Insert Your Course Name Here
(Course #)
Term Project/Home Work/Short or Full Lab Report …..

School of Engineering
The University of Jordan, Amman-Jordan

Project/Experiment/Report Title Goes here

by

FirstName Initial LastName (ID #)
FirstName Initial LastName (ID #)

Section #:

Month 9999

Abstract

An abstract consists of answering three basic questions:

1. What was done?
2. How it is was done? and
3. What were the basic findings and conclusions?

- ✓ Abstract should be written in passive voice.
- ✓ Abstract should not exceed 200 words.
- ✓ It should be written in three separate paragraphs.
- ✓ This section and all the coming sections should be written in Font 12, Times New Roman with regular style and single line spacing.
- ✓ This page should contain the abstract ONLY and numbered using the Roman Style (i.e. I, ii, iii …etc)
- ✓ It should be written in passive voice.

Nomenclature

The nomenclature defines the parameters, symbols and acronyms used in the report. Standardized symbols should be used whenever possible.

- The units should be added to the nomenclature.
- The parameters should be arranged alphabetically.
- This section should be written in separate page(s).

A	Area	[m2]
P	Pressure	[N/m2]
Re	Reynolds Number	[ND]

Subscript

f	Liquid
s	surface

Greek Symbols

μ	Dynamic viscosity	[N-s/m2]
α	Angle of attack	[deg]

Objective

The objective(s) should be written based on the instructor's explanation of the experiment.
DO NOT copy from laboratory manual.

Experimental Setup and Procedure

This section should contain the working principle of the setup used in the experiment.
It should contain a clear image of the setup with the main parts identified in suitable manner.
The figure's caption (name) should be written below it.

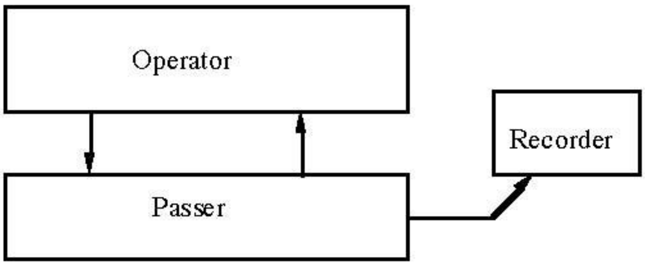


Figure (1): Some numbers from the result of the experiment on nothing

- ✓ Never start any paragraph with figure, table, graph …etc. You should allways write few introductry lines (e.g. This section discusses the setup used in conducting this experiment. The setup is shown below in Figure (1)).
- ✓ Define the major components of the setup.
- ✓ Explain briefly how it works.
- ✓ Finally, explain with your own words (DO NOT COPY FROM USER MANUAL) how you conducted the experiment.
- ✓ As of this page onwards, the page numbering should start using the 1-100 Arabic numbers.

Data Observation

The data observed are divide into two main items.

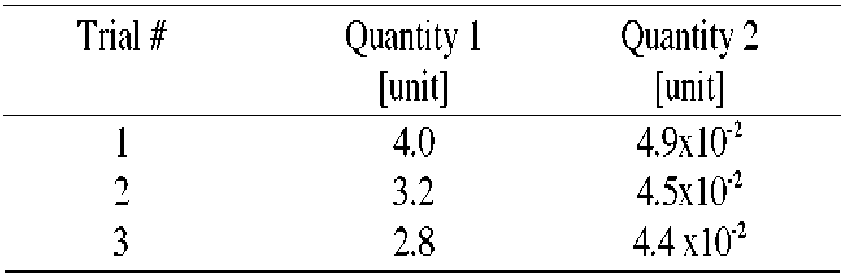
Given data

- o This includes the constants that were not changed in the experiment e.g atmspheric conditions, certain setup dimensions (if not changed) e,g diameter, length ….etc.
- o As for the material's properties e,g, density, viscosity, thermal conductivity …etc these should be mentioned with the reference wherefrom they were copied cited.

Observed data

- ✓ The data that were taken from the setup ONLY should be mentioned in the table.
- ✓ Table columns should be writen with units and without abbreviations.
- ✓ The table caption should be mentioned on top of the table.
- ✓ Do not add any calculated data in the table.

Table (1): The observed data



Trial #	Quantity 1 [unit]	Quantity 2 [unit]
1	4.0	$4.9\text{x}10^{-2}$
2	3.2	$4.5\text{x}10^{-2}$
3	2.8	$4.4\ \text{x}10^{-2}$

If the experiment consists of several parts, put the tables with each case defined before that.
For example :

Case (I) : Partially submerged torous
Inset the data observed table for this case below.

Case (II) : Totally submerged torous
Inset the data observed table for this case below.

Sample calculations

In this section you are required to provide with proper explanation (NOT only use equations and substitute numbers) the steps for your calculations.

You should state which data you are taking for sample calculations.

If the calculations involve theoretical and experimental values for comparison, you should calculate the percentage error in the experimental value.

Uncertainty analysis

This is extremely important part that tells the accuracy of the test procedure (NOT ONLY in the final value).

This can be extremely helpful if one wishes to find the main factor responsible for the error.

There are many methods suggested for this section :

1) Uncertainty propagation (you can use suitable software for that as you have been taught)
2) Limiting and relative limiting errors using equations.
3) Limiting and relative limiting errors using maximum/minimum method.

Finally a summery of the calculations should be added in separate table(s) with errors and uncertainity calculations.

Results and discussion

Present your results in a logical sequence, highlighting what is important and how the data you obtained have been analyzed to provide the results you discuss.

- You should discuss what you infer from the data.
- You need to adopt a critical approach.
- For example, discuss the relative confidence you have in different aspects of the measurements.
- Make sure that all diagrams, graphs etc. are properly labeled and have a caption.

- A *neat hand drawn diagram is preferable to a poorly made computer diagram*, or a poor resolution image copied from the web.

