore\ \sigma_{Proof} = \frac{F_{Proof}}{A} = \frac{1130}{78.575} = 14.381 \frac{Kg}{mm^2} = 14.381 \times 9.81 = 141.079\ MPa$$

2. Fracture Tensile strength (σ_{FTS}):

$$\sigma_{FTS} = \frac{F_{max}}{A} = \frac{1150}{78.575} = 14.636 \frac{Kg}{mm^2} = 14.636 \times 9.81 = 143.576\ MPa$$

3. Percentage of elongation (e %):

$$e\ \% = \frac{\Delta L}{L} = \frac{0.1}{50} \times 100\ \% = 29.8\ \%$$

4. Modulus of elasticity (E):

$$E = \frac{\sigma_P}{\varepsilon_P} = \frac{\frac{F}{A}}{\frac{\Delta L}{L}} = \frac{F\ .L}{\Delta L\ .A} = \frac{200 \times 50}{0.018 \times 78.575} = 7070.386 \frac{Kg}{mm^2}$$

$$= 7070.386 \times 9.81 = 69360.484\ MPa\ \approx 69.36\ GPa$$

5. Reversibility coefficient (U_r)

$$U_r = \frac{1}{2}\ \sigma_P\ .\varepsilon_P = \frac{1}{2} \times \frac{800}{78.575} \times \frac{0.072}{50} = 0.00713\ N/mm^2$$

6. Durability coefficient (T)

$$T = \frac{1}{2}\left[\frac{(Yield\ Load + Ultimate\ Load) \times Total\ Elongation}{Sample\ Volume}\right]$$

$$T = \frac{1}{2}\left[\frac{(800 + 1150) \times 29.8}{78.575 \times 50}\right] = 7.395\ N/mm^2$$

References

1. ASM International, Tensile Testing, second edition.
2. www. mathalino.com / Engineering math review
3. www.nde-ed.org/ Nde research center
4. www.azo.com/ Azo materials

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Second Experiment

Compression Test Experiment

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1. Introduction

In theory the compression test is just the opposite the tensile test. However, there are special limitations on the compression test:

1- Appling a truly axial load is difficult.
2- There is always a tendency for bending stresses to be set up.
3- Friction between the heads of the testing machine or bearing plates and the end surfaces of the sample.

2. Objective

The compression test is used to:

1. Observe the stress - strain behavior of some metals under compression load.
2. Determine the strength and other properties of various materials.

3. Theory

For a compression test, the stress – strain diagrams have different shapes from those of for tension. Ductile metals such as steel, aluminum, and copper have proportional limits in compression very close to those in tension; and therefore the initial regions of their compression stress – stain diagrams are very similar to the tension diagrams. However, when yielding begins, the behavior is quite different. In a tension test, the specimen is stretched, necking may occur, and fracture ultimately takes place. When a small specimen of ductile material is compressed, it begins to bulge outward on the sides and become barrel shaped. With increasing load, the specimen is flattened out, thus offering increased resistance to further shortening (which means the stress-strain curve goes upward). These characteristics are illustrated in Figure 1, which shows a compression stress-strain diagram for copper.

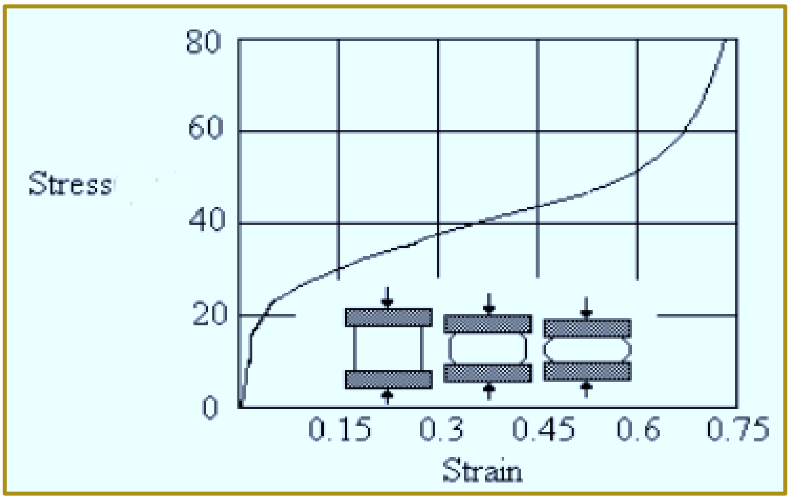


Figure 1. Explain compression stress-strain diagram for copper

Brittle materials in compression typically have an initial linear region followed by a region in which the shortening increases at a higher rate than does the load. Thus, the compression stress-strain diagram has a shape that is similar to the shape of the tensile diagram. However, brittle materials usually reach much higher ultimate stresses in compression than in tension. Also, unlike ductile materials in compression, brittle materials actually fracture or break at the maximum load.

4. Apparatus

Test Set-up and Specification of Machine

A compression testing machine shown in figure 3, below has two compression plates/heads. Theupper head is movable while the lower head is stationary.

Under ideal conditions where there is no friction between the work piece and the dies, the billet deforms homogeneously (the cylindrical σ_y shape of the billet remains cylindrical throughout the process), the distribution of compressive stress on its flat face is uniform and is equal to the flow-stress in compression, . This also remains constant for all stages of compression (i.e. for all heights of the compressed cylinder) if the metal in question is perfectly plastic (Non-work hardening, e.g. lead).

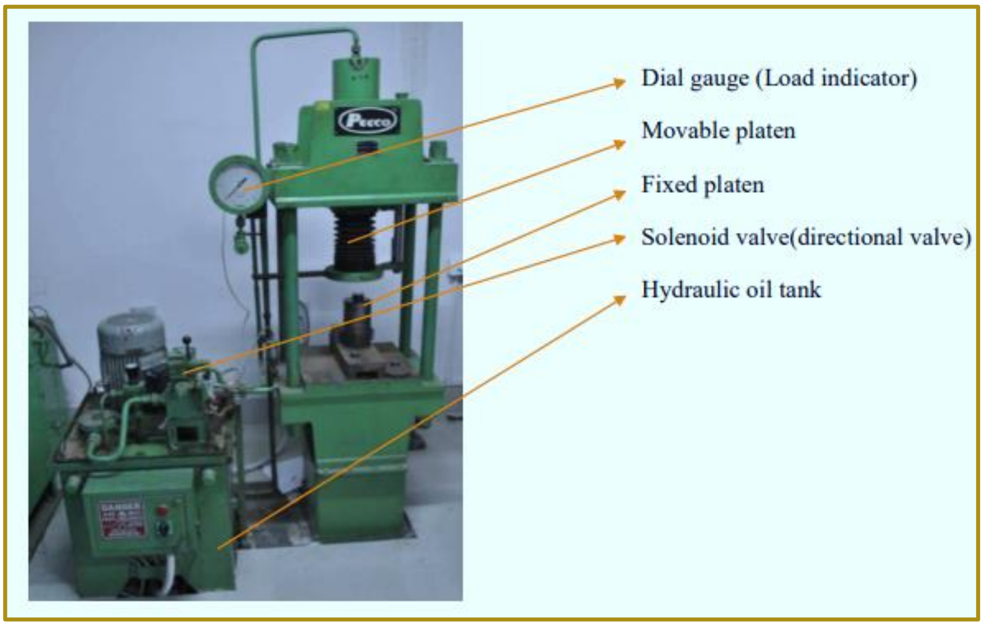


Figure 2. Hydraulic Compression testing machine

5. Precautions:

1- Machined surfaces should be finished to 1.6µm or better.
2- Test specimens ends should be flat and parallel within .0005 in/in.
3- Test specimens should be loaded concentrically.

6. Procedure:

1- Measure Do and Lo at three locations along the circumference, or any other dimensions of the used specimen, figure 3.
2- Lubricate bearing surfaces using suitable lubricant.
3- Start the machine, and apply a compressive force to the ends of the specimen until failure occurs.
4- The results are taken as a load deflection curve.

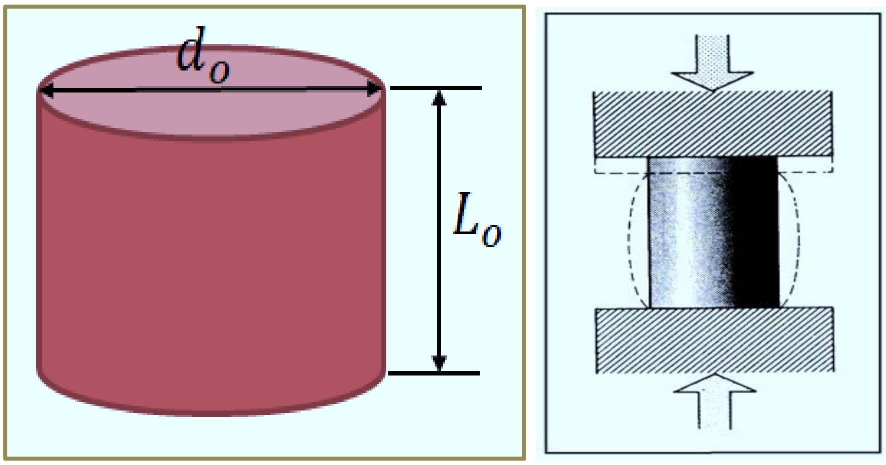


Figure 3. Sample compression test

7. Results & Analysis

1. From the load – deflection curve construct the stress – strain curve.
2. From the stress – strain curve determine the following properties for tested material:
   a- Proportional limit.
   b- Yield point.
   c- Yield stress for an offset of .2 %.
   d- Ultimate and fracture stress.
3. Percentage elongation and reduction in area at fracture.
4. Modulus of Elasticity.
5. Modulus of Resilience.
6. Modulus of Toughness.

7. Shear Modulus of elasticity (G)
8. Bulk Modulus of elasticity (K).
9. Compare between engineering and true stress measures and comment on the difficulty in
   1- obtaining a uniform measure in tension and compression with the engineering stress - strain.
10. Comment in the calculated values of E, G, and ν as compared to known values in tension.
11. In compression test a greater load is necessary to cause yielding than that required in tension test for the same sample. State the reason.

8. Examples

The tensile test was performed on a standard high carbon steel specimen, which has a length (200 mm) and a circular cross-section area (100 mm^2) . The load readings in newtons and the corresponding elongation in mm were in the table below?

Load, (Kg)	0	2700	2750	10100	12500	20250	2700
Elongation, mm	0	0.055	0.138	0.205	0.275	0.450	0.700

Draw the load and elongation curves, then determine the following:

1. Find the stress and strain values for the points for which the load and compression were recorded?
2. Stress – Strain compression curve in (N/mm^2)?
3. Calculate the fracture stress (N/mm^2)?

Solution

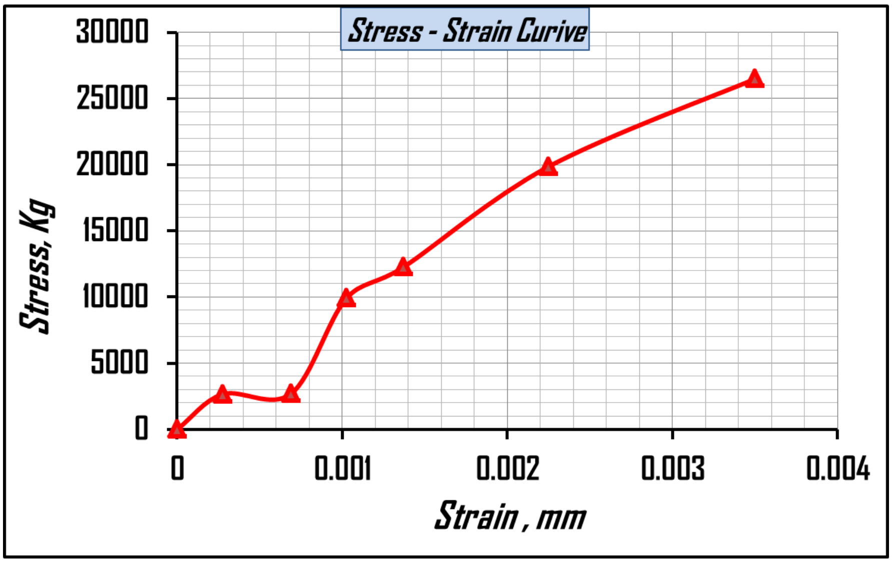
1. **Stress and strain values for the points for which load and compression were recorded:**

$$\sigma = \frac{F}{A} \quad , \quad A_o = 100\ mm^2$$

$$e = \frac{\Delta L}{L} \quad , L_o = 200\ mm$$

Stress, (Kg/mm^2)	0	270	275	1010	1250	2025	2700
Strain, mm/mm	0	0.000275	0.00069	0.001025	0.00137	0.00225	0.0035

Stress, (N/mm^2)	0.00	2648.70	2697.75	9908.10	12262.50	19865.25	26487.00
Strain, mm/mm	0.00	0.000275	0.00069	0.001025	0.00137	0.00225	0.0035



2. **Breaking stress:**

$$\sigma_{BS} = \frac{F_{max}}{A_o} = \frac{27000}{100} = 270\,\frac{Kg}{mm^2} = 270 \times 9.81 = 2648.7\ N/mm^2$$

References

5. ASM International, Tensile Testing, second edition.
6. www. mathalino.com / Engineering math review
7. www.nde-ed.org/ Nde research center
8. www.azo.com/ Azo materials

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Third Experiment

Shear Test Experiment

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1. Introduction

If the cross-section of the rod is affected by a force parallel to the cross-sectional area only, then this state of stress in the rod is called shear. Shear stress acts parallel to a surface, while tensile or compressive stress acts perpendicular to the surface. As for material tests, direct shear and torsional shear usually receive attention.

2. Purpose of the experiment

Calculate the value of the maximum shear stress (τ_{max}) of the sample metal.

3. Device used

The Universal Testing Machine (shown in Figure 1) is used to conduct this experiment.

4. Components of the testing device

The testing device consists of the following main components, as shown in Figure (1), and is called the general testing device:

1. Examination form,
2. Hydraulic piston installed with the machine structure to apply force in a hydraulic way,
3. Jaws and screws to install the model in the testing device.
4. Measure of applied force,

5. The device is attached to a digital scale to measure the applied force in kN and the resulting elongation in mm.

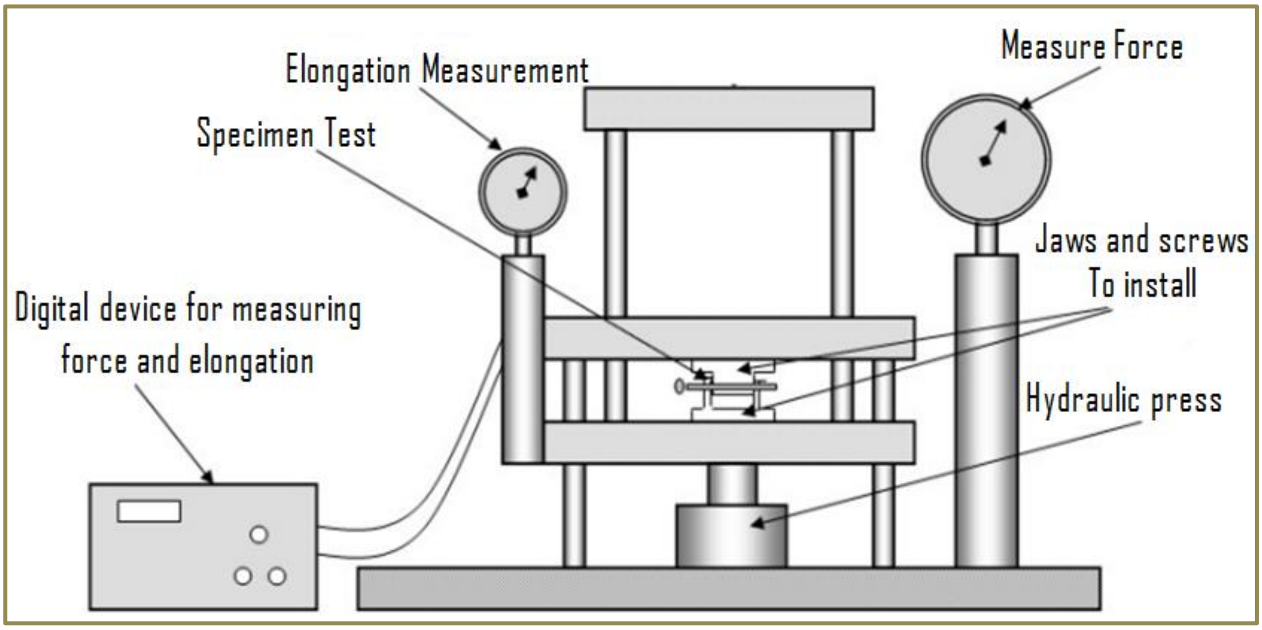

Figure 1. General testing apparatus with shear specimen

5. Test steps

1. Measure the diameter of the sample (the sample is a rivet made of soft iron),
2. Install the sample in a special tool attached to the device,
3. Apply force to the sample and increase it gradually until we reach the shear stress that causes the sample to break (rivet shearing),
4. Record the value of the applied load causing the shear,
5. Repeat the above steps for another sample (rivet) with a different cross-sectional area than the first sample.

6. Calculations

Direct shear can be referred to in general as Figure (2), as this figure represents a rivet nail (Rivet) in shear. In this case, there is direct shear within the path of the rivet on the two surfaces (XX) and (YY), Because there are two surfaces exposed to direct shear, but in the case of one surface exposed to direct shear, this case is called single shear.

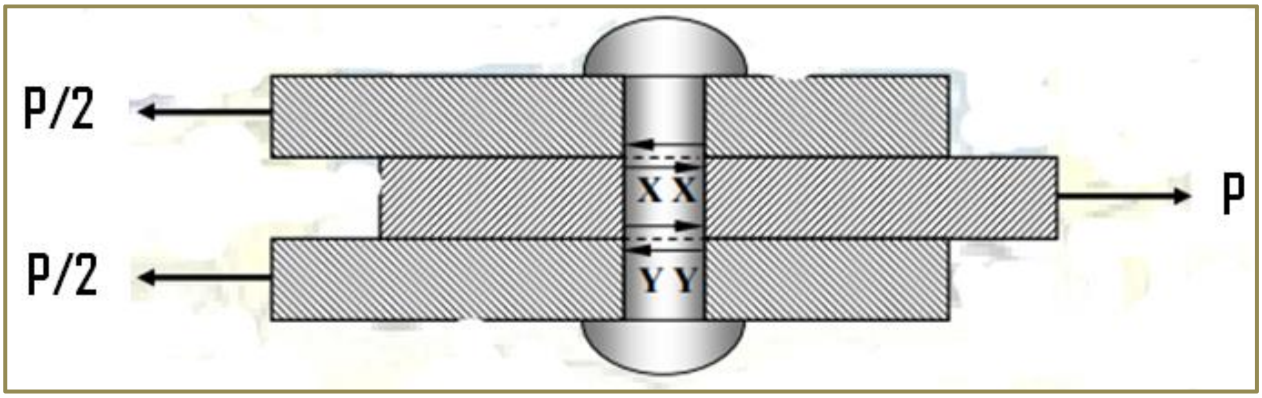

Figure 2. A double-cut rivet

$$Dual\ direct\ shear\ resistance\ (\tau) = \frac{Maximum\ load(P)}{2.\ Crosssectional\ area\ of\ the\ sample\ (2A)}$$

$$\tau_{max} = \frac{P}{2\ A},$$

Where:

$$A = \frac{\pi\ d^2}{4}\ ,\quad d = Diameter\ of\ Rivet$$

7. Example

The shear test was performed on a rivet, which has a length (50 mm) and a diameter (15 mm) . The shear load readings in kilonewtons and the corresponding displacement in millimeter were in the table below?

Shear Load, (KN)	0	50	100	150	200	250	300	350	400	450	500	550	600	650	600	550
Displacement, mm	0	0.6	1.2	1.8	2.5	3.3	4.2	5.2	6.5	7.9	9.5	11.5	13.5	16	17.5	18

Find the following:

1. Draw the load and displacement curve for each of the samples,
2. Calculate the value of the maximum shear stress that the material under examination can withstand (τ_{max}).

Solution:

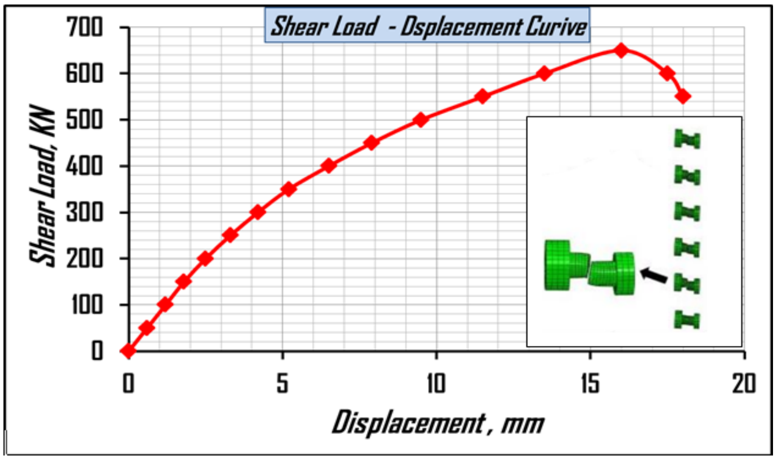

Figure 3. Shear stress force curve with displacement

From the figure:

$$P_{max} = 650\ KN = 650000\ N\ \ \&\ \ Displacement\ (\delta) = 16\ mm$$

$$\tau_{max} = \frac{P}{2\ A}$$

$$A = \frac{\pi\ d^2}{4} = \frac{3.143 \times\ 15^2}{4} = 176.794\ mm^2$$

$$\tau_{max} = \frac{P}{2\ A} = \frac{650000}{2\ \times 176.794} = 1838.298\ MPa$$

References

9. ASM International, Tensile Testing, second edition.
10. www. mathalino.com / Engineering math review
11. www.nde-ed.org/ Nde research center
12. www.azo.com/ Azo materials

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Fourth Experiment

Bending Test

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Bending Test

1. Introduction

When an external load or the structural load applied in beam is large enough to displace the beam from its present place, then that deflection of beam from its resent axis is called bending of beam. That applied force which produce bending in beam also produces stresses in beam these stresses are called bending stresses.

2. The Purpose of Bending

Test Aim of this experiment is to study the effect of force of different magnitude on the bending stresses in beam. Furthermore, study the relationship between the applied force and the deflection, and compute the maximum stress on sample.

3. Objectives

1. Understanding the free-body diagrams FBD for bending and drawing the reactions,
2. moment diagram and shear diagram for simply supported beam.
3. Calculation of bending stress and deflection caused by the load and calculation of the moment of inertia of different cross-sections.
4. Obtaining the Modulus of Elasticity from deflection formula.
5. Understanding the concept of Neutral Axis N.A and Neutral Plane and Distinguishing Between Layers in Compression and Layers in Tension in Bending.
6. Performing Practical Bending Tests.

4. Introduction to Bending Test

If the deflection within the elastic range is known then the Modulus of Elasticity can be obtained from the above-mentioned formula as follow:

$$E = \frac{PL^3}{48\, I\, \delta} \qquad (MPa \;\; or \;\; GPa)$$

Where:

P: The load applied at the middle of beam, It is expressed in N.

L: The distance between supports, It is expressed in mm

I: The moment of inertia of cross section, It is expressed in mm^4

δ: Deflection

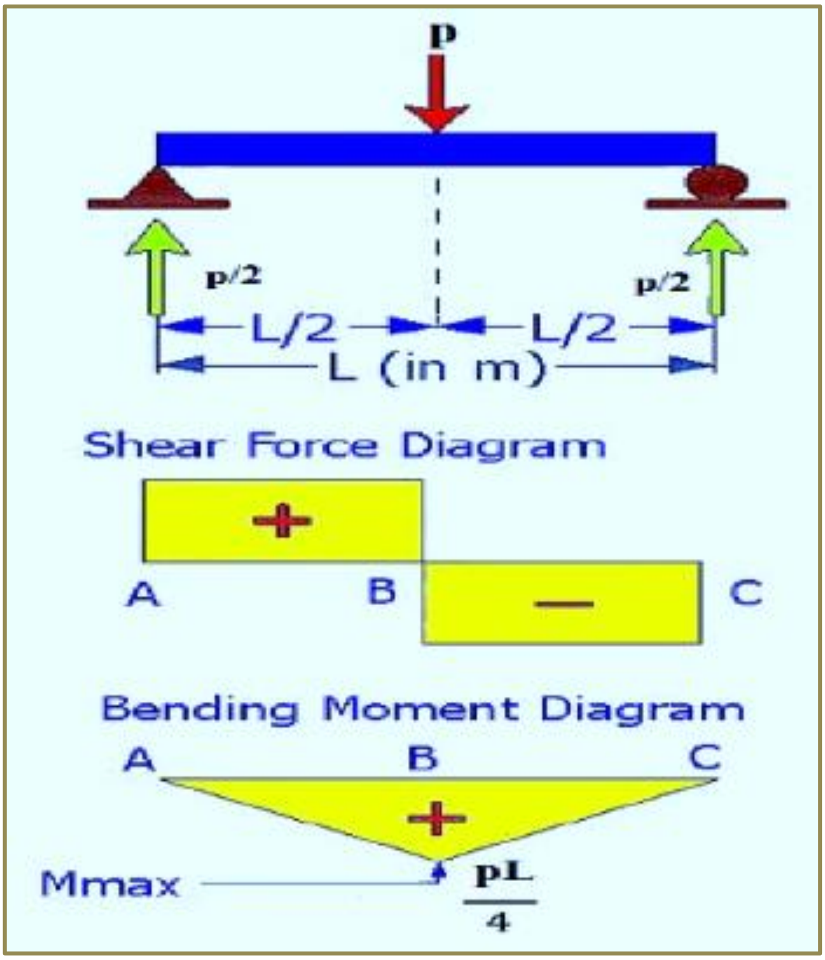


Figure 1: FBD, Shear Force Diagram & Bending Moment Diagram

Moment of inertia:

1. For rectangular cross section $I = b\,h^3/12$, Where b is the width and h is the height.
2. For square cross section $I = a^4 / 12$, Where 'a' is the side length of the square.
3. For circular cross section $I= \pi\, D^4 /64$, Where D is the diameter of the circle.
4. For triangular cross section $I = b\,h^3 /36$, Where b is the base length and h is height of triangle.

During bending test , the outer most upper layer fiber are exposed to compression stresses and the length of the beam at that layer is decreased , While the lowest layer fiber are exposed to tension stresses and the length of the beam at that layer is increased . The stress in middle of the beam in the neutral axis (see figure 1) is equal to zero; because this layer separates between the layers in compression, and layers in tension. The length of the beam remains the same as before bending at the middle layer which is called the neutral plane through which the centroid longitudinal axis of the beam passes and it is called the neutral axis (N.A). The bending stress (σ_b) in the beam is determine from the flexure formula as follows:

$$\sigma_b = \frac{M\,.Y}{I} \qquad (MPa)$$

$M = \frac{P.L}{4}$ (Moment for a rectangular beam)

Where M: It is the bending moment.

Y: It is the distance from the Neutral Axis (N.A) to the point of stress. It is expressed in mm. The moment is identical around the midpoint and begins from a value of zero at each support and reaches the maximum value in middle forms a shape of triangle with equal legs as shown in figure 1. The maximum bending stress occurs at the top of the beam (in compression) :

it holds a negative sign, and in the bottom of the beam (in tension) ;

it holds positive sign and each of these stresses are located at distance y=h/2 mm from the neutral line and their value at the middle of the beam length can obtained from flexure formula as follows :

$$\sigma_{max} = \frac{P\ L\ h}{8\,I} \qquad (MPa)$$

$$\sigma_{max} = \frac{12\,P\,L\,h}{8\,bh^3} = \frac{3\,P\ L}{2\,bh^2} \qquad (MPa)$$

5. Bending Machine

In our experiment, the universal testing machine will be used, figure 2. This bending machine uses an adjustable feed to a fixed set of rollers, the specimen is fixed between the roller and a specific maximum load is applied on it.

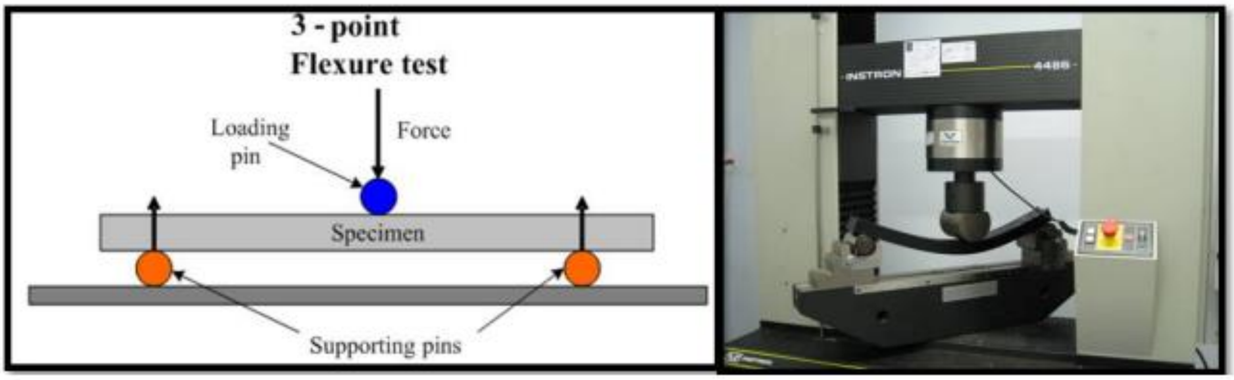


Figure 2: Universal Testing Machine

All practical tests for bending of different kinds of metal of different products and shapes are to prove the ductility of the tested product, and their ability to bend around specified mandrel or plunger for specified bending angle without cracks. First of all we will concern on the shape of tested specimen, the mandrel diameter about which it will be bent and the angle of bending specified, the maximum applied load , deflection and whether crack occurs during the bending process or not. Load – deflection curve is the major curve that is generated from bending test.

6. Equipment's

Wp 310 Hydraulic Universal Material Tester 50 KN (UTM), caliper, metals Specimens, PC Measurement Data Acquisition.

7. Experimental Procedure

1. Measure the width and thickness of the specimen.
2. Mark on the locations where the load will be applied under three-point bending. Note the length of between support.
3. Place the sample carefully on to the stage of 3-point bending fixture of a universal testing machine.
4. Make sure that the loading point is placed on to the marked location.
5. Carry out the bend test.

8. Steps To Conduct The Test

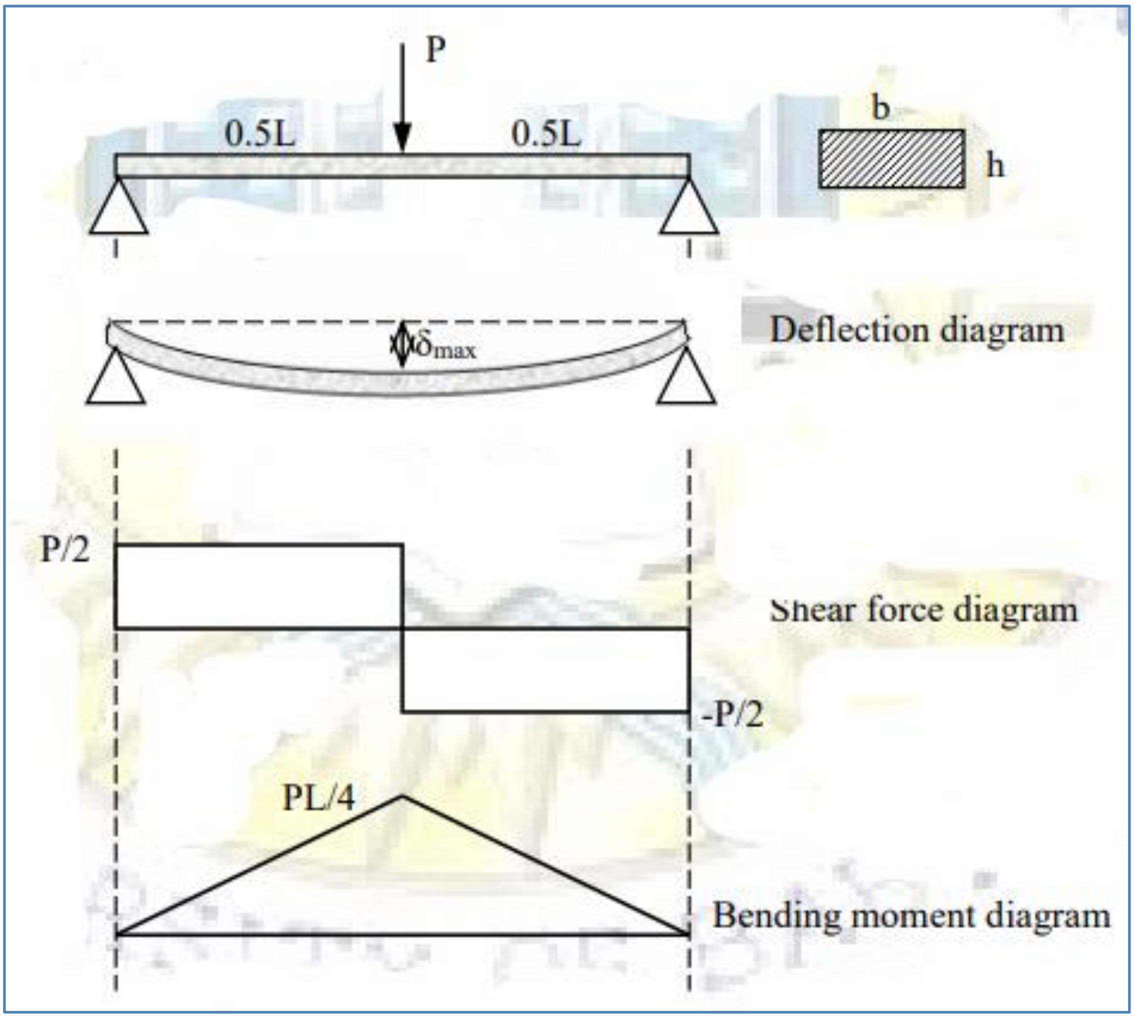
We measure the dimensions of the sample, record it, and place it in the device.

We apply different loads to the sample and record the value (δ_{exp}) in millimeters corresponding to each load and record the results in the table shown below. Then we use these results to perform the required calculations later.