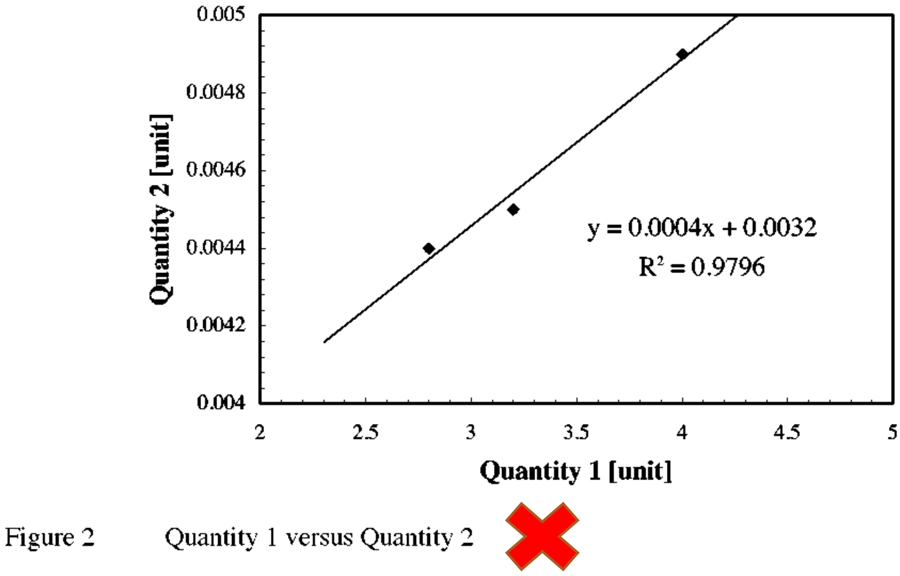


Figure (2) : Variation of Quantity (2) with Quantity (1)

- Graphs should be clear, informative, with proper legends and unit.
- If curve fiting is implemented, it should contain the fit model and its R2.
- Graph outline should be removed.

Conclusion

This is the section in which you need to put it all together. It differs from the abstract in that :

- It should be more informative, something that can easily be accomplished because you may devote more words to it. You should include a concise version of your discussion, highlighting what you found out, what problems you had, and what might be done in the future to remedy them.
- You should also indicate how the investigation could usefully be continued.

References

For this section, you should provide the source of information wherefrom you got the equations, fluid or materials properties.

Use this website : https://scholar.google.com/

- ✓ Textbooks, articles, company websites are trusted sources.
- ✓ Do not use the lab manual as a reference.
- ✓ List the references in same order as they appear in the text.
- ✓ For my students, I ask them to use the APA or Chicago style.

Book

Holman, J. P. (2012). Experimental methods for engineers. McGrawHill, New Yourk.

Journal article,
Sang, J., Yuan, Y., Yang, W., Zhu, J., Fu, L., Li, D., & Zhou, L. (2022). Exploring the underlying causes of optimizing thermal conductivity of copper/diamond composites by interface thickness. Journal of Alloys and Compounds, 891, 161777.

Web page,
http://www.gobbeldygook.co.uk. Viewed on 22/10/2020.

A word of caution on web based information. Journal articles and most books are peer reviewed. This means that other workers in the field have checked them for accuracy etc.. This is not true of web sites. Be careful in taking information from such sources and if at all possible verify the information by checking in books etc. You should also read the web information critically to see that it makes sense to you.
You are an engineer and should take pride in not being duped into making easy mistakes by faulty information.

CREEP TEST

INTRODUCTION

The term creep refers to the slaw plastic deformation that occurs with prolonged loading usually at elevated temperatures. Soft metals (e.g. lead) creep at room temperatures; in general, the higher the melting point of the material, the better its creep resistance. This gradual deformation over a long period of time may result in fracture at a stress well below the normal strength of the material. Therefore, in assessing the behavior of a metal under stress, especially at elevated temperatures, it is necessary to consider the time factor because the strain does not cease after the immediate application of the load, but continues with time and may eventually result in inter crystalline fracture.

Creep may occur under static tension, compression, bending, torsion or shear stress: However, it has been mainly studied in tension under conditions of constant load.
Creep is important in the following applications:

1. Soft metals used at about room temperature, e.g. lead pipes and white metal bearings.

2. Plant operating at high temperatures, e.g. furnace equipment, gas turbines, steam and chemical processing plant.

In designing plant to work well above atmospheric temperatures, consideration must be given to the maximum strain that can be tolerated, the consequences of fracture, and the anticipated life of the plant. These design considerations depend largely on the type of component and the service conditions.

Creep is a function of stress, time, and temperature. A metal is more likely to creep at a higher stress level or after a long period of time even if the temperature is not elevated.

The engineer must design the part so that the stress is low enough to limit creep to an allowable value. This maximum permissible stress is often called the Creep strength or creep limit. Creep strength is defined as the highest stress that a material can stand for a specified time without excessive deformation. The creep rupture strength, sometimes called the Rupture strength, is defined as the highest stress a material can stand for a specified time without rupture.

Creep caused by constant load can be studied by measuring the permanent extension, after various time intervals, of test pieces maintained at a constant temperature. When the creep strain, $\mathcal{E}^C$, is plotted against time, a curve is obtained such as the one shown in **figure (1).**

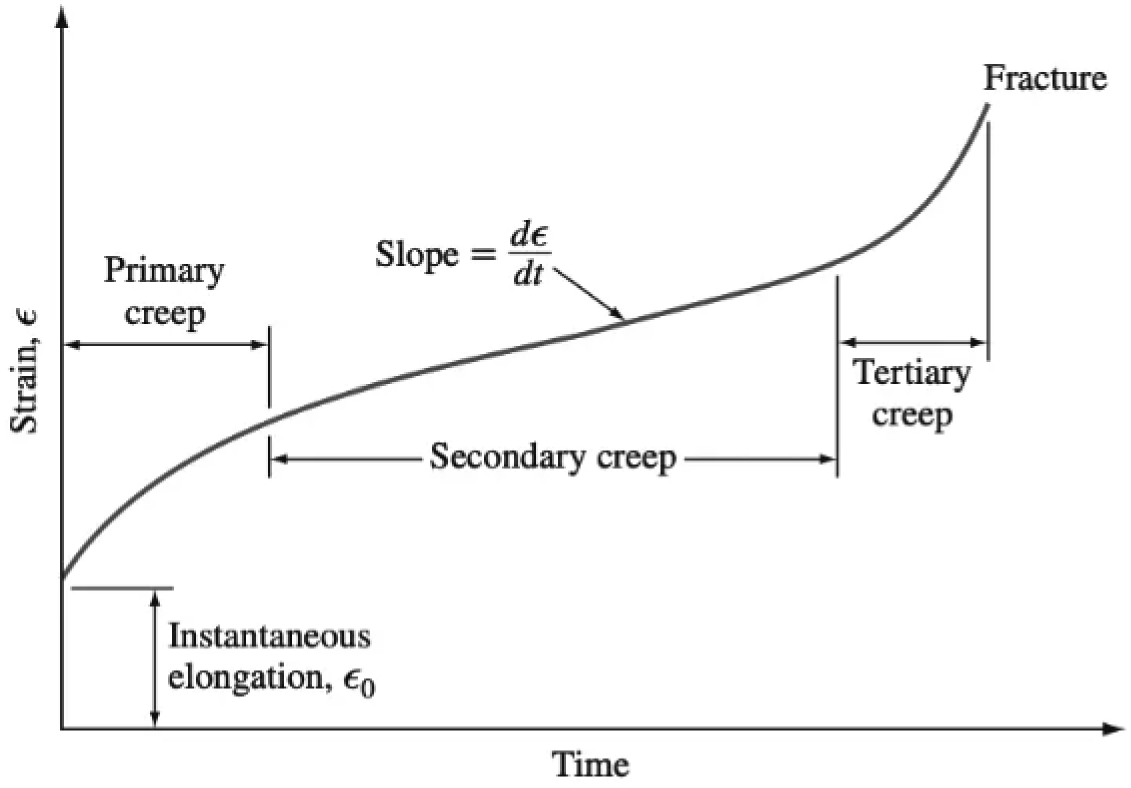


Figure (1) Typical creep curve showing three stages of creep

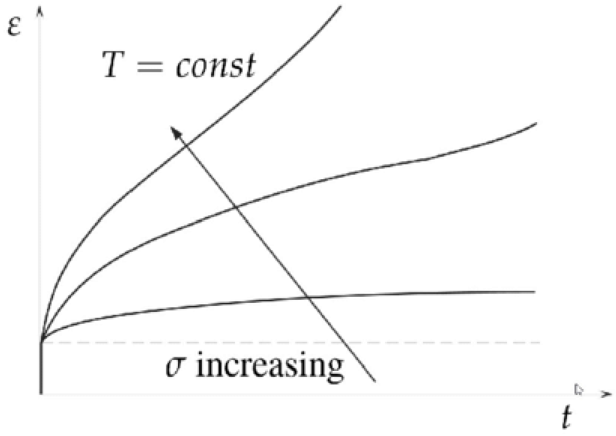
After the initial instantaneous extension, it can be seen that the curve is made up of three portions:

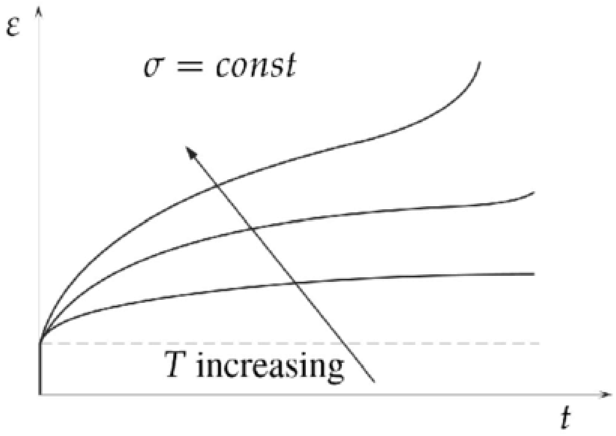
1. The primary stage AB, after the instantaneous strain, elastic strain, at the time of application of the load begins the transient or primary creep, which is characterized by a relatively high strain rate. The deformation in this stage is accompanied by strain hardening which quickly reduces the rate of strain.

2. The secondary stage BC, in which the material is almost entirely viscous. The strain rate (SLOPE) is approximately constant. This steady state is the most important part. Of the curve and should cover the entire estimated life of the component.

3. The tertiary Stage CD; in which the strain rate increases rapidly due to local necking of the test piece or the formation of internal cavities. The effective stress therefore increases and finally leads to fracture at D.

The relative duration of the three stages depend on the temperature, stress, and prior history of the sample. **Figure 2(a)** shows a family of actual creep curves for a constant temperature and three stress levels. **Figure 2(b)** shows another common way of presenting creep data. Here the time to rupture is plotted against stress for various temperatures.





In many cases the three parts of the curve are not clearly distinguishable. At low stresses and temperature the primary creep resembles the bounded creep of linear viscoelasticity, with a limiting value attained asymptotically and secondary- and tertiary--creep never appear (**Figure (3))**. At higher stress or temperature, however, the primary creep shows a logarithmic or a power dependence on time:

$$\varepsilon^{c} \text{ a } \ln(t) \text{ or } \varepsilon^{c} \text{ a } t^{\alpha}$$

Where a is between 0 and 1, a frequently observed value being $\frac{1}{3}$

Creep described by the power law can be derived from a formula relating stress, creep strain and creep strain rate that has the form:

$$\sigma = c(\varepsilon^{c})^{n}(\varepsilon^{c})^{r}$$

Where C, n, and r depend on the temperature.

A common approximation for the creep strain as a function of time, at given stress and temperature, is given by:

$$\sigma = \varepsilon^{c}(t) = \varepsilon_{n}^{c} + \varepsilon^{c} \times t$$

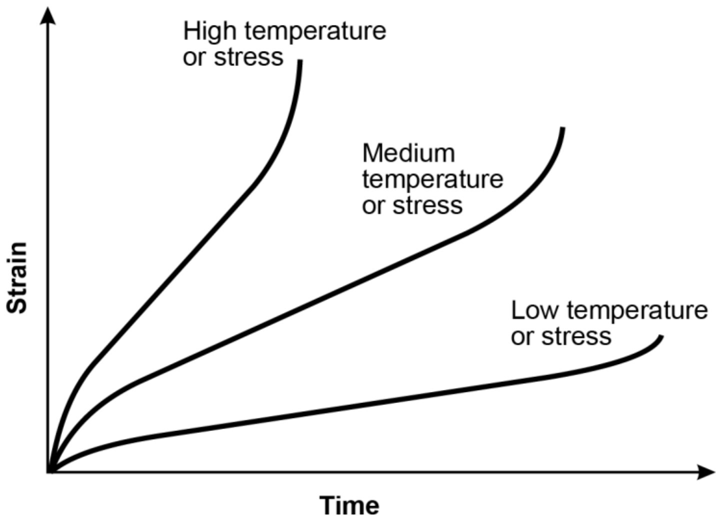


Figure (3) Curves of Creep at Different Temperatures and Stress

Where ε_n^c is a fictions initial value defined by the ε^c-intercept with the straight line tangent to the actual creep curve at point of inflection or in the steady creep portion.
Figure (4) shows a family of typical creep curves, where more properties of creep are indicated:

1. Curve A represents _a typical creep curve for a relatively high stress. After the application of the load, creep proceeds at a gradually diminishing rate. The second stage is reduced to a point where inflection occurs and the rate of creep (extension/time) increases until the specimen breaks.