NO.	P , (KN)	δ_{exp} , (mm)	δ_{the} , (mm)	M_{max} , $(N.m)$	σ_{max} , $(\frac{MN}{M^2})$
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

9. Calculations and Results

1. We first draw a shear force diagram and a bending moment diagram (Figure 2-5), from which we calculate the amount of maximum torque (M_{max}) and from this value of torque we calculate the maximum bending stress that the sample can bear.



$$\sigma_{max} = \frac{M_{max} \cdot y}{I} \qquad y = \frac{h}{2}, \qquad I = \frac{bh^3}{12}$$

2. We calculate the theoretical value of the deviation (δ_{the}) for each reading from the following law and compare it with (δ_{exp}).

$$\delta_{the} = \frac{PL^3}{48EI} \qquad \text{E=Modulus of elasticity}$$

3. We draw the graphical relationship between (P – δ) for the practical and theoretical values.

10. Example

Before doing the test, recoding the specimen dimensions involves: Thickness (t = 4 mm) , width (w = 38 mm), and span length (L = 152 mm). Then recording the load and deformation values as shown in the following table:

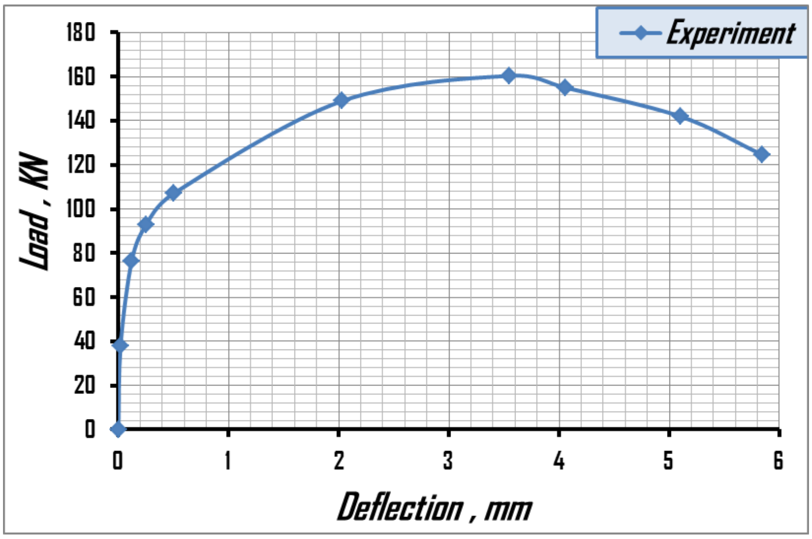
NO.	$P, (KN)$	$\delta_{exp}, (mm)$	$\delta_{the}, (mm)$	$M_{max}, (N.m)$	$\sigma_{max}, (\frac{MN}{M^2})$
1	0	0	0.000		
2	38	0.02	0.065		
3	76.2	0.12	0.131		
4	92.7	0.25	0.159		
5	107	0.5	0.184		
6	149	2.03	0.256		
7	160.4	3.55	0.276		
8	155	4.06	0.266		
9	142	5.1	0.244		
10	124.7	5.84	0.214		
Equation used	-----	-----	$\delta_{the} = \frac{PL^3}{48\,EI}$		$\sigma_{max} = \frac{M_{max} \cdot y}{I}$ $y = \frac{h}{2}$, $I = \frac{bh^3}{12}$

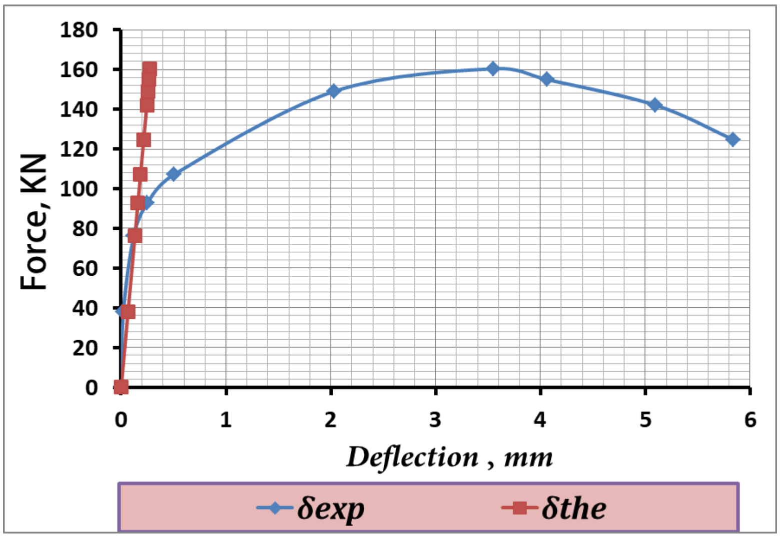
If Modulus of Elasticity (E = 210 MPa). Determining the following values :

1. Bending moment and bending stress.
2. Plot a graph of bending stress Verse deflection.
3. Draw the Shear force and bending moment in beams.

<u>**Solution**</u>

$$\delta_{the} = \frac{PL^3}{48\ EI}$$





References

13. ASM International, Tensile Testing, second edition.
14. www. mathalino.com / Engineering math review
15. www.nde-ed.org/ Nde research center
16. www.azo.com/ Azo materials

Ministry of Higher Education
and Scientific Research

Northern Technical University
College of Engineering Technology
Department of Chemical and Petroleum Industries

Fifth Experiment

Torsional testing of Circular Shafts

2024

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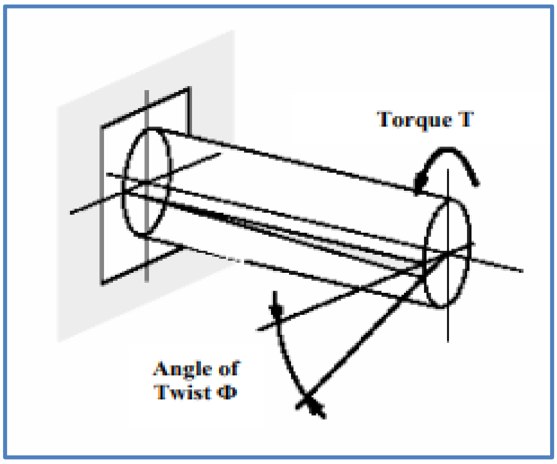
Torsional testing of Circular Shafts

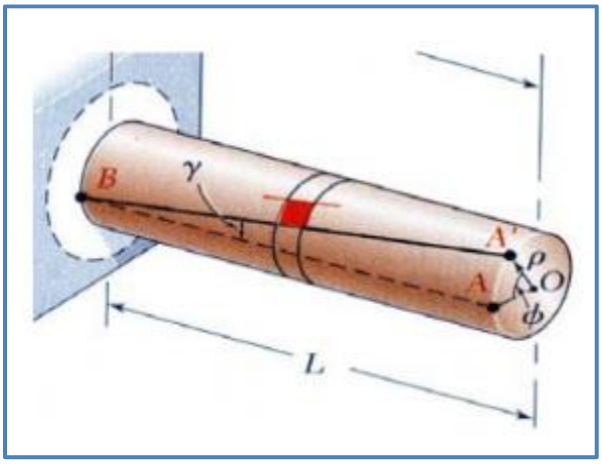
1. Introduction

Torsion occurs when any shaft is subjected to a torque. This is true whether the shaft is rotating (such as drive shafts on engines, motors and turbines) or stationary (such as with a bolt or screw). The torque makes the shaft twist and one end rotates relative to the other inducing shear stress on any cross section. Failure might occur due to shear alone or because the shear is accompanied by stretching or bending.

2. Objectives

To determine Shear Modulus of Elasticity (G) of some Steel, Aluminum and Brass circular shafts and develop a relationship among the Torque (TO and Clamping length (L) and the angle of twist (θ).





3. Apparatus

1. Torsion Testing Rig, Apparatus above. The device will apply a torque to the shaft fixed between two holding clamps. Torque is developed by applying a force of F via load handle above the system thru a distance spindle arm. 2. The shaft should be securely tightened between the end holding clamps as much as possible.
2. The measuring dial will measure the displacement of an arm handle at a fixed distance.
3. This displacement is proportionally related to the angle of twist of the rod.

4. Theory

As the two aforementioned names imply, the test specimen will encounter shearing stresses as a result of the twisting of the specimen and the specimen which is more rigid, or more resistant to twisting, will have a higher modulus of rigidity. Again, the modulus of rigidity is a material property and, under non-extreme environmental conditions, is a constant value for each material. In this experiment two or three specimens will be tested. These specimens will possess identical geometric measurements and differ only in material type. The various materials tested may include brass, aluminum and steel. The experimental determination of the modulus of rigidity is similar to the experimental determination of the modulus of elasticity. However, the modulus of elasticity was determined by the application of an axial load and the test specimen was not plastically deformed. The modulus of elasticity was calculated by determining the slope of the axial stress versus axial strain curve. The modulus of rigidity will be determined by twisting the test specimen and calculating the slope of the shear stress versus shear strain curve. In addition, the torsion test specimen will be twisted to failure in order to determine the shear stress at the limit of proportionality. The shear stress at the limit of proportionality is the largest value of the shear stress for which the material will behave elastically. Throughout this discussion the plot of the shear stress versus shear strain has been mentioned. The actual values recorded experimentally, as the specimens are being twisted, are the angle of twist applied to the specimen and the corresponding value of torque at a particular angle of twist. The instructor should indicate location of the 6 degree and 360-degree Vernier scale and the torque scale. Equations are provided within the student manual to convert the twist and torque values to the corresponding shear stress and shear strain values.

5. Preparation for the lab

Simply answer the following questions:

1. Is there a relationship between the modulus of rigidity and the modulus of elasticity of a material?
2. What are the units of the modulus of rigidity?
3. Which material, brass or steel, would you expect to have a higher modulus of rigidity?
4. If testing steel and aluminum, which material would fail at a higher angle of twist?
5. Which specimen would have a greater value of torque at failure?

6. Procedure and Experimental setup

Circular Shafts

1. Mount the shaft onto test equipment holding chucks, by losing the tightening screws and slide in the rod. Tighten the rod by securing tightening screws and sliding arm.
2. Measure a fixed length, of 200 mm span length. Measure the diameter of the rod.
3. Measure the distance between load application point and the center of rod. Compare this measurement with specified value on the Lab poster.
4. Measure the distance between the Vernier measuring point and the center of the rod. Compare this value with equipment value.
5. Set the Vanier reading to Zero, or register the Zero Load location.
6. Apply Loads gradually and record the Deflection at Vernier point. Make sure that if the gauge reader has been rotated more than one full rotation, keep record of that.
7. Increase the load in fraction of 100 gm, force from Zero to 2000 gm, record the deflections.
8. Repeat for each specimen.
9. Change the length from 150 mm to maximum span, steep of 100 mm 450 mm and repeat the measurements.

Use the following Suggested Table for gathering Data

Torsion test Data						
	Specimen Material	Steel	Distance D1 mm	Distance D2 mm	Test Date/ Time	Rod Diameter mm
NO.	**Length**	**Applied Load**	**Measured Deflection**	**Angle of Twist Radian**	**Calculated Angle of Twist**	**Modulus of Rigidity**
1.		100				
2.		200				
3.		300				
4.		400				
5.		500				
6.		600				

7.		700				
8.		800				
9.		900				
10.		1000				
11.		1100				
12.		1200				
13.		1300				
14.		1400				
15.		1500				
16.		1600				
17.		1700				
18.		1800				
19.		1900				
20.		2000				

7. Determination of Modulus of Rigidity, Shear Modulus G and Torsional Stress for Steel and Aluminum

A. Using the reading of above to calculate the shear modulus and torsional stress for Steel, Aluminum and Brass, by using the following formulas. Compare the experimental results with theoretical values.

$$\emptyset = \frac{180\,T\,.L}{\pi\,J\,.G} \qquad (1)$$

$$\tau = \frac{T\,.C}{J} \qquad (2)$$

$$J = \frac{\pi\,.d^4}{32} \qquad (3)$$

Data: Theoretical values for Shear Modulus of elasticity (modulus of Rigidity):

Aluminum: [G= 26 GPa , E= 70 GPa]

Steel: [G= 80 GPa , E= 270 GPa]

Brass (red): [G= 44 GPa , E= 120 GPa]

8. Required Calculations

1. Plot a graph of Toque Verse twist angle for all three material.
2. Plot a graph of Twist Angle vs. Length L for all three materials.
3. Determine shear modulus of elasticity (G) and torsional shear stress on the top surface using data from task 1 and formulas for all material.
4. Compare the calculated value of G with theoretical value and quantify the errors.
5. What are the Experimental Sources of Errors?

9. Example

Calculation and Observation Table:

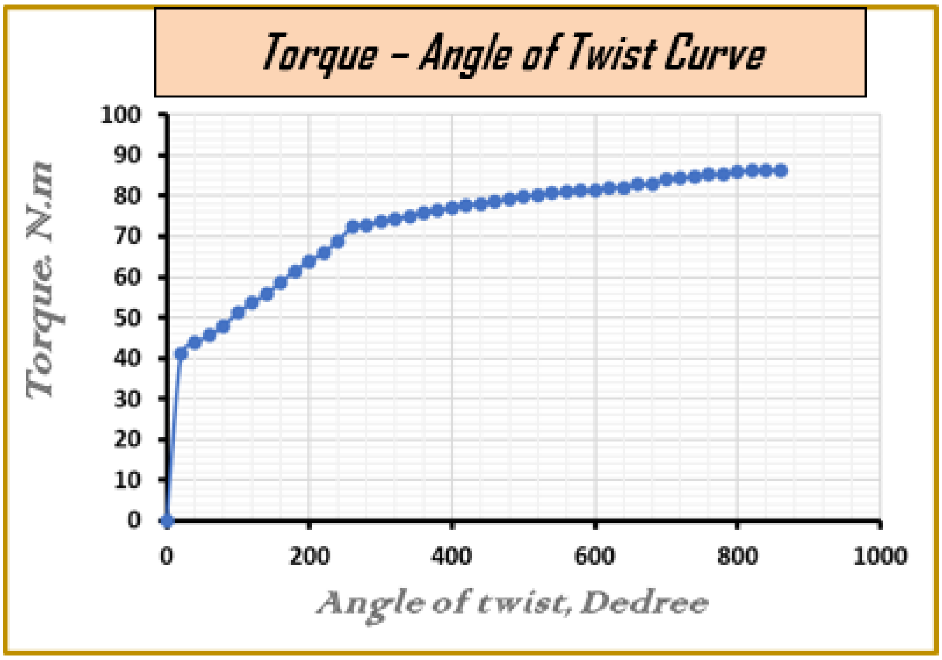
1. Total length: 80mm
2. Effective length: 78.9mm
3. Diameter of specimen: 10mm

NO.	Angle of twist, (Degree)	Angle of twist, (Radian)	Torque, (N.m)	Shear strain(γ)	Shear stress(τ), (N/m^2)
1.	0	0.000	0	0.000	0
2.	20	0.349	41	0.022	208970438.3
3.	40	0.698	43.8	0.044	223241590.2
4.	60	1.047	45.6	0.066	232415902.1
5.	80	1.396	48	0.088	244648318
6.	100	1.745	51.2	0.111	260958205.9
7.	120	2.094	53.7	0.133	273700305.8
8.	140	2.443	55.9	0.155	284913353.7
9.	160	2.793	58.7	0.177	299184505.6
10.	180	3.142	61.5	0.199	313455657.5
11.	200	3.491	63.9	0.221	325688073.4
12.	220	3.840	66	0.243	336391437.3
13.	240	4.189	68.9	0.265	351172273.2
14.	260	4.538	72.3	0.288	368501529.1
15.	280	4.887	72.8	0.310	371049949
16.	300	5.236	73.7	0.332	375637105
17.	320	5.585	74.3	0.354	378695209
18.	340	5.934	75	0.376	382262996.9

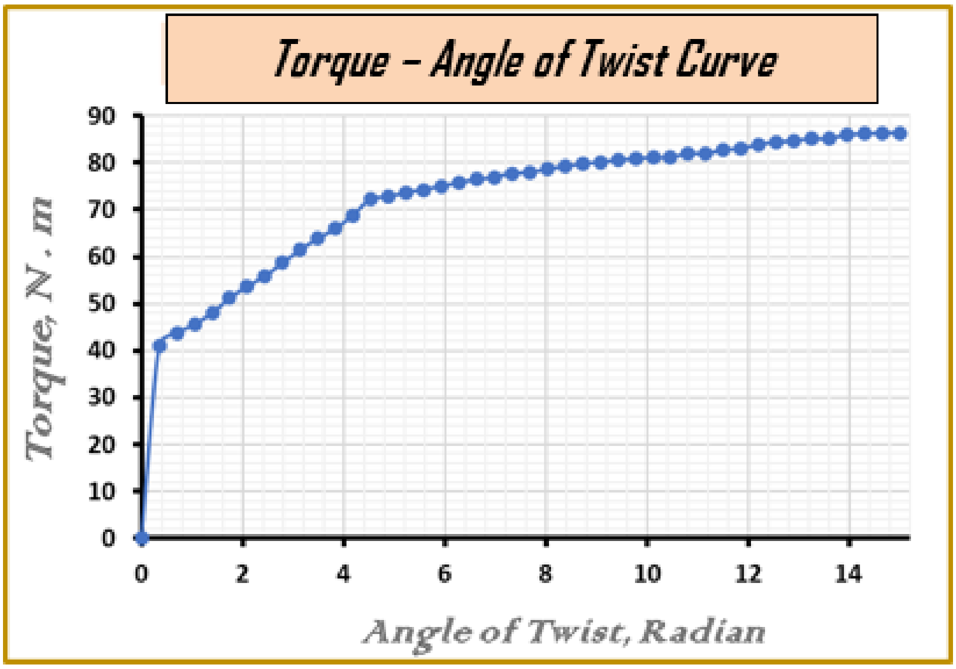
19.	360	6.283	75.9	0.398	386850152.9
20.	380	6.632	76.5	0.420	389908256.9
21.	400	6.981	77	0.442	392456676.9
22.	420	7.330	77.8	0.465	396534148.8
23.	440	7.679	78	0.487	397553516.8
24.	460	8.029	78.7	0.509	401121304.8
25.	480	8.378	79.3	0.531	404179408.8
26.	500	8.727	79.8	0.553	406727828.7
27.	520	9.076	80.2	0.575	408766564.7
28.	540	9.425	80.6	0.597	410805300.7
29.	560	9.774	80.9	0.619	412334352.7
30.	580	10.123	81.2	0.642	413863404.7
31.	600	10.472	81.2	0.664	413863404.7
32.	620	10.821	82	0.686	417940876.7
33.	640	11.170	82	0.708	417940876.7
34.	660	11.519	82.8	0.730	422018348.6
35.	680	11.868	83	0.752	423037716.6
36.	700	12.217	84	0.774	428134556.6
37.	720	12.566	84.4	0.796	430173292.6
38.	740	12.915	84.8	0.818	432212028.5
39.	760	13.265	85.2	0.841	434250764.5
40.	780	13.614	85.2	0.863	434250764.5
41.	800	13.963	86	0.885	438328236.5
42.	820	14.312	86.2	0.907	439347604.5
43.	840	14.661	86.4	0.929	440366972.5
44.	860	15.010	86.4	0.951	440366972.5