2. Curve B is of similar shape of A, but due to the lower stress applied; it takes more time to fracture since the second stage is present.

3. Curves C and D still have lower applied stresses and longer duration is needed to reach the inflection points and thus to reach the fracture point.

4. Curve E, a test of very long duration. The second stage range is very long. Sometimes the curve beyond the initial stage is a straight line and neither the inflection point nor the rupture of the-specimen will be reached, or they will may be reached after very long period of time. The creep rate of such curve approaches zero.

5. Curve G, connects all the inflection points of all curves, except curve E where it becomes the tangent of curve G in the infinity (Asymptote).

To develop a mathematical formula describing creep as function of stress, temperature, and time is difficult, and furthermore it is beyond the scope of this test. But when studying creep, two effects are in evidence:

1. The strain hardening of material due to plastic strains, i.e. the material resistance to deformation increases after exceeding the elastic limit.

2. The thermal softening of the material due to prolonged effect of high temperature, i.e. the material resistance to deformation decreases.

These two effects work against each other, namely, the thermal softening tries to remove the strain hardening.

The time extension curves thus demonstrate that the rate of elongation gradually diminishes due to strain hardening. At the point of inflection the rates of strain hardening and thermal softening counter act each other, i.e., the strain hardening produced by creep is continuously destroyed by thermal softening effect. Creep then continues at a constant rate depending upon the magnitude of stress and temperature.

Laboratory sheet

Objective:

To inspect the property of creep in metals (lead in this experiment)

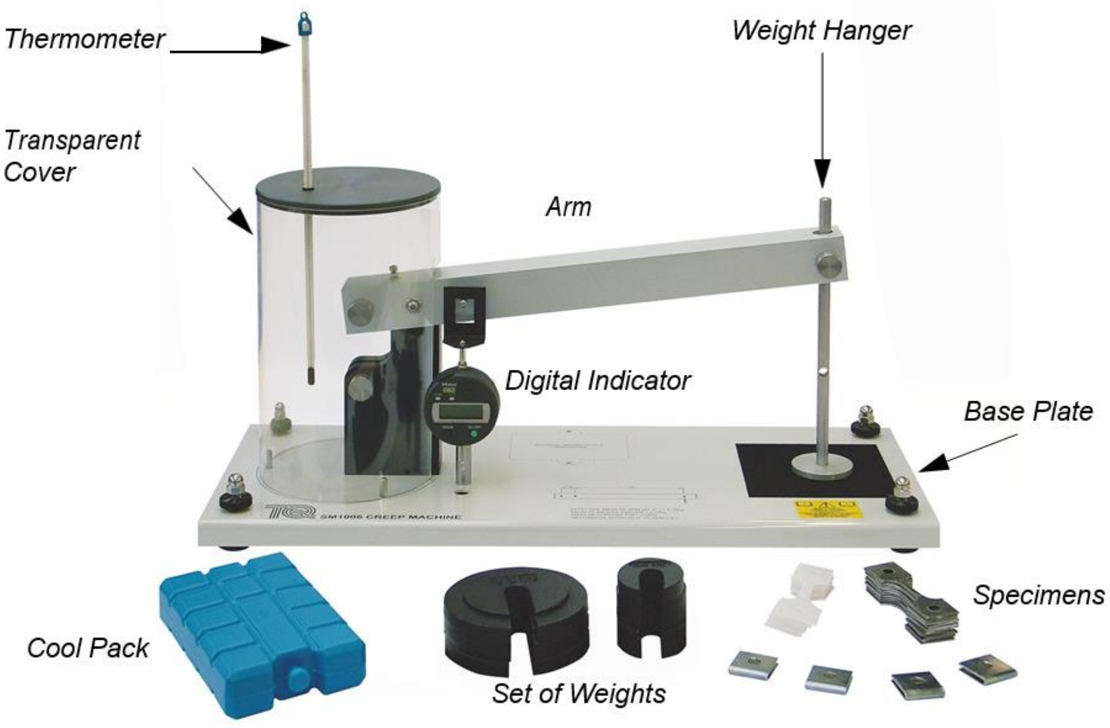
Apparatus

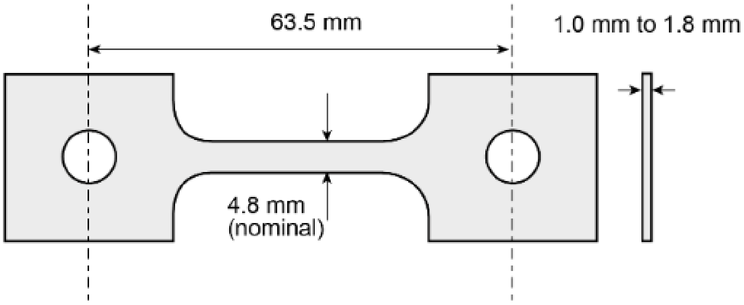
The SM1006 Creep Measurement Apparatus, illustrated in Figure(5), uses a simple lever to apply a steady load to the specimen. The specimen is attached at one end to the lever mechanism by a steel pin and fixed at the other end to the bearing block by another steel pin.

Loads are applied to the lever arm by placing weights on the weight hanger, which is pinned to the lever arm.

The Creep Machine also teaches students about:

- The three stages of Creep.
- The effect of temperature on Creep.
- Material failure (fracture) due to Creep.
- Plastic and elastic limits.
- Creep recovery.





Procedure

1. Accurately measure and record the width and thickness of the specimen

NOTE *If using TecQuipment's optional VDAS, enter into the software the measurements and the type of specimen to be tested.*

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 can be allowed
7. Ask an assistant to prepare the timer.

NOTE *If using TecQuipment's optional VDAS, set the timed data acquisition for 2 second intervals and 'continue indefinitely'.*

8. Carefully remove the Weight Hanger support pin from the highest hole in the Weight Hanger.
9. Switch on the digital indicator and press its origin button to set its display to zero. Make sure that it is set to work in reverse (press the +/- button so that the word REV is shown in its display).
10. Lift the Weight Hanger and support it while fitting the support pin in the lowest hole.
11. Gently (and at the same time) - let go of the Weight Hanger and start the timer. Slide the rubber mat (supplied) onto the Base Plate, underneath the Weight Hanger.
12. Record the specimen extension every 2 seconds, until it fractures or stops extending due to the limits of the machine.
13. Repeat the test on new specimens at higher loads (stresses), so that there is a set of at least two more stress results.