Solution

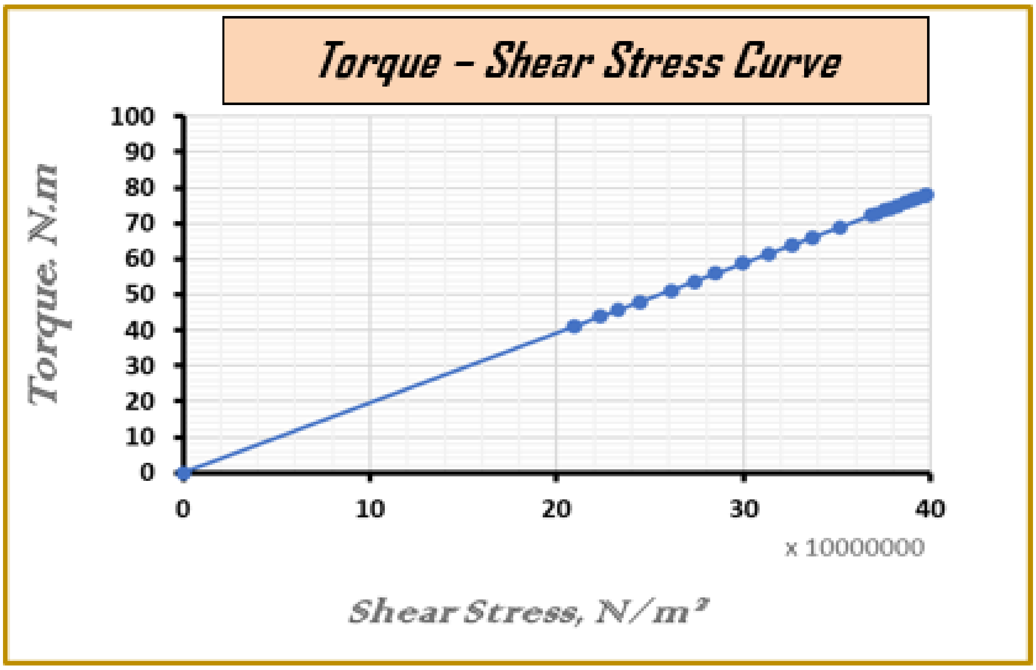
1. Relation between torque and angle twist in degree



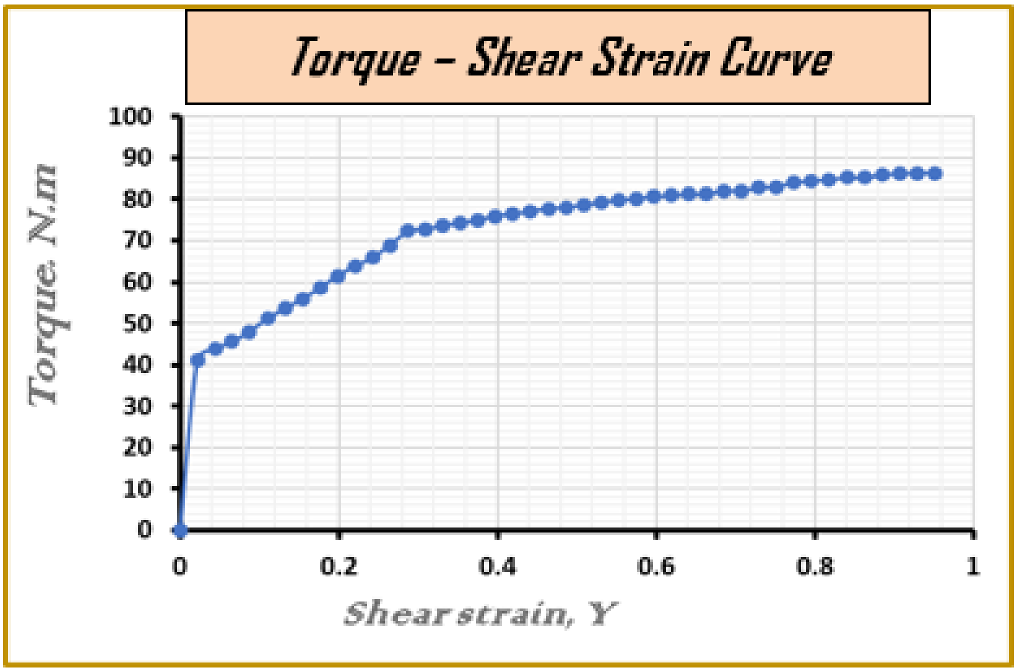
2. Relation between torque and angle twist in radian



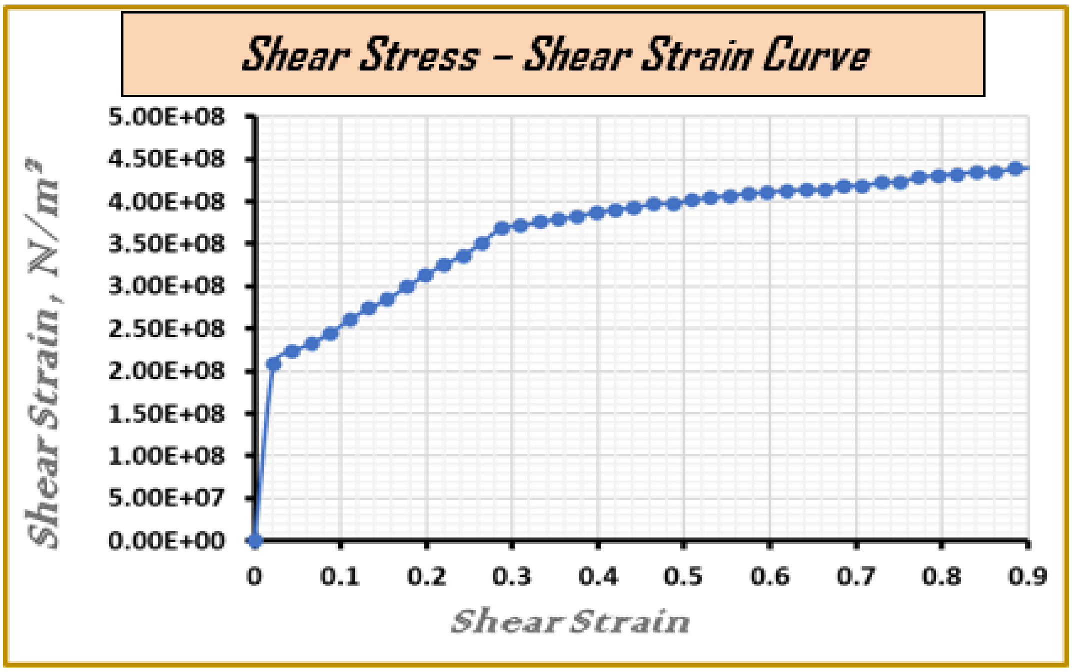
3. Relation between torque and shear stress



4. Relation between torque and shear strain



5. Relation between shear strain and shear stress



$$Polar\ moment\ (J) = \frac{\pi d^4}{32} = \frac{3.143 \times 10^4}{32} = 982.188\ mm^4$$

$$Maximum\ bending\ stress\ = 440366972.5\ Pa$$

$$From\ graph, dt/d\Phi\ = 43.8/0.698 = 62.75$$

So,

$$G = (dt/d\Phi) * L/J$$

$$= (62.75) * (78.9 * 10^\wedge - 3)/ (9.81 * 10^\wedge - 10)$$

$$= 5.046\ GPa$$

$$Modulus\ of\ rupture$$

$$= (Maximum\ bending\ stress$$

$$* \ distance\ between\ the\ two\ supports$$

$$* \ Factor\ of\ safety)/(Width * height^\wedge 2)$$

$$= (440366972.5 * 0.0789 * SF)/ (0.010 * 0.010^\wedge 2)$$

$$= SF * 3.4743 * 10^\wedge 13Pa$$

Ministry of Higher Education

and Scientific Research

Northern Technical University

College of Engineering Technology

Department of Chemical and Petroleum Industries

Sixth Experiment

Hardness Test Experiment

2024

CONTENTS

HARDNESS TEST

1. Introduction

Hardness is defined as the resistance of a material to permanent deformation such as indentation, wear, abrasion, scratch. Principally, the importance of hardness testing has to do with the relationship between hardness and other properties of material. For example, both the hardness test and the tensile test measure the resistance of a metal to plastic flow, and results of these tests may closely parallel each other. The hardness test is preferred because it is simple, easy, and relatively nondestructive.

There are many hardness tests currently in use. The necessity for all these different hardness tests is due to the need for categorizing the great range of hardness from soft rubber to hard ceramics.

2. Objectives

The hardness test is a mechanical test for material properties which are used in engineering design, analysis of structures, and materials development. The principal purpose of the hardness test is to determine the suitability of a material for a given application, or the particular treatment to which the material has been subjected. The ease with which the hardness test can be made has made it the most common method of inspection for metals and alloys.

3. Theory

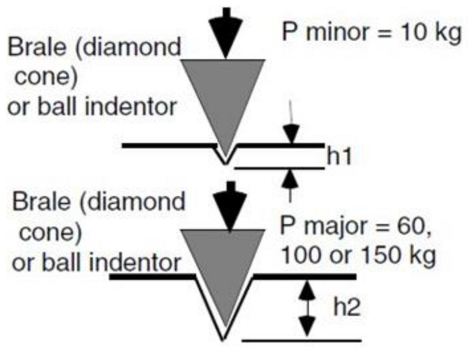
Current practice divides hardness testing into two categories: microhardness and microhardness. Microhardness refers to testing with applied loads on the indenter of more than 1 kg and covers, for example, the testing of tools, dies, and sheet material in the heavier gages. In microhardness testing, applied loads are 1 kg and below, and material being tested is very thin (down to 0.0125 mm, or 0.0005 in.). Applications include extremely small parts, thin superficially hardened parts, plated surfaces, and individual constituents of materials.

1. Macro Hardness Testers Loads > 1 kg
    a. Rockwell
    b. Brinell
    c. Vickers
2. Micro Hardness Testers < 1 kg
    a. Knoop diamond
    b. Vickers diamond pyramid

3.1 Macro Hardness Test Methods

3.1.1 Rockwell Hardness Test

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load $F0$ (Fig. 1A) usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration (Fig. 1B). When equilibrium has again been reached, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration (Fig. 1C). The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.



Rockwell Scale (X =)	Indentor	Pmajor (kg)
A	Brale (diamond)	60
B	1/16" ball	100
C	Brale (diamond)	150
D	Brale (diamond)	100
E	1/8" ball	100
F	1/8" ball	60
M	1/4" ball	100
R	1/2" ball	60

$$HRX = R_X = M - \frac{(h_2 - h_1)}{0.002}$$

M = 100 for A, C, and D scales

M = 130 for B, E, M, R, etc. scales

Figure 1. Rockwell Principle

There are several considerations for Rockwell hardness test

1. Require clean and well positioned indenter and anvil,
2. The test sample should be clean, dry, smooth and oxide-free surface,
3. The surface should be flat and perpendicular to the indenter,
4. Low reading of hardness value might be expected in cylindrical surfaces,
5. Specimen thickness should be 10 times higher than the depth of the indenter,
6. The spacing between the indentations should be 3 to 5 times of the indentation diameter,
7. Loading speed should be standardized.

3.1.2 The Brinell Hardness Test

The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a load of 3000 kg. For softer materials the load can be reduced to 1500 kg or 500 kg to avoid excessive indentation. The full load is normally applied for 10 to 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation. When the indentor is retracted two diameters of the impression, d1 and d2, are measured using a microscope with a calibrated graticule and then averaged as shown in Fig.2(b).

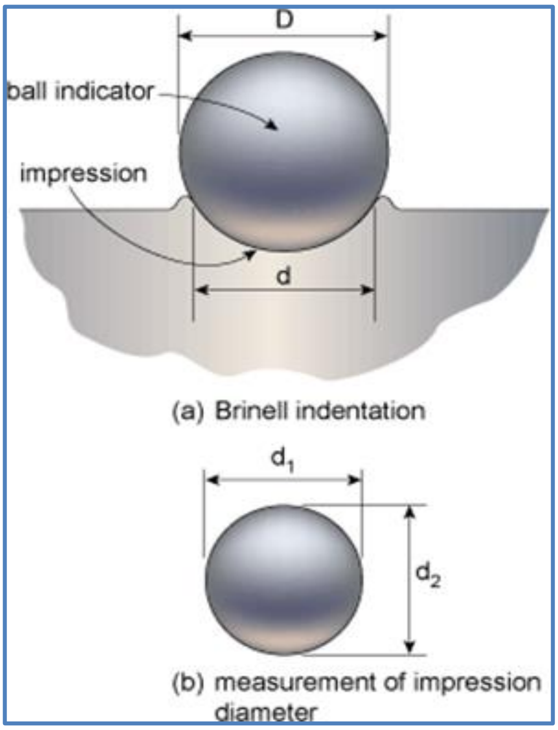


Figure 2. Brinell Principle

$$BHN = \frac{P}{\frac{\pi D}{2}\left[D - \sqrt{D^2 - d^2}\right]}$$

Where:

P is the test load [kg]

D is the diameter of the ball [mm]

d is the average impression diameter of indentation [mm]

The diameter of the impression is the average of two readings at right angles and the use of a Brinell hardness number table can simplify the determination of the Brinell hardness. A well-structured Brinell hardness number reveals the test conditions, and looks like this, "75 HB

10/500/30" which means that a Brinell Hardness of 75 was obtained using a 10mm diameter hardened steel with a 500-kilogram load applied for a period of 30 seconds. On tests of extremely hard metals a tungsten carbide ball is substituted for the steel ball. Compared to the other hardness test methods, the Brinell ball makes the deepest and widest indentation, so the test averages the hardness over a wider amount of material, which will more accurately account for multiple grain structures and any irregularities in the uniformity of the material. This method is the best for achieving the bulk or macro-hardness of a material, particularly those materials with heterogeneous structures.

3.1.3 Vickers Hardness Test

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.

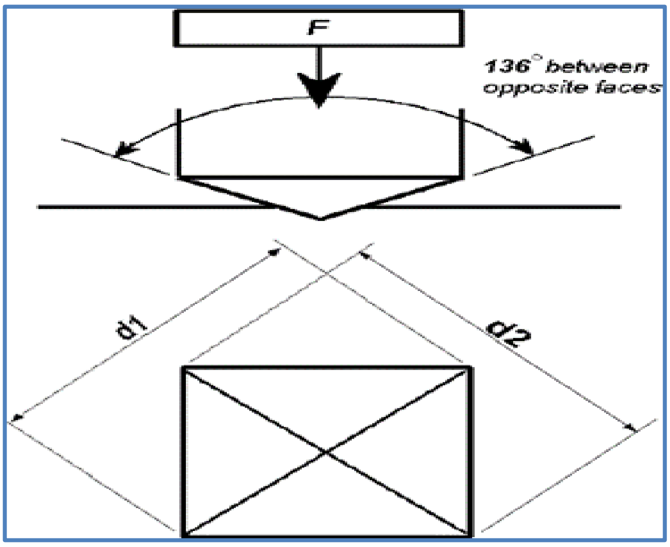


Figure 3. Vickers Principle

$$HV = \frac{2F\sin\frac{136^o}{2}}{d^2} \qquad HV = 1.854\frac{F}{d^2} \text{ approximately}$$

F= Load in kgf

d = Arithmetic means of the two diagonals, d1 and d2 in mm

HV = Vickers hardness

When the mean diagonal of the indentation has been determined the Vickers hardness may be calculated from the formula, but is more convenient to use conversion tables. The Vickers hardness should be reported like 800 HV/10, which means a Vickers hardness of 800, was obtained using a 10 kgf force. Several different loading settings give practically identical hardness numbers on uniform material, which is much better than the arbitrary changing of scale with the other hardness testing methods. The advantages of the Vickers hardness test are that extremely accurate readings can be taken, and just one type of indenter is used for all types of metals and surface treatments. Although thoroughly adaptable and very precise for testing the softest and hardest of materials, under varying loads, the Vickers machine is a floor standing unit that is more expensive than the Brinell or Rockwell machines.

Hardness testing in estimating other material properties:

Hardness testing has always appeared attractive as a means of estimating other mechanical properties of metals. There is an empirical relation between those properties for most steels as follows:

$$UTS = 0.35 * BHN \text{ (in kg/mm}^2\text{)}$$

This equation is used to predict tensile strength of steels by means of hardness measurement. A reasonable prediction of ultimate tensile strength may also be obtained using the relation:

$$UTS = \frac{VHN}{3}\left[1-(n-2)\right]\left\{\frac{12.5(n-2)}{1-(n-2)}\right\}^{(n-2)}$$

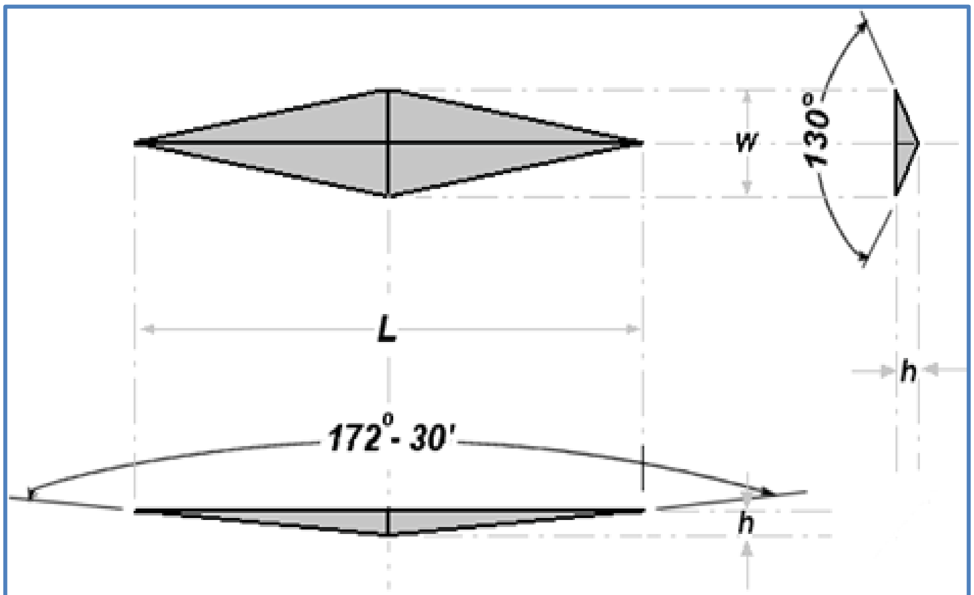
Where VHN is the Vickers Hardness number and n is the Meyer's index.

The 0.2 percent offset yield strength can be determined with good precision from Vickers hardness number according to the relation: (Hint: For steels, the yield strength can generally be taken as 80% of the UTS as an approximation).

$$YS_{0.2} = \frac{VHN}{3}(0.1)^{(n-2)}$$

3.2. Micro Hardness Test Methods

The term microhardness test usually refers to static indentations made with loads not exceeding 1 kgf. The indenter is either the Vickers diamond pyramid or the Knoop elongated diamond pyramid. The procedure for testing is very similar to that of the standard Vickers hardness test, except that it is done on a microscopic scale with higher precision instruments. The surface being tested generally requires a metallographic finish; the smaller the load used, the higher the surface finish required.



Knoop Hardness Indenter Indentation

The Knoop hardness number KHN is the ratio of the load applied to the indenter, P (kgf) to the unrecovered projected area A (mm^2).

KHN = F/A = P/CL2

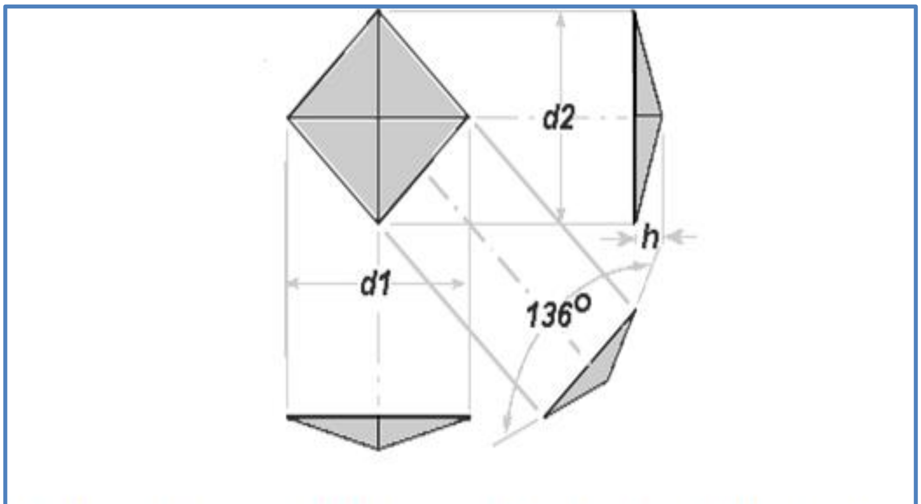
Where:

F=applied load in kgf

A=the unrecovered projected area of the indentation in mm^2

L=measured length of long diagonal of indentation in mm

C = 0.07028 = Constant of indenter relating projected area of the indentation to the square of the length of the long diagonal.



Vickers Pyramid Diamond Indenter Indentation

The Vickers Diamond Pyramid hardness number is the applied load (kgf) divided by the surface area of the indentation (mm^2).

$$HV = \frac{2F \sin \frac{136^o}{2}}{d^2} \qquad HV = 1.854 \frac{F}{d^2} \text{ approximately}$$

Where:

F= Load in kgf

d = Arithmetic means of the two diagonals, d1 and d2 in mm

HV = Vickers hardness

Comparing the indentations made with Knoop and Vickers Diamond Pyramid indenters for a given load and test material:

1. Vickers indenter penetrates about twice as deep as Knoop indenter,
2. Vickers indentation diagonal about 1/3 of the length of Knoop major diagonal,
3. Vickers test is less sensitive to surface conditions than Knoop test,
4. Vickers test is more sensitive to measurement errors than knoop test,
5. Vickers test best for small rounded areas,
6. Knoop test best for small elongated areas,
7. Knoop test good for very hard brittle materials and very thin sections.

4. Experiment

Selected samples will be selected to be tested by Brinell, Vickers and Rockwell hardness test, the results are given to students in the class lab by the Qness hardness test machine in Fig. 4. Different materials specimens will be tested in this laboratory experiment namely: aluminum alloy, carbon steel, brass, commercial pure copper, brass, and stainless steel etc.

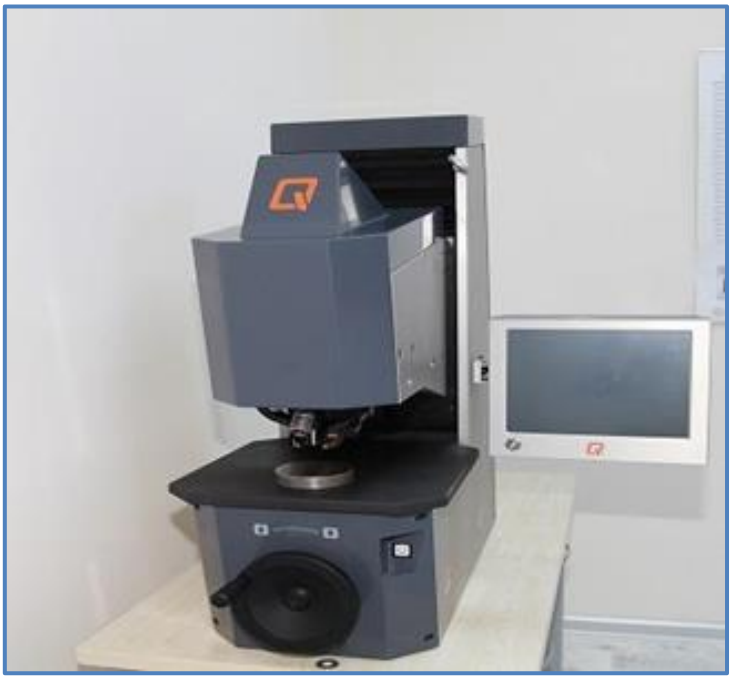


Figure 4. Hardness test equipment

5. Results

Samples will be selected to be tested by Brinell, Vickers and Rockwell hardness test, the results are given to students in the class lab.

a) For Brinell experiment, student has to calculate the BHN and depth of impression (***h)*** through the following formulas for each material tested:

$$BHN = \frac{P}{\frac{\pi D}{2}\left[D-\sqrt{D^2-d^2}\right]} \qquad h = \frac{1}{2}\left[D-\sqrt{D^2-d^2}\right] \; or \; h = \frac{P}{\pi D \times BHN}$$

In the class, the values of *P* and *d* (*d* and *d*) hane been given to students.

b) For Vickers experiment, student has to calculate the VHN through the following formula for each material tested:

$$VHN = \frac{2\,P\,\sin\frac{136}{2}}{d^2}$$

In the class, the values of *P* and *d* (d_1 and d_2) had been given to students.

c) For Rockwell experiment, student has to calculate the depth (h_2-h_1) due to the major load through the following formulas for each used indenter:

$$HRX = R_X = M - \frac{(h_2 - h_1)}{0.002}$$

M = 100 for A, C, and D scales

M = 130 for B, E, M, R, etc. scales

d) Which factors affect the selecting of the appropriate hardness test?

e) Discuss the advantages and disadvantages of the Brinell, Vickers and Rockwell Hardness Tests.

f) Discuss the relationship between hardness and tensile properties.

6. Report

In your laboratory reports must have the followings;

1. Cover
2. A short introduction
3. All the necessary calculations using measured data.
4. Discussion of your results and a conclusion.

References

1. ASM International, Hardness Testing, 2nd Edition, 06671G. http://www.gordonengland.co.uk/
2. Metals Handbook, 9th ed., Mechanical Testing, Vol. 8, 1990.
3. N. Dowling, Mechanical Behavior of Materials, Prentice Hall, 1993

Ministry of Higher Education
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Northern Technical University
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Seven Experiment

The Impact Test

2024

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The Impact Test

1. INTRODUCTION

Toughness is a measure of the amount of energy required to cause an item to fracture and fail. The more energy that is required then the tougher the material. Recall that ductility is a measure of how much something deforms plastically before fracture, but just because a material is ductile does not make it tough. The key to toughness is a good combination of strength and ductility. A material with high strength and high ductility will have more toughness than a material with low strength and high ductility. Therefore, one way to measure toughness is by calculating the area under the stress strain curve from a tensile test. This value is simply called "material toughness" and it has units of energy per volume. Material toughness equates to a slow absorption of energy by the material. Figure 1: Toughness of Different Materials.

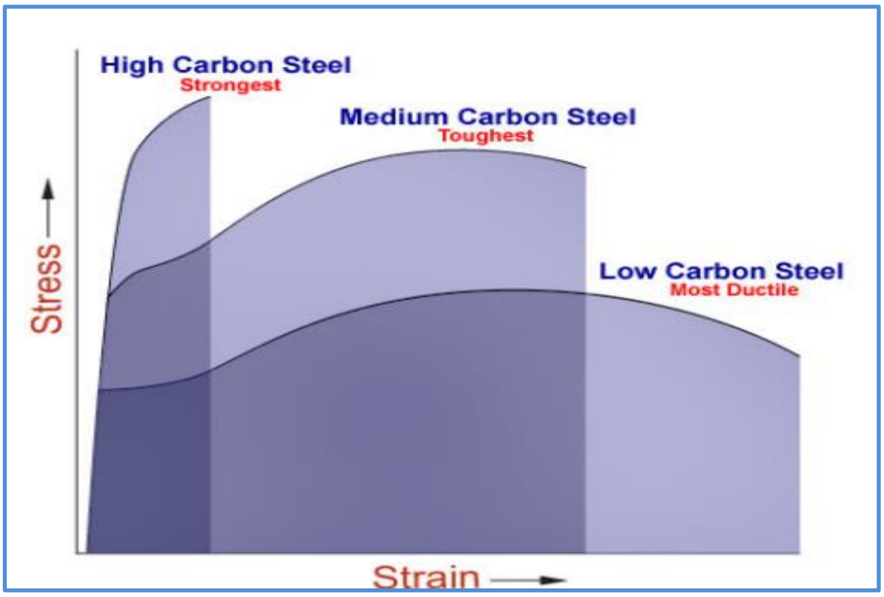


Figure 1: Toughness of Different Materials

2. OBJECTIVES

1. To determine the toughness of metals by an impact testing machine.
2. To observe the behavior of metals under high strain rate loading (impact loading).

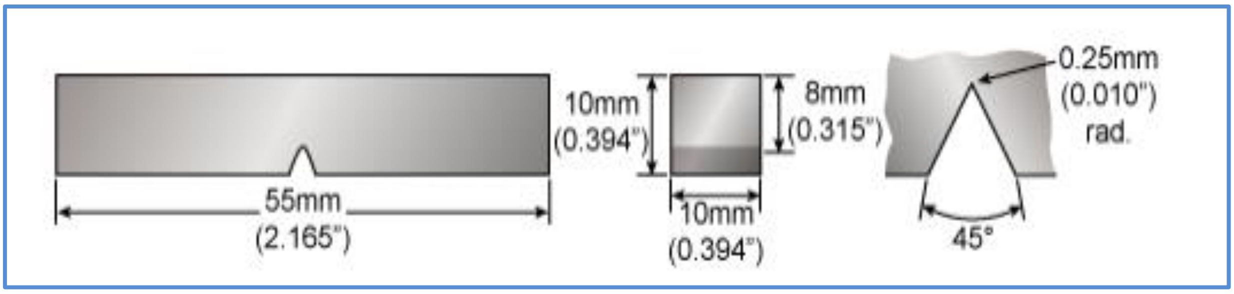
3. Methods of impact test

In order to determine the impact toughness of a material there are two types of Impact Test methods differs in specimens' specifications and methods of holding the specimens. These five types are:

1. Charpy test
2. Izod test
3. Instrumented Impact Test
4. Drop-Weight Test
5. Dynamic Tear Test

4. Charpy Test

- The specimen is tested as a simply supported beam.
- The edge of the pendulum strikes at mid-span directly behind the milled notch.
- The standard Charpy-V specimen, illustrated in Figure 2 Standard Charpy-V notch specimen and Figure 3 Schematic of an impact test
- Dimension specimen is 55mm long, 10mm square and has a 2mm deep notch with a tip radius of 0.25mm machined on one face.



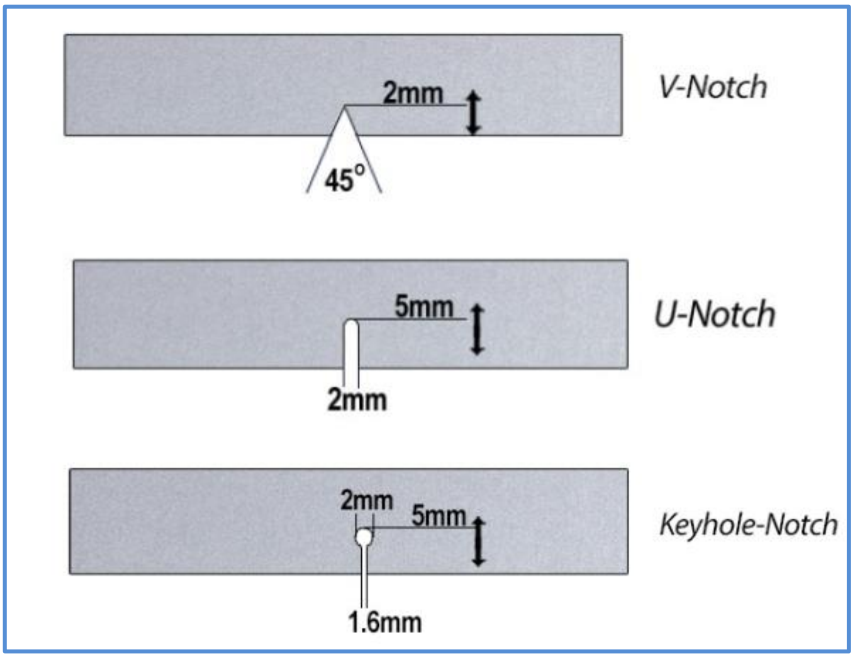
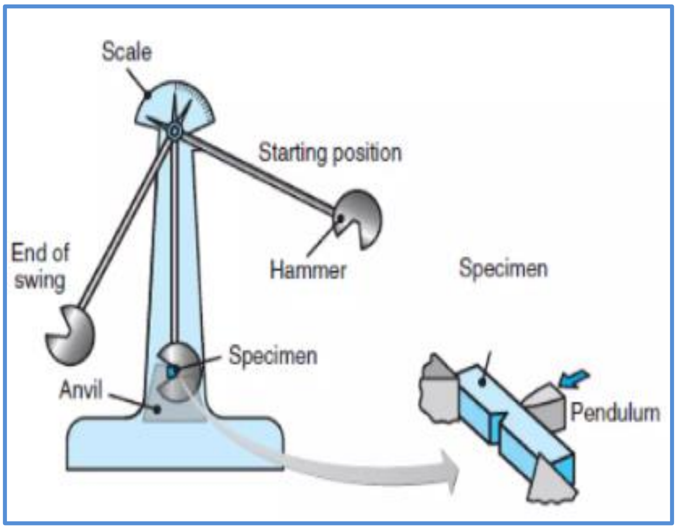


Figure 2. Standard Charpy-V notch specimen



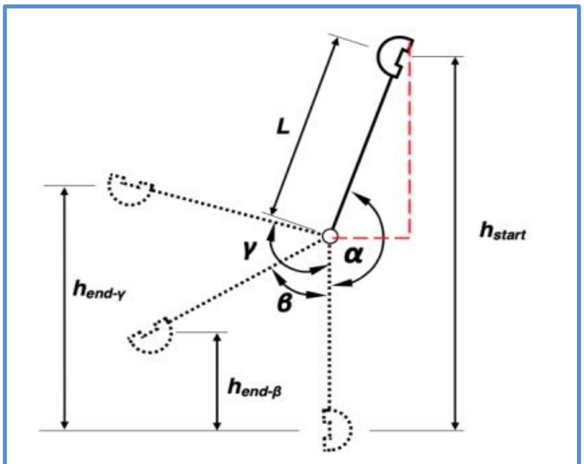


Figure 2. Schematic of an impact test.

Figure 3. Schematic of an impact test

Calculation of Charpy Impact test

1. Calculate Energy (W)

$$\boldsymbol{W = m \,.\, g \,.\, R \,.\, (Cos\ \beta - Cos\alpha)}$$

W: $Energy, (N.m)$
m: $Weight, (\text{Kg})$
g: $Gravitational\ Acceleration, (\frac{m^2}{s})$
R: $Pendulum\ length, (m)$
β: $Angle\ of\ incidence\ of\ the\ pendulum, (Degree)$
α: $Angle\ of\ elevation\ of\ the\ pendulum, (Degree)$

1. Calculate Toughness (T)

$$\boldsymbol{Toughness\ (T) = \frac{Energy\ (W)}{Area\ (A)}}$$

T: $Toughness\ , (Kg.m/cm^2)$

A: $Area\ , (cm^2)$

5. Izod Test

- The specimen is tested in cantilever mode.