NOTE *Too much weight gives a very high stress and a very short test time on lead specimens, so results can be inaccurate. Lower value weights give longer test times, but better results. Choose weights that will give tests as long as the laboratory time will allow.*

Results Analysis - All Specimens

1. For each test, plot a chart of specimen extension (mm) on the vertical axis against time (minutes) on the horizontal axis.

2. On the most linear (secondary creep) part of the curve, calculate the gradient. This is the minimum creep rate (in mm.minute^{-1}).

FATIGUE TEST

INTRODUCTION

Fatigue of metals is a well-known situation where yielding (and then rupture) can be caused by a large number of stress variations (magnitude and/or direction) at a point even though the max stress is less than the yield stress, and respectively the ultimate stress.

A fatigue failure begins with a small crack resulting from a tensile stress at macro or microscopic flaw. Once started, the crack will develop at point of discontinuity in the material, such a change in cross section, a keyway or a hole. Less Obvious points at which fatigue failure is likely to begin are internal cracks, or even irregularities caused by machining. In other words, when a load below the yield strength of a material is applied repeatedly to a metallic specimen, localized hardening occurs. Then a small crack appears this crack is a line of stress concentration, which causes it to grow. As the crack grows, the cross sectional-area of the metal smaller until it can no longer support the load. When fracture takes place, the loading is called Fatigue loading and the fracture is called **fatigue failure**.

Cracks generally start at the surface of the metallic material. As the crack grows, the two surfaces rub against each other; polishing both faces to a dull metallic finish, whereas the fractured surface show signs of plastic deformation and a crystalline finish. See Fig. (1)

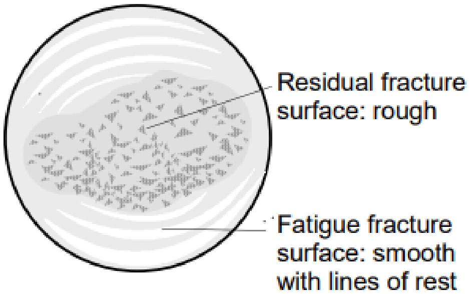


Fig (1) Appearance of the fracture surface of a sample

To determine the strength of materials under the action of fatigue loads, specimens are subjected to repeated or varying forces of specified magnitudes while the cycles of stress reversals are counted to destruction. To establish the fatigue strength of a material, quite number of test are necessary. For the rotating test, a constant bending load is applied, and the number of revolutions (stress reversals) of the beam required for failure is recorded. The first test is made at a stress which is somewhat under the ultimate strength of the material. The second test is made with a stress which is less than that used in the first.

This process is continued, and the results plotted as an S-N diagram (Fig. (2)). This chart may be plotted on semilog papers or on Log-Log papers.

The ordinate of the S-N diagram is called the fatigue strength; (σfat the stress above endurance limit at which failure is likely to occur after a given number of cycles) a statement of this strength must always be accompanied by a statement of the number of cycles, N, to which it corresponds. In the case of STEELS, a knee occurs in the graph, and beyond this knee failure will not occur, no matter how great number of cycles. The strength corresponding to the knee is called the endurance limit S or the fatigue limit.

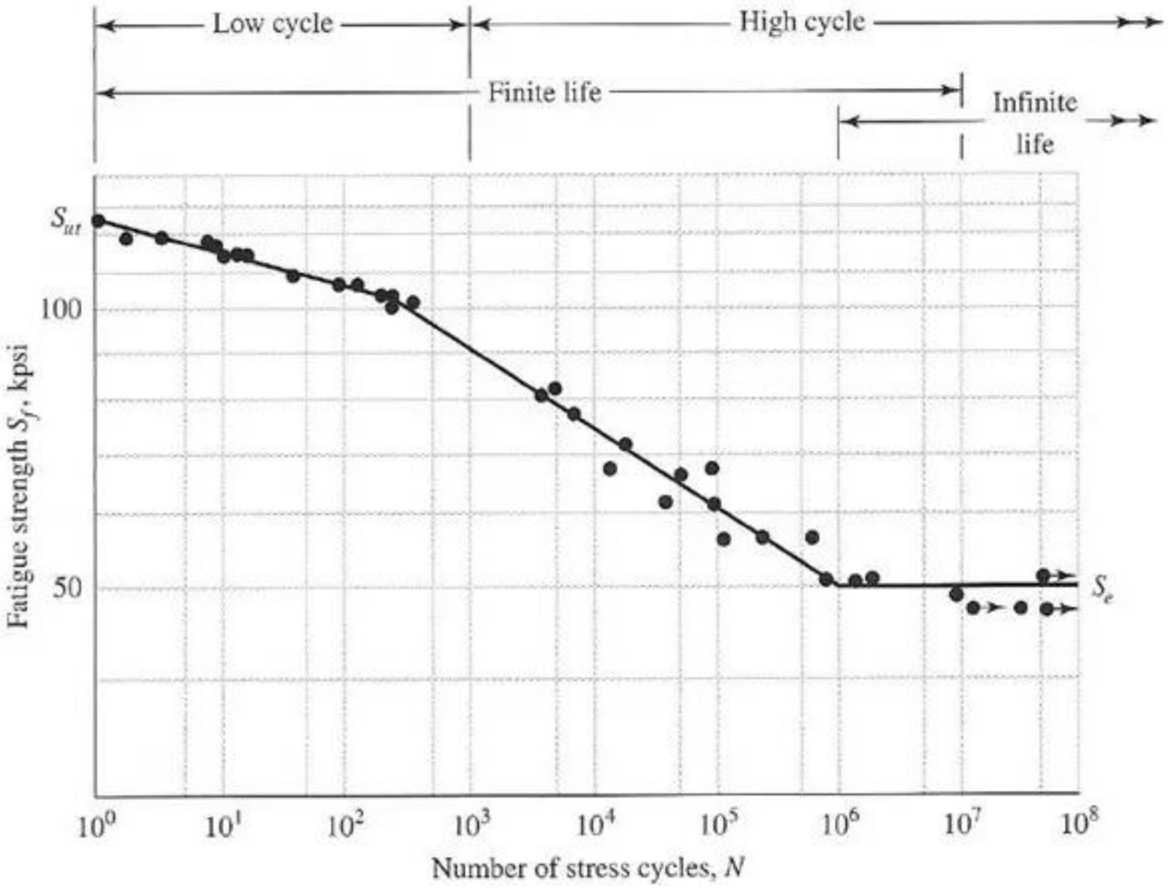


Figure (2) S-N diagram for UNS G41300 Steel.

In many situations we need a rapid estimate of the endurance limit (FOR STUDENT USE ONLY). It was found that for steel the following could be used:

$$S_e = 0.5\, S_{ult}\ ,\ S_{ult} \le 1400\ \text{MPa}$$
$$S_e = 700\text{MPa},\ S_{ult} > 1400\ \text{MPa}$$

For the cast irons and cast steels:

$$S_e = 0.45\, S_{ult}\ ,\ S_{ult} \le 600\ \text{MPa}$$

$$S_e = 270\text{MPa}\ \ ,\ S_{ult} > 600\ \text{MPa}$$

Processors of Aluminum and Magnesium alloys publish very complete tabulations of the properties of these materials, including the fatigue strength, which ordinarily run from about 30 to 40 percent of the tensile strength, depending whether the material is cast or wrought. These materials do not have an endurance limit, and the fatigue strength is usually based on (108) or 5x(108) cycles of stress reversals.

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 which shown in figure (3).

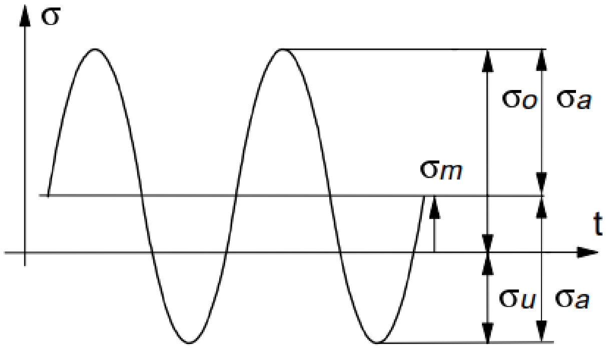
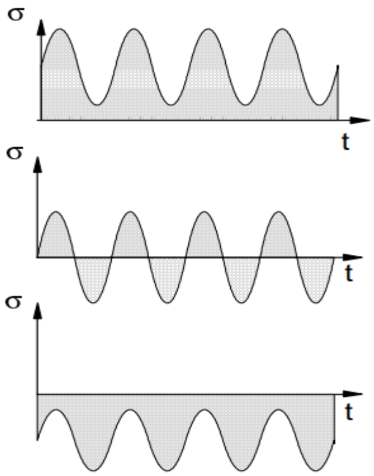


Figure (3) Alternating cyclic stress

The largest stress occurring is termed maximum stress $\sigma_{\text{o}} = \sigma_m - \sigma_a$ and the smallest stress is termed minimum stress $\sigma_{\text{u}} = \sigma_m - \sigma_a$. Three ranges are distinguished in alternating cyclic stress:



- Range of pulsating stresses (tensile force):
  Mean stress larger than the alternating stress Amplitude $\sigma_m > \sigma_a$

- Range of alternating stresses:
  Mean stress is smaller in total than the alternating stress amplitude $|\ \sigma_m\ | > \sigma_a$

- Range of pulsating stresses (compression):
  Mean stress is smaller than the negative alternating stress amplitude $\sigma_m < (-\sigma_a)$

Fatigue and Design:

Fatigue must be considered in the design of all structural and machine components which are subjected to repeated or fluctuating loads:

1. Usage of endurance limit: With material like mild steel, the actual stress range could be kept below the endurance limit.

2. Usage of number of reversals, N: Alternatively, one can design for a specified number of stress variations (magnitude and direction) on condition that the element will be replaced at that stage.

3. Increasing fatigue life of parts: Cracks occur usually under the action of tensile stresses.

Therefore, reduction of tensile stresses will prevent fatigue and thus make the part lire longer. Tensile stress reduction can be achieved through creating a constant compressive stress (compressive a stress closes cracks). Two methods for creating constant Compressive stresses are known:

- Cutting-slots method.
- Shot-peening method.

Factors affecting fatigue life of materials:

Evidently, since fatigue is a localized stress phenomenon, its performance is affected any of forth of stress raisers, such:

1. Surface condition of material: It is known that highly polished elements withstand fatigue much better than normally machined ones.

2. Type of stress variation: The most damaging type of stress variation is the complete reversals (Fig. (4-a)) for which the stress range $S = 2\sigma$. Fluctuating stresses are less damaging (Fig. (4-c)); the stress range is S = σ .

3. Influence of the shape of specimen on stress flow: The shape (If the specimen is very important, since at corners ant notches the local stress can be several times more than the calculated average value

4. Imperfections inside the material and at the surface: In certain materials, failure as result of repeatedly cycled stress generates localized slip pattern. Each slip segment works so that very small cracks form in the material. The notch effect causes the cracks to multiply until a network develops to cause fracture. If these cracks are reversible-sealed-with the cycle, the material is said to be ductile. If not, it will fracture. It is, therefore, important that when a structure is to be cycled, sharp corners, surface scratches, or notches must be avoided by the designer.

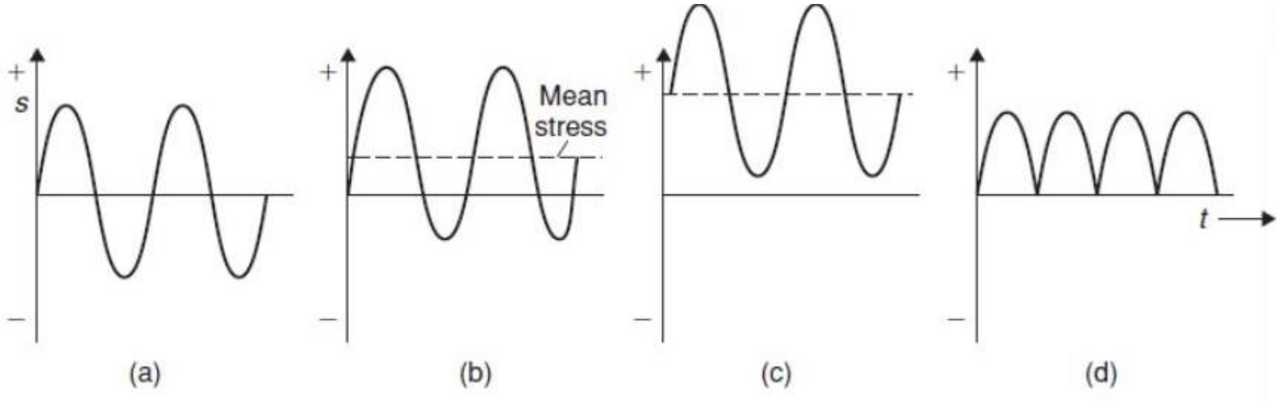


Fig (4) Alternative forms of stress cycling: (a) reversed; (b) alternating (mean stress ≠ zero); (c) fluctuating and (d) repeated