- The specimen is firmly clamped in a vice with the prepared notch levels with the edge of the vice.
- The impact blow is delivered on the same side as the notch. Figure 4. Standard Izod-V notch specimen

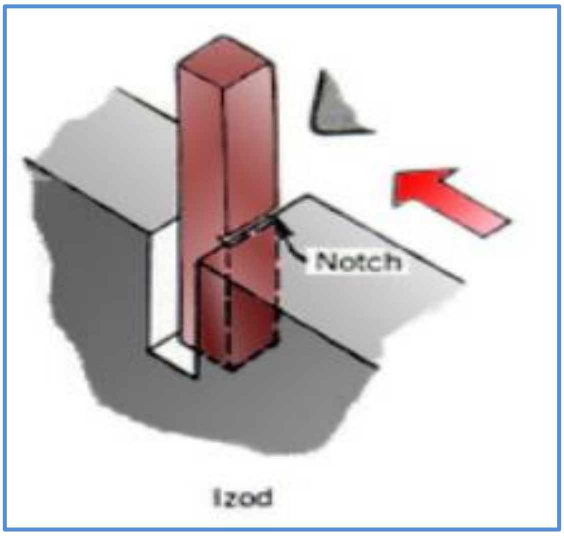


Figure 4. Standard Izod-V notch specimen

1. Test Procedure Izod Test

The specimen is clamped into the pendulum impact test fixture with the notched side facing the striking edge of the pendulum. The pendulum is released and allowed to strike through the specimen. If breakage does not occur, a heavier hammer is used until failure occurs. Since many materials (Especially thermoplastics) exhibit lower impact strength at reduced temperatures, it is sometimes appropriate to test materials at temperatures that simulate the intended end use environment, figure 5.

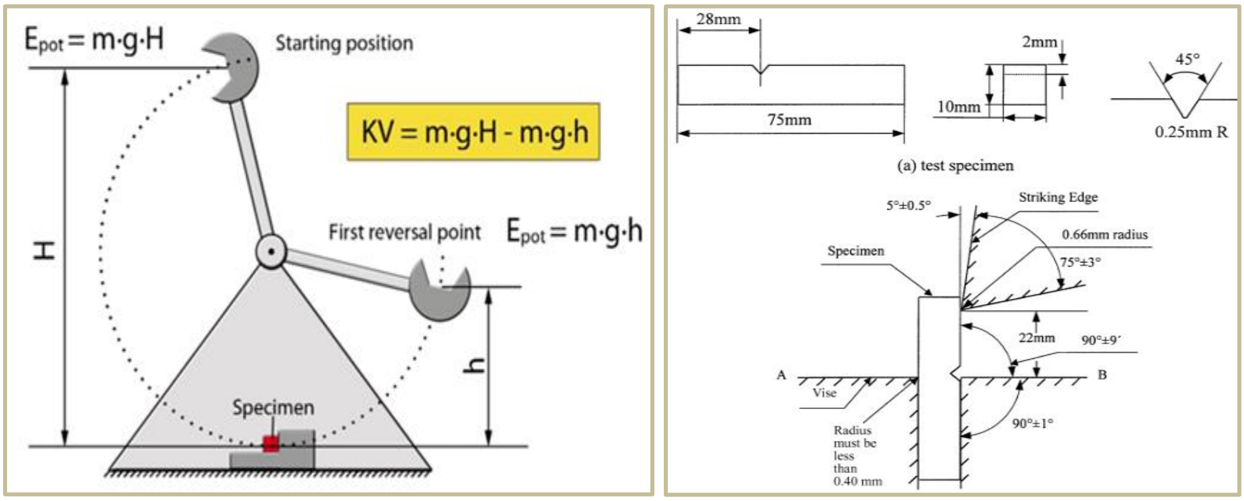


Figure 5. Izod impact test machine.

2. Calculation of Izod impact test

$$E = m \,.\, g \,.\, (H - h)$$

E: $Energy$
m: $Weight$
g: $Gravitational\ Acceleration$
H: $Starting\ height$
h: $End\ height$

6. The Fracture surface

The shape of the fracture and its surface differs from specimen material to another depending on its structure. Figure 6. The Fracture surfaces

Brittle fracture shows a clean granular structure with little deformation, while ductile fracture shows fibrous structure. In the very ductile materials, the fractures will not complete. sometimes due to the very high ductility of a material the test is held at low temperature.

Figure 6. The Fracture surfaces

5. Discussion and Conclusion

- In this experiment we learned about toughness testing of materials (the impact test).
- Applying this test, we can study the ability of a metal to deform plastically and to absorb energy in the process before fracture.
- There are two common methods to apply impact test differs in specimen holding method; Izod and Charpy methods.

- In figure.4 (on the next page) you can recognize the differences between the two methods and the procedure of Impact test.
- In this experiment we learned specifically about Charpy method.
- In order to get the true results from the impact machine you must use a specimen with the specifications shown in figure 2 [Standard BS EN 10045-1].
- The toughness is proportionally related to hardness and strength; it can be determined by the area under the stress strain diagram.
- The Impact test is very important method to determine the toughness of metals, and this is necessary when designing machines ...etc.

7. Example

The results in Table 1 were obtained from impact tests of samples of metal and section as shown in figure 5, at different temperatures, with the following required:

1. Absorbed energy (W) in joule unit of all specimens.
2. Toughness (T) in (Kg. m / cm^2) units of all specimens.
3. Draw relation between absorbed energy (J) and temperature (^{0}C).

Table 1. Result of an impact test

NO.	Temperature, (Degree)	Maximum angle after impact, β (Degree)	Constants	
45.	80	114.953	Mass of the pendulum (M), Kg	28.81
46.	60	96.804		
47.	40	79.968		
48.	20	64.974	Acceleration of gravity (g), mls^2	9.81
49.	10	57.729		
50.	0	51.824	Radius of pendulum (R), m	0.75
51.	-10	49.978		
52.	-20	49.680	Angle of pendulum before release (α), ^{0}C	141.5
53.	-40	49.454		
54.	-60	49.228		
55.	-80	48.468		

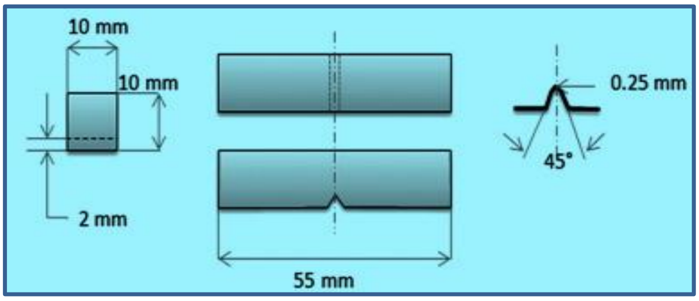
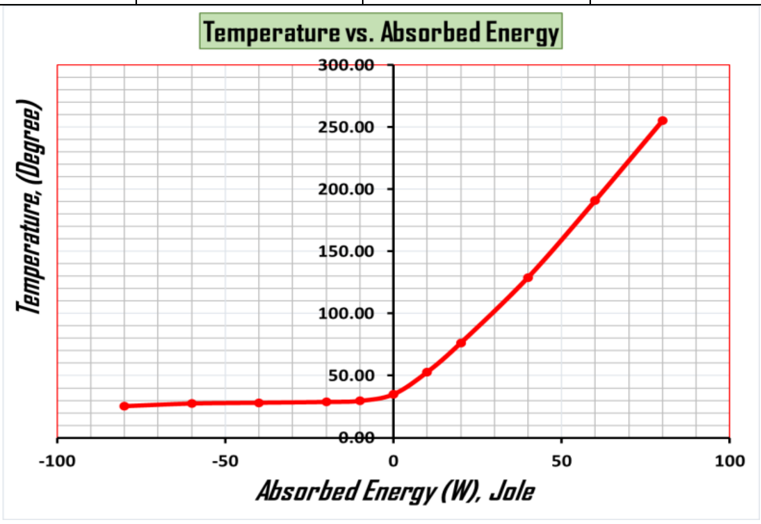


Figure 5. Dimension of an impact test specimen

Solution

NO.	Temperature, (Degree)	Maximum angle after impact, β (Degree)	Absorbed Energy (W), (J)	Absorbed Energy (W), (Kg.m)	Toughness(T). (Kg.m/cm^2)
1.	80	114.953	255.47	26.042	32.553
2.	60	96.804	191.15	19.485	24.356
3.	40	79.968	129.08	13.158	16.448
4.	20	64.974	76.31	7.779	9.724
5.	10	57.729	52.79	5.381	6.726
6.	0	51.824	34.94	3.562	4.453
7.	-10	49.978	29.63	3.020	3.775
8.	-20	49.680	28.79	2.935	3.669
9.	-40	49.454	28.15	2.870	3.588
10	-60	49.228	27.52	2.805	3.506
11.	-80	48.468	25.40	2.589	3.236



References

17. ASM International, Tensile Testing, second edition.
18. www. mathalino.com / Engineering math review
19. www.nde-ed.org/ Nde research center
20. www.azo.com/ Azo materials

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The Creep Test

2024

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1. Introduction

Creep is a type of metal deformation that occurs at stresses below the yield strength of a metal, generally at elevated temperatures. One of the most important attributes of any metal is its yield strength because it defines the stress at which metal begins to plastically deform.

1. It is a time- dependent deformation under a certain applied load.
2. Generally, occurs at high temperature (thermal creep), but can also happen at room temperature in certain materials (e.g., lead or glass), albeit much slower.
3. As a result, the material undergoes a time dependent increase in length, which could be dangerous while in service.

2. Objectives

The creep test aims to accurately measure the rate at which secondary or continuous creep occurs, and is used to test the failure of materials by measuring the following:

1. Load over a long period of time (continuous load and high temperature),
2. The stress that occurs over time in a stressed specimen.

3. Classical Creep Curve

The rate of deformation is called the creep rate. It is the slope of the line in a Creep Strain vs. Time curve, figure 1.

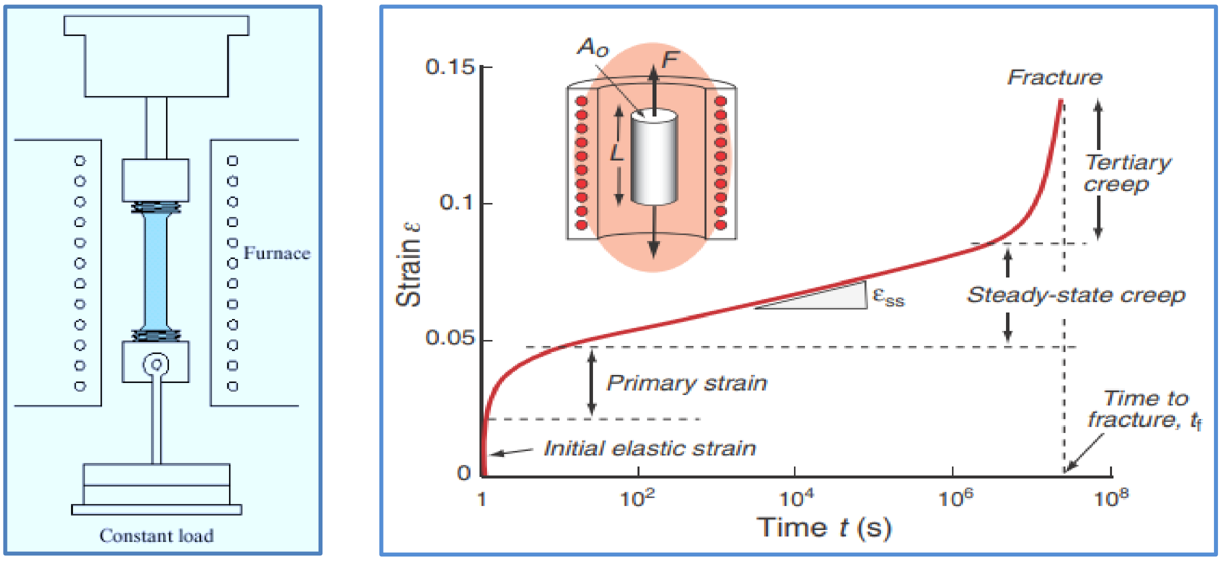


Figure 1. Creep Strain vs. Time curve

4. Creep Stages

1. **Primary Creep:** starts at a rapid rate and slows with time.
2. **Secondary Creep:** has a relatively uniform rate.
3. **Tertiary Creep:** has an accelerated creep rate and terminates when the material breaks or ruptures. It is associated with both necking and formation of grain boundary voids.

5. Applications

Creep machines are most commonly used in experiments to determine how efficient and stable a material is. The machine is used by students and companies to create a creep curve on how much pressure and stress a material can handle. The machine is able to calculate the stress rate, time and pressure.

Creep testing has three different applications in the industry:

1. **Displacement-Limited applications**: the size must be precise and there must be little errors or tendency to change. This is most commonly found in turbine rotors in jet engines.
2. **Rupture Limited applications**: in this application the break cannot occur to the material but there can be various dimensions as the material goes through creep. High pressure tubes are examples of them.
3. **Stress relaxation limited application**: the tension at the beginning becomes more relaxed and the tension will continue to relax as the time goes by, such as cable wires and bolts. Figure 2 SEM creep.

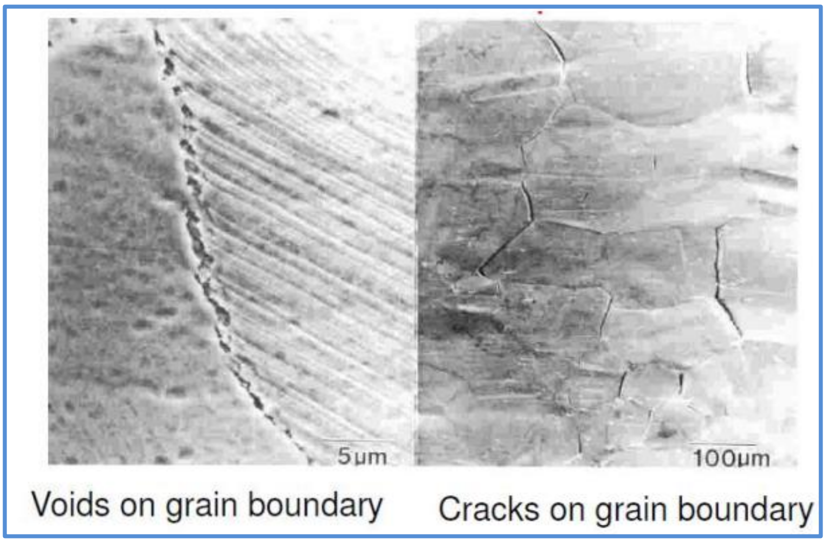
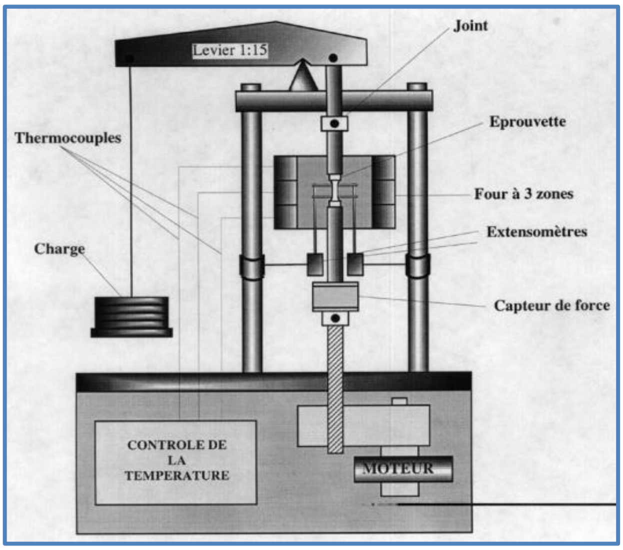


Figure 2: SEM creep

6. Apparatus

The Creep Machine is a simple lever and weight machine. It has a long lever (Arm) with a pivot point near to one end. The pivot point is a bearing, for very low friction. Students fit specimens of different materials to the short end of the lever and known weights to the long end of the lever. The lever gives a large mechanical advantage, so that even small weights will apply a large load (tensile stress) to the specimen. This simple system gives a predictable, uniform and constant load to the specimen. For accuracy, the Base Plate of the equipment is labelled with the effective mass of the Arm at point 'P', where the Weight Hanger applies its load. During the tests, students add this to the mass of the Weight Hanger, the weights that they use and the mass of the support pin. This gives them an accurate value of the load at point 'P'. The force at the specimen is then the product of the load, the mechanical advantage of the Arm and the acceleration due to gravity. A digital displacement indicator measures the change in length (extension) of the specimen during the experiments. The indicator is exactly the same distance from the lever pivot as the specimen, but on the opposite side. This ensures that it measures the specimen displacement in a 1:1 ratio, and is not affected by the slight angular movement of the arm. A thermometer measures the ambient temperature around the specimen. Supplied with the machine is a set of precision loads and a Weight Hanger. A 'cool pack' is provided for the student to freeze in a suitable refrigerator (not supplied) and put it next to the specimen to test the effects of lower temperatures on Creep. The student may also heat the pack in heated water and put it next to the specimen to test the effects of higher temperatures on Creep. A clear enclosure fits around the specimen area to help keep the temperature constant and provide some protection when specimens are tested to fracture.