Fatigue Life:

It is the number of cycles to cause failure at a specific stress taken from S-N curve

Fatigue strength:

It is the stress at which failure will occur for a specified number of cycles e.g. 106

Fatigue Endurance Limit:

It is the stress level at which fatigue will never occur, that is the largest value of fluctuating stress that will not cause failure for infinite number of cycles.

Endurance:

Endurance refers to the number N of load cycles until rupture at a certain load

Laboratory sheet

Objective:

1. To investigate the failure of metals due to fatigue loading
2. demonstrate the basic principles of fatigue strength testing, including the production of a stress-number diagram.

Apparatus

In the revolving fatigue testing machine, a rotating sample which is clamped on one side is loaded with a concentrated force. As a result, an alternating bending stress is created in the cylindrical sample. Following a certain number of load cycles, the sample will rupture as a result of material fatigue. The revolving fatigue testing machine (figure 5) essentially consists of:

- Spindle with sample receptacle (1)
- Drive motor (2)
- Load device (3)
- Switch box with the electrical control and counter (4)
- Protective hood (8)

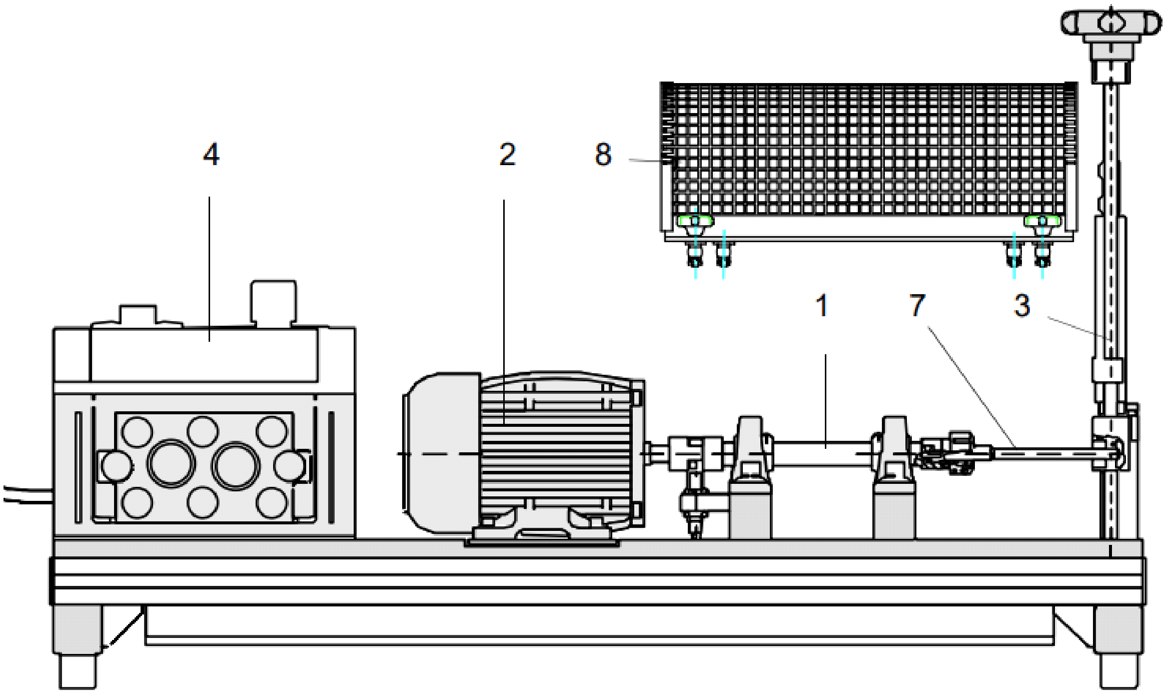


Figure (5): The revolving fatigue testing machine

The spindle is mounted on two amply dimensioned rolling-contact bearings. The spindle is driven by a smooth running A.C. motor with a speed of approximately 2750 RPM.

Specimens:

Test bars are made of f tempering steel, the recommended standard specimen is shown in figure (6)

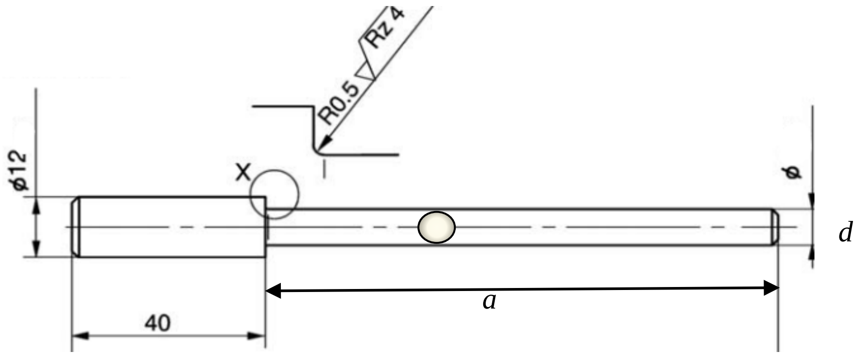


figure (6) Fatigue standard specimen

Loading of the sample

Loading of the sample corresponds to a clamped bending bar under a concentrated force (F). This induces a triangular bending moment Mb in the sample shown in figure (7).

As the bending moment is fixed but the sample is rotating, it is loaded by an alternating, sine-shaped bending stress. The highest bending stress occurs on the shoulder of the sample.