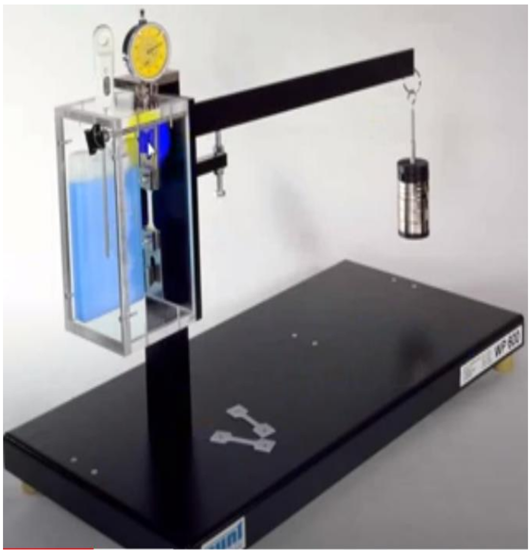
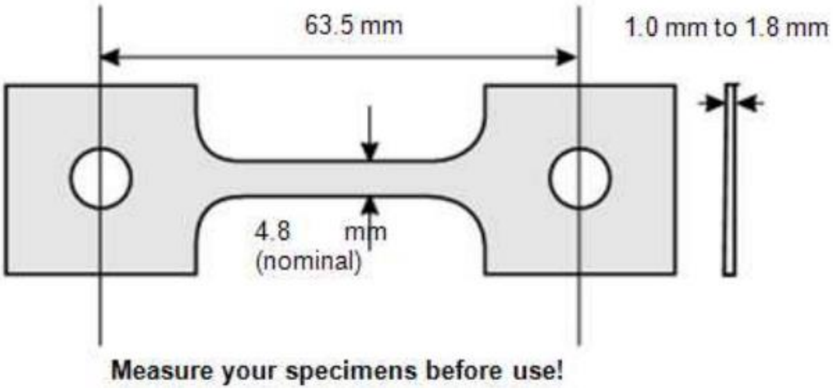
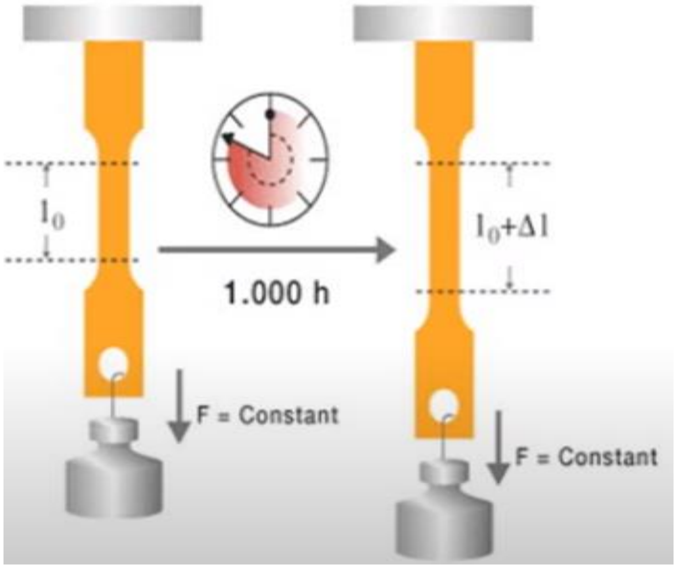


Figure 2: The creep machine

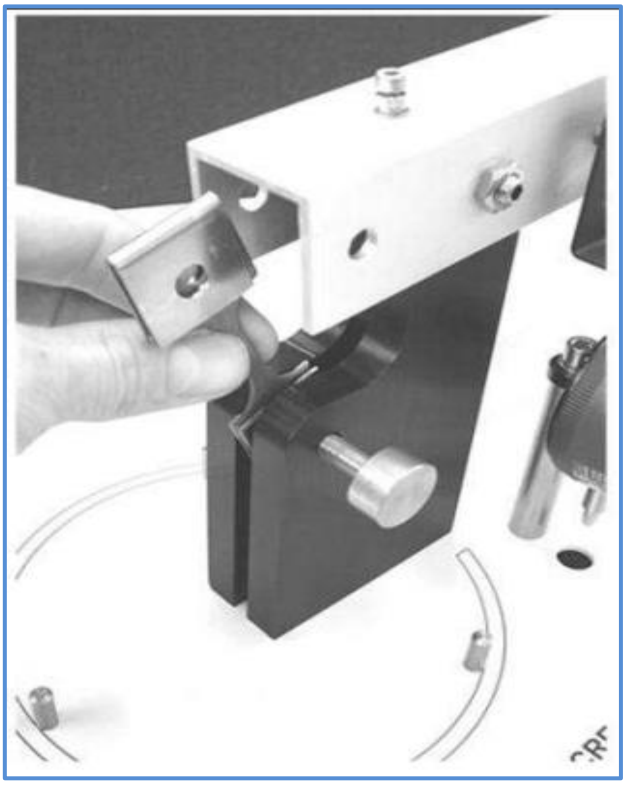
7. Procedure

1. Measure and record the width and thickness of the specimen.





2. Put the weight hanger in position and fit its support pin in its highest hole to hold the arm up and ready for the test specimen
3. Fit the steel specimen support clips to the specimen
4. Fit the specimen into place between the black support block and the arm, and fit the pins.
5. Put the transparent cover into place around the specimen. Make sure that the thermometer is in its hole in the top of the cover and its tip is near to the specimen. Wait for at least five minutes for the temperature reading to stabilize, then record the temperature around the specimen.
6. Fit a suitable weight to the Weight Hanger, to give a stress that gives the longest test time that you can allow. Figure 3 Fit the Specimen into Place (bottom first) and Fit the Pins.



7. Find the value of creep strain

It can be found value of creep strain by applying the following steps

$$\varepsilon_t = \varepsilon_o + \varepsilon^o \, . t \qquad (1)$$

$$\varepsilon^o = \frac{d\varepsilon}{dt} = K\, \sigma^n \qquad (2)$$

Whereas:

ε^o: It is the lowest rate of increase of creep over time.

n, K : Are constant values at the test temperature, and are found by plotting the logarithm of stress and creep.

To calculate the time required to reach the specified crawl, the following relationship is used:

$$t = \frac{\varepsilon_t - \varepsilon_o}{K\, \sigma^n} \qquad (3)$$

8. Methods to stop creep failure

In general, there are three ways to prevent metal creep, which are as follows:

1. Use of metals with high melting point ($T > 0.4\, T_{melting}$).
2. Use of materials with large grain size,
3. Use of alloys.

9. Examples

Example – 1

If the final length of the steel sample is (170 mm), after being subjected to a tensile load of (75 KN) at a temperature of (750 °C), and the elastic elongation is (8.33 mm), and the relationship between stress and the minimum creep rate is ($\varepsilon^o = 6.133 * 10^{-21}\, \sigma^{8.33}$):
Calculate the time required for it to reach this length, knowing that the diameter of the sample is (25 mm) and its original length is (150 mm).

Solution

$$\varepsilon_o = \frac{\Delta L}{L} = \frac{8.33}{130} = 0.06408$$

$$A = \frac{\pi\, d^2}{4} = \frac{3.143 \times\ 25^2}{4} = 491.0938\, mm^2$$

$$\sigma = \frac{F}{A} = \frac{75000}{491.0938} = 152.72\, MPa$$

$$\varepsilon^o = 6.133 * 10^{-21}\, \sigma^{8.33} = 6.133 * 10^{-21}\, 152.72^{8.33} = 0.00954$$

$$\varepsilon_t = \frac{L_{new} - L_{orginal}}{L_{orginal}} = \frac{170 - 130}{130} = 0.30769$$

$$\varepsilon_t = \varepsilon_o + \varepsilon^o\, .t \qquad \Rightarrow \qquad t = \frac{\varepsilon_t - \varepsilon_o}{\varepsilon^o}$$

$$t = \frac{0.30769 - 0.06408}{0.00954} = 25.54\, hr.$$

Example – 2

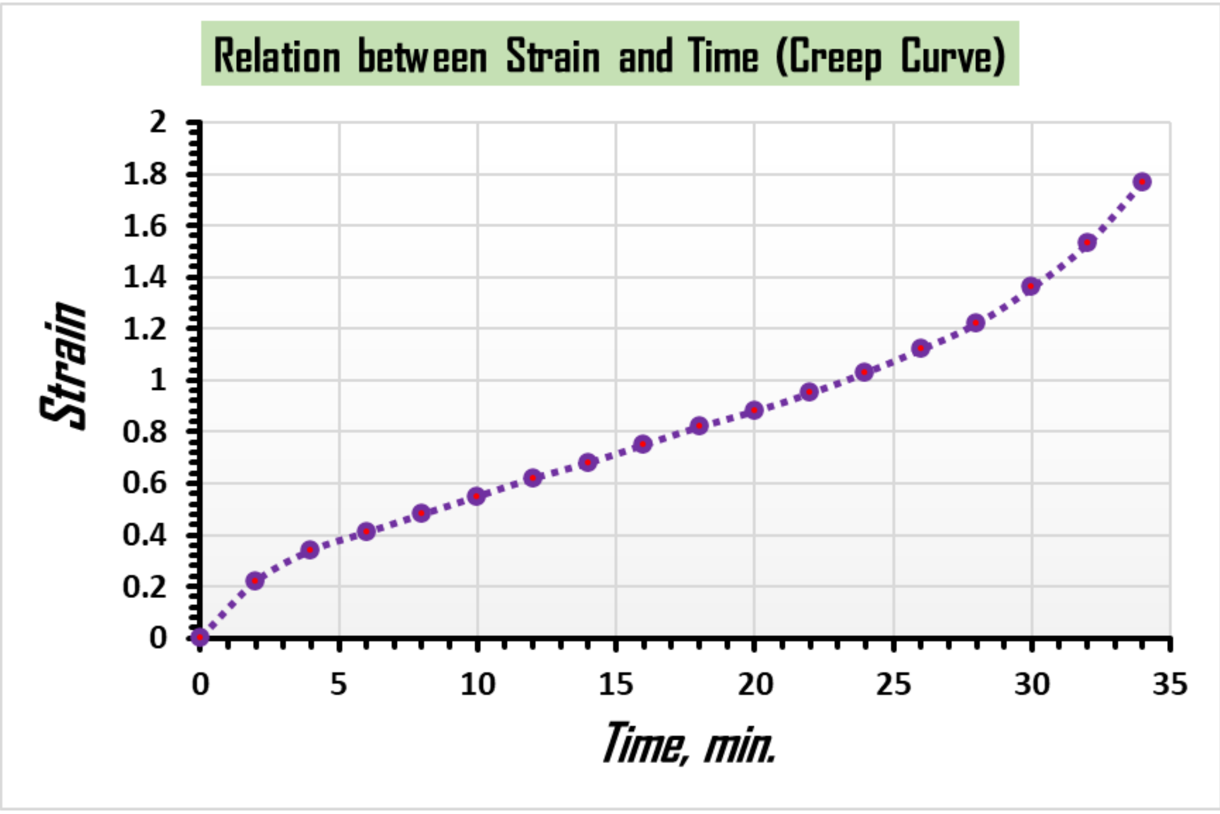
The following creep data were taken on an aluminum alloy at (500 ^{0}C) and a constant stress of (3.5 MPa).

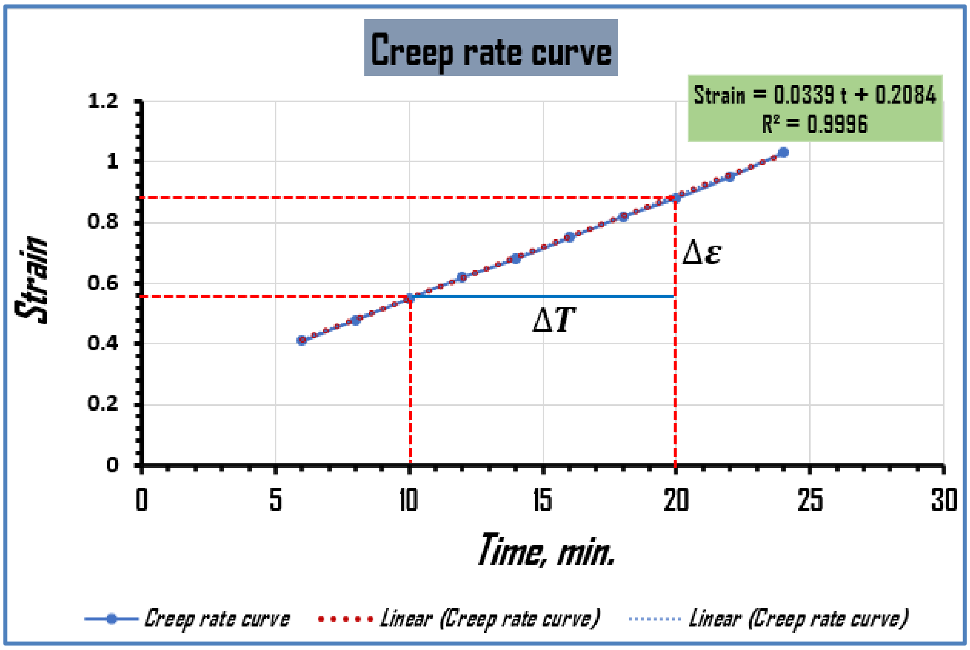
Plot the data at strain verse time. Then determine the steady state or minimum creep rate.

Note: The initial and instantaneous strain is not included.

Time, min.	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
Strain	0	0.22	0.34	0.41	0.48	0.55	0.62	0.68	0.75	0.82	0.88	0.95	1.03	1.12	1.22	1.36	1.53	1.77

Solution





$$Creep\ Rate = \frac{\Delta\varepsilon}{\Delta T} = \frac{0.88 - 0.56}{20 - 10} = 0.032\ \ Extension/min$$

References

1. Kalkhouran, Abbas Aghajani (2017-01-17). A Creep Testing Machine: Second Edition. LAP LAMBERT Academic Publishing. ISBN 978-3-330-02611-7.
2. W. Blum, Materials Science and Engineering: A; Volumes 319-321, December 2001, pg.735-740.
3. A. I. Smith, D. Murray, M. F. Day, "Creep Testing Equipment-Design Features and Control"; Volume 180 Pt. 3A, 1965-66, pg.303-307
4. J.B. Grishaber,"A Novel Computer Controlled Constant Stress Lever Arm Creep Testing Machine", Review of Scientific Instruments; Jul97, Vol. 68 Issue 7, pg.2812
5. Dr. Sabbah Ataya, "Creep Testing Machines", 2008, http://www.slideshare.net/ea2m/creep-testing-machines-presentation
6. Experiment 4 Lab, Center for Reliability of Ceramics, Department of Mechanical Engineering, University of Houston, "Archived copy" (PDF). Archived from the original (PDF) on 2004-12-01. Retrieved 2011-10-19.
7. Narayana, V. J. S., K. Balasubramaniam, and R. V. Prakash. "Detection And Prediction of Creep-Damage of Copper Using Nonlinear Acoustic Techniques." AIP Conference Proceedings 1211.1,2010, pg.1410-1417.
8. API 579-1/ASME FFS-1, June 5, 2007.
9. R. K. Penny and D. L. Marriott, Design for Creep.

Ministry of Higher Education
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Ten Experiment

The Fatigue Test

2024

CONTENTS

1. Introduction

A perusal of the broken parts in almost any scrap yard will reveal that the majority of failures occur at stresses below the yield strength. This is a result of the phenomenon called fatigue which has been estimated to be responsible for up to 90% of the in-service part failures which occur in industry. If a bar of steel is repeatedly loaded and unloaded at say 85% of its' yield strength, it will ultimately fail in fatigue if it is loaded through enough cycles. Also, even though steel ordinarily elongates approximately 30% in a typical tensile test, almost no elongation is evident in the appearance of fatigue fractures. Basic fatigue testing involves the preparation of carefully polished test specimens (surface flaws are stress concentrators) which are cycled to failure at various values of constant amplitude alternating stress levels. The data are condensed into an alternating Stress, S, verses Number of cycles to failure, N, curve which is generally referred to as a material's S-N curve. As one would expect, the curves clearly show that a low number of cycles are needed to cause fatigue failures at high stress levels while low stress levels can result in sudden, unexpected failures after a large number of cycles.

A fatigue test helps determine a material's ability to withstand cyclic fatigue loading conditions. By design, a material is selected to meet or exceed service loads that are anticipated in fatigue testing applications. Cyclic fatigue tests produce repeated loading and unloading in tension, compression, bending, torsion or combinations of these stresses. Fatigue tests are commonly loaded in tension – tension, compression – compression and tension into compression and reverse.

2. Objectives

Usually, the purpose of a fatigue test is to determine the lifespan that may be expected from a material subjected to cyclic loading, however fatigue strength and crack resistance are commonly sought values as well. The fatigue life of a material is the total number of cycles that a material can be subjected to under a single loading scheme. A fatigue test is also used for the determination of the maximum load that a sample can withstand for a specified number of cycles. All of these characteristics are extremely important in any industry where a material is subject to fluctuating instead of constant forces.

3. Types of Fatigue Tests

There are several common types of fatigue testing as well as two common forms:

1. Load controlled high cycle and

2. Strain controlled low cycle fatigue.

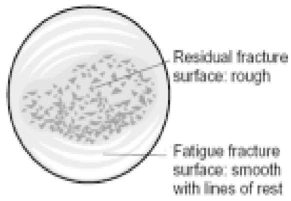
A high cycle test tends to be associated with loads in the elastic regime and low cycle fatigue tests generally involve plastic deformations.

Theory

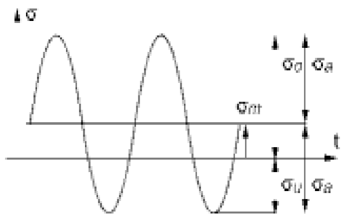
Oscillating stresses are far more dangerous for structural parts and components than a static force applied once.

In the event of frequent repetition of a static load which is in itself permissible, a machine part may rupture as a result of **material fatigue**. As the number of load cycles increases, the permissible stress level declines.

Even stresses which are below the yield point of the material in the elastic range may lead to minor plastic deformations as a result of local peak stresses inside the part. This effect gradually destroys the material due to the constant repetition and eventually results in rupture. The absolute **number of load cycles** is a more decisive factor for failure than the frequency.



Appearance of the fracture surface of a sample

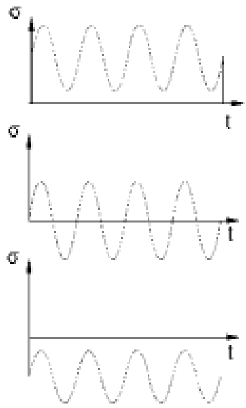


Alternating cyclic stress

The cyclic stress is composed of a constant part, the mean stress σ_m caused by an initial load, and a superimposed cyclic part with the alternating stress amplitude σ_a.

The largest stress occurring is termed maximum stress $\sigma_o = \sigma_m + \sigma_a$, and the smallest stress is termed minimum stress $\sigma_u = \sigma_m - \sigma_a$. Three ranges are distinguished in alternating cyclic stress:

1. **Range of pulsating stresses (tensile force)** Mean stress larger than the alternating stress amplitude $\sigma_m > \sigma_a$
2. **Range of alternating stresses** Mean stress is smaller in total than the alternating stress amplitude $|\sigma_m| > \sigma_a$
3. **Range of pulsating stresses (compression)** Mean stress is smaller than the negative alternating stress amplitude $\sigma_m < (-\sigma_a)$



3. Method of Wear Test

Common techniques used to measure wear include measuring the length or thickness change of the test specimen, profiling surfaces to determine the wear depth or cross-sectional area worn away, using a precision balance to measure mass loss, measuring the relative displacement of specimens on the testing machine

4. Experimental Procedure of Wear Test

Dry sliding wear tests for different number of specimens was conducted by using a pin-on-disc machine (Model: Wear & Friction Monitor TR-20) supplied by DUCOM is shown in Figure 1.

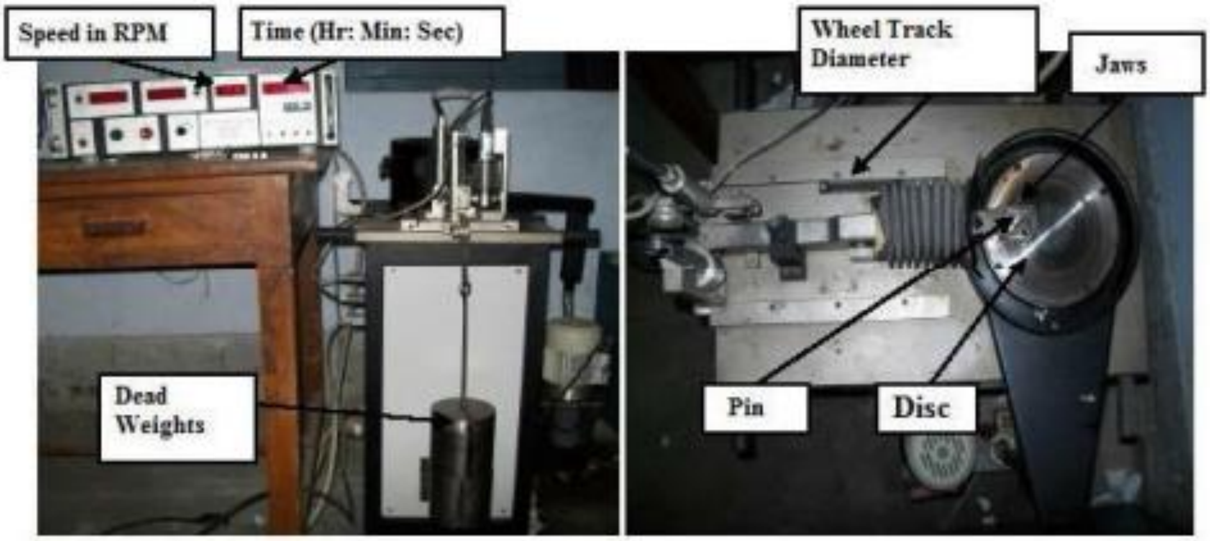


Figure 1. Wear test machine

The pin was held against the counter face of a rotating disc (EN31 steel disc) with wear track diameter 60 mm. The pin was loaded against the disc through a dead weight loading system. The wear test for all specimens was conducted under the normal loads of 20N, 40N and a sliding velocity of 2 and 4 m/s. Wear tests were carried out for a total sliding distance of approximately 3000 m under similar conditions as discussed above. The pin samples were 30 mm in length and 12 mm in diameter. The surfaces of the pin samples were slides using emery paper (80 grit size) prior to test in order to ensure effective contact of fresh and flat surface with the steel disc. The samples and wear track were cleaned with acetone and weighed (up to an accuracy of 0.0001 gm using microbalance) prior to and after each test. The wear rate was calculated from the height loss technique and expressed in terms of wear volume loss per unit sliding distance.

In this experiment, the test was conducted with the following parameters:

1. Load
2. Speed
3. Distance

In the present experiment the parameters such as speed, time and load are kept constant throughout for all the experiments. These parameters are given in Table 1.

Table 1. Parameter taken constant during sliding wear test

Pin material	Al, Al/C, Al/C/3B_4C, Al/C/6B_4C, Al/C/9B_4C
Disc material	EN 31 steel
Pin dimension	Cylinder with diameter 12 mm height 30 mm
Sliding speed (m/s)	2, 4
Normal load	20, 40
Sliding distance (m)	3000

5. PIN-ON-DISC TEST

In this study, Pin-on-Disc testing method was used for tribological characterization. The test procedure is as follows: Initially, pin surface was made flat such that it will support the load over its entire cross-section called first stage. This was achieved by the surfaces of the pin sample ground using emery paper (80 grit size) prior to testing Run-in-wear was performed in the next stage/ second stage. This stage avoids initial turbulent period associated with friction and wear curves Final stage/ third stage is the actual testing called constant/ steady state wear. This stage is the dynamic competition between material transfer processes (transfer of material from pin onto the disc and formation of wear debris and their subsequent removal). Before the test, both the pin and disc were cleaned with ethanol-soaked cotton.

Before the start of each experiment, precautionary steps were taken to make sure that the load was applied in normal direction. Figure 2 represents a schematic view of Pin-on-Disc setup.

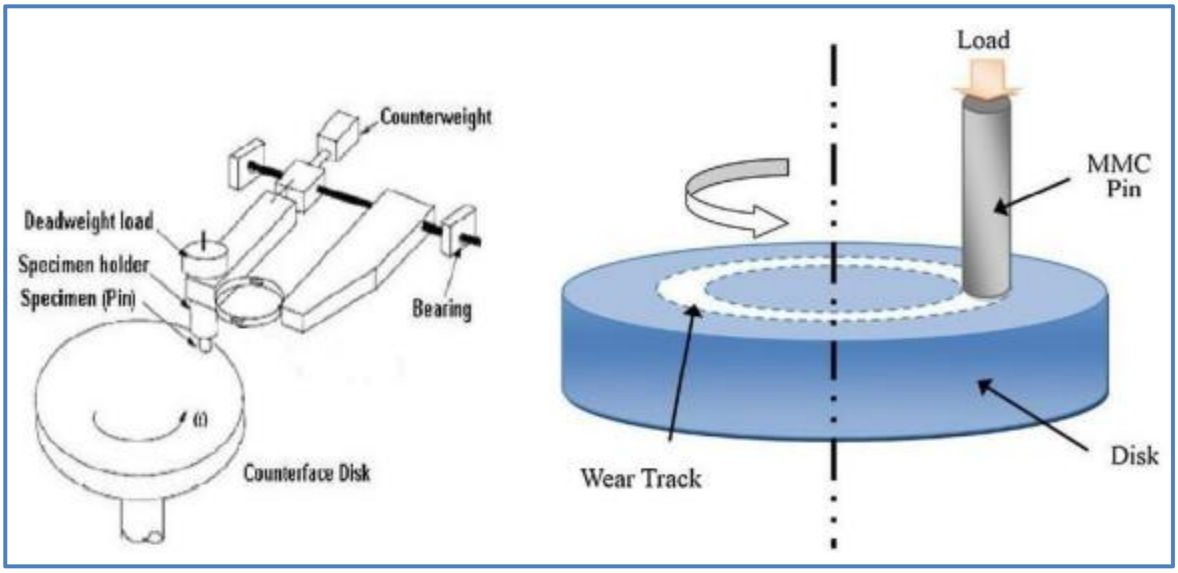


Figure 2. Schematic views of the pin-on-disk apparatus

6. Weight Loss

The alloy and composite samples are cleaned thoroughly with acetone. Each sample is then weighed using a digital balance having an accuracy of ± 0.1 mg. After that, the sample is mounted on the pin holder of the tribometer ready for wear test. For all experiments, the sliding speeds are adjusted to 2 and 4 m/s. The specific wear rates of the materials were obtained by $W = \frac{\Delta w}{L . \rho . F}$

Where:

W denotes specific wear rates in mm^3/N.

Δw is the weight loss measured in grams,

L is the distance in meters

ρ is density of the worn material in g/mm^3 and

F is the applied load in N.

Weight loss of the alloy and composite samples in grams is shown in Table 2.

Table 2. Data of cumulative wear loss of alloy and composites

Weight loss of alloy and composite								
S.No.	Specimen Name	Sliding Speed 2m/s			Sliding Speed 4m/s		
		Initial weight (gm)	Final weight (gm)	Weight loss (gm)	Initial weight (gm)	Final weight (gm)	Weight loss (gm)
1	LM 25	8.27122	8.246	0.02522	8.27122	8.2422	0.02902
2	LM 25 + C	8.09076	8.073	0.01776	8.09076	8.067	0.02376
3	LM 25+C + 3%B_4C	8.16358	8.1494	0.01418	8.16358	8.14182	0.02176
4	LM 25+C + 6%B_4C	8.00555	7.9927	0.01285	8.00555	7.985	0.02055
5	LM 25+C + 9%B_4C	8.35572	8.3444	0.01132	8.35572	8.33629	0.01943

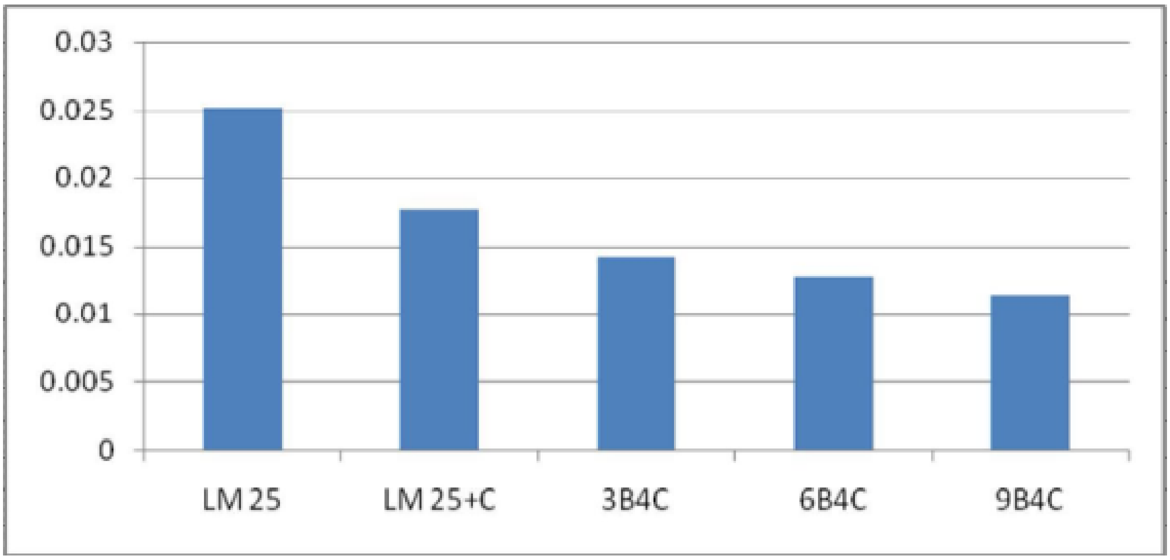


Figure 3. Weight loss of alloy and composite with 2 m/s

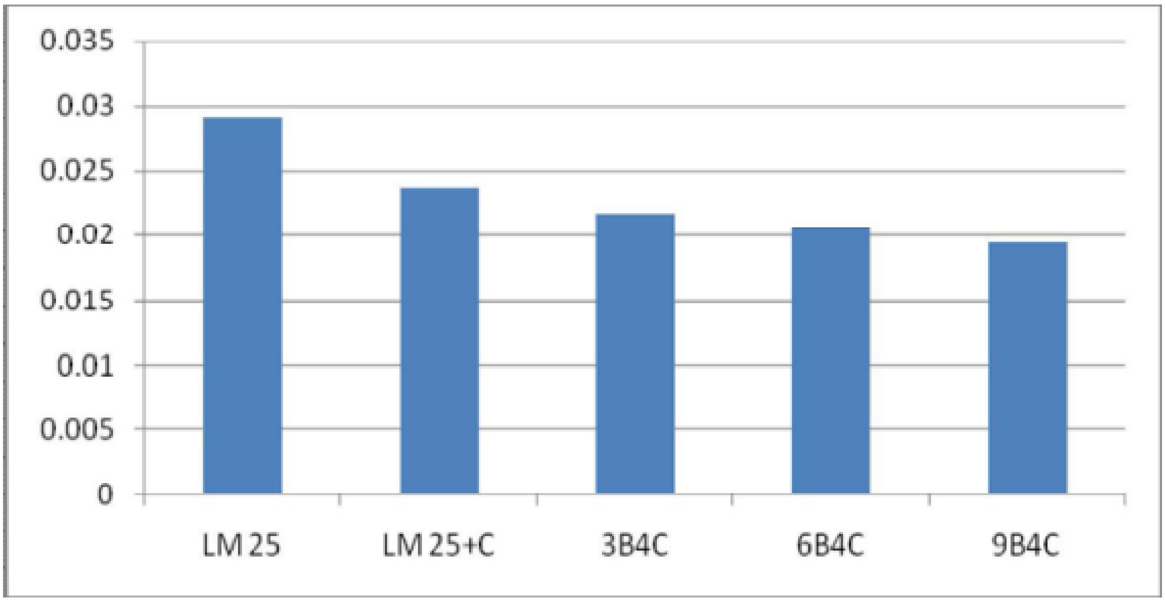


Figure 4. Weight loss of alloy and composite with 4 m/s

Figures 3 and 4 show the cumulative weight loss of the alloy specimen after addition of graphite and boron carbide produced with the help of stir casting technique. After addition of reinforced material, the sliding wear decreases significantly or says that weight loss is decreasing as the graphite and boron carbide addition is increasing as compared to matrix metal.

7. Wear Calculation

1. Area

   Cross sectional Area, $A = \pi r^2$

2. Volume loss

   Volume loss = Cross sectional Area x Height loss

3. Wear rate

   Wear rate = Volume loss / Sliding distance

4. Wear resistance

   Wear resistance = 1/ Wear rate

5. Specific wear rate

   Specific wear rate = Wear rate/load

8. Graph

Table 3. Specimen vs wear rate (mm^3 /m)

Specimen	Wear rate (mm^3/m)	
	2 m/s	4 m/s
p	6.58676928	40.49484735
g4	1.70248684	20.06797604
b3	1.27498018	17.07768475
b6	1.13700184	14.43573299
b9	0.90552998	8.4144354

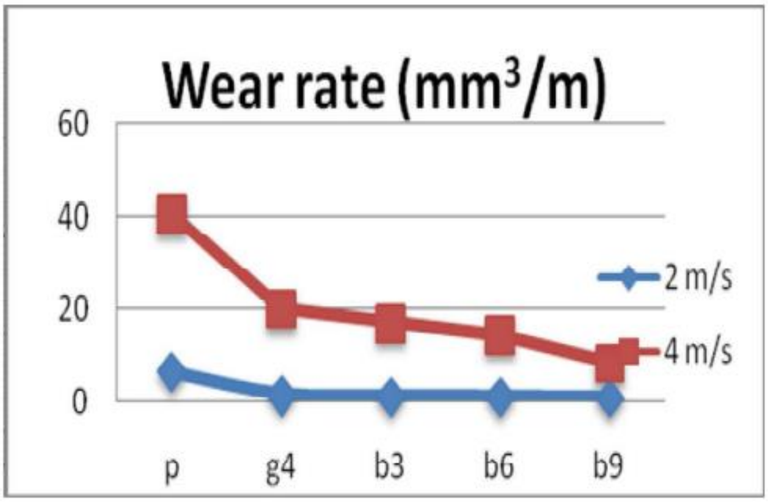


Figure 5. Specimen vs wear rate (mm3/m) with 2 and 4 m/s

LM-25 and composites reinforced with boron carbide and graphite particles of size ranges (200 meshes) at a load of 20, 40 N and total time is 5 minutes. It can be attributed to the increase in hardness of the material due to the presence of hard ceramic particles. Material removal in a ductile material such as aluminum alloy matrix is due to the indentation and ploughing action of the sliding disc which is made from hard steel material (EN31 steel disc). Incorporation of hard graphite and B4C particles in the Al alloy LM25 restricts such ploughing action of hard steel counterpart and improves the wear resistance. Comparing the wear properties of composites reinforced with graphite and B4C particles, it is observed that despite their higher hardness, composites reinforced with graphite and B4C particles show improved wear resistance as compared to Al 6061 composites reinforced with SiC particles.

References

10. Rhotagi Pradeep, Cast M.M.C. Past, Present & Future, AFS Transactions, University of Wisconsin, Milwaukee, Wisconsin, Silver Anniversary paper, Div.2. 01-25, 200, (2001)
11. Das S, Trans Indian Inst Metals, 5(4) (2004) 325-334.
12. Surappa M K, Sadhana, 28(1&2) (2003), 319-334.
13. Shashidara S M, Mallikarjuna C & Muralidhara, J Manuf Eng, 3(1) (2008).
14. Rosenberger M R, Forlerer E & Schvezov C E, Wear, 266 (2009) 356-359.
15. Prabhu Swamy N R, Ramesh C S & Chandrashekar T, Bull Mater Sci, 33(1)(2010) 49-54. 7 Wlodarczyk–Flingier A & Dobrzeanski Adamiak LA, J Achieve Mater Manuf Eng, 30(2) (2008) 147-150.
16. Chikanna N, Sankaran P & Mukunda P G, J Manuf Eng, 3(1) (2008).
17. Benal Mahagundappa M & Shivand H K, Wear, 262 (2007) 759-763.
18. Miyajima T & Iwa Y, Wear, 255 (2003) 606- 616.
19. Ranganath G, Sharma S C & Krishna M, Wear, 251 (2001) 1408-1413.

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