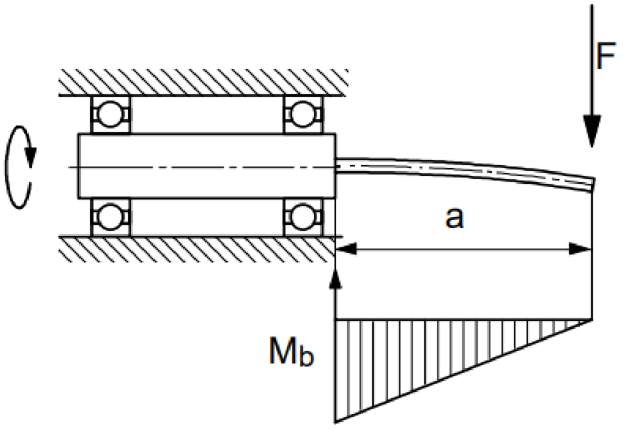


Figure (7) clamped test specimen under concentrated force.

This is a pure reversed bending stress without mean stress. For this reason, it is only possible to determine fatigue strength under complete stress reversal W with a revolving fatigue testing machine. It represents a special case of fatigue strength D. The bending moment is calculated with the load and the lever arm as follows:

$$M_b = F \cdot a$$

By using the section modulus of the sample $W_b = \frac{\pi \cdot d^3}{32}$ it is possible to calculate the alternating stress amplitude

$$\sigma_a = \frac{M_b}{W_b} = \frac{32\,a}{\pi\,d^3} \cdot F$$

Procedure:

1. Relieve the load device using the hand wheel (the floating bearing must be at the height of the spindle).
2. First insert the test bar in the floating bearing of the load device.
3. Then insert the test bar in the collet chuck and push in as far as the end stop
4. Check concentricity of the sample by rotating the spindle by hand (correctly seated in the collet chuck, sample not deformed).
5. Mount the protective hood and lock with the knobs
6. Switch on the motor.
7. Swiftly apply the required load by rotating the hand wheel. Read off the load from the scale on the spring balance.
8. Reset the counter using the RST button in order to begin counting.
9. The motor halts automatically when the sample ruptures. Read off the number of load cycles from the counter and make a note of the number

Results & Analysis:

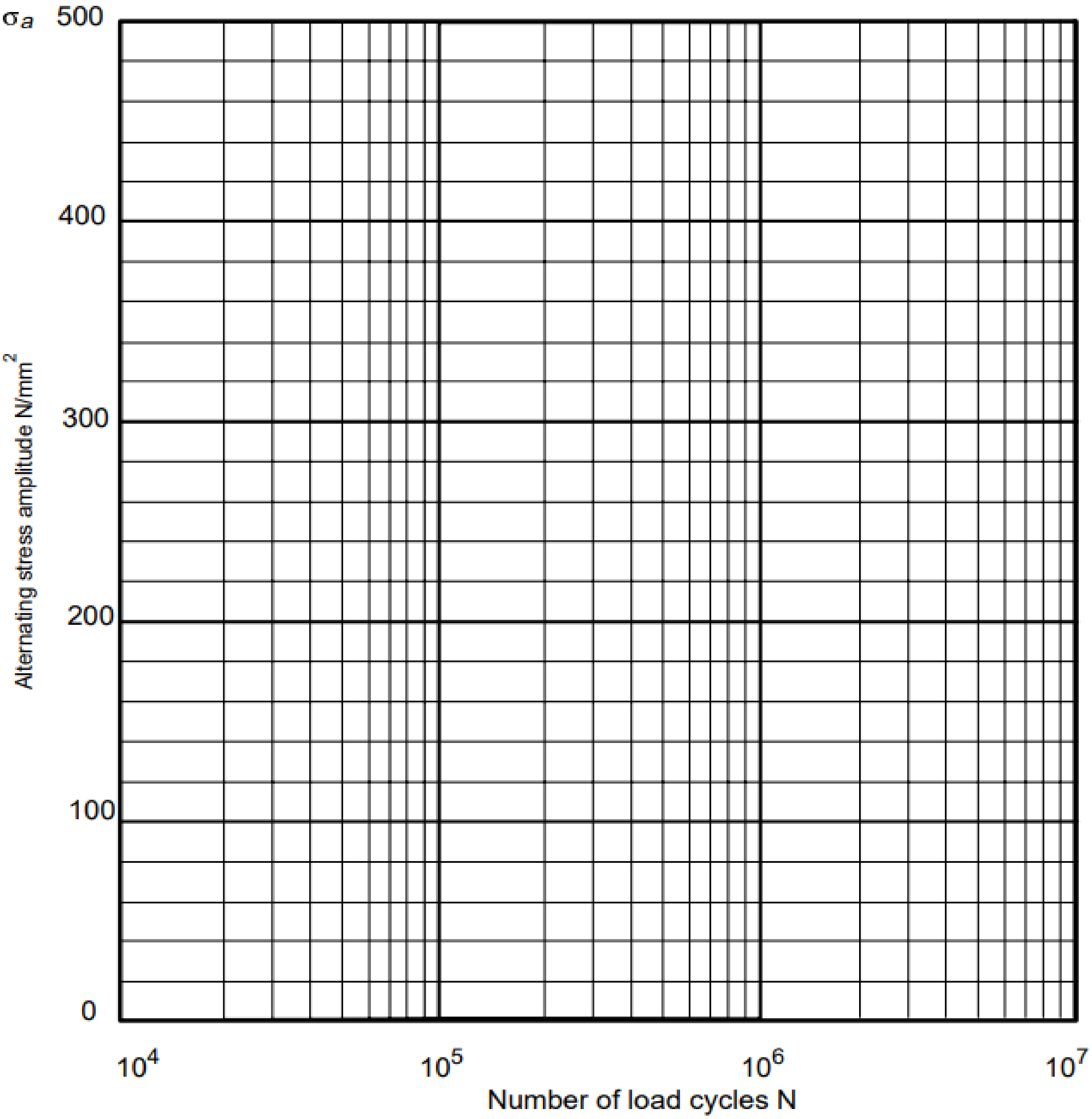
Table (1) geometrical dimensions

Sample No.	**length (mm)**	**Diameter (mm)**	**Cross sectional area (mm^2)**

Table (2) Number of load cycles for test bar under different loads

Number of load cycles for test bar under different loads			
No.	**Load F (N)**	**Endurance N**	**Stress σ_a (N/mm^2)**
1	200	14030	
2	170	48800	
3	150	167000	
4	130	455000	
5	120	1280800	

1. Calculate the bending stress.
2. Plot stress against number of cycles (endurance) S-N diagram on Semi-log paper.
3. Find the endurance limit from the S-N diagram.
4. Estimate the expected fatigue life corresponding to a bending stress of 250 MPa.



Work sheet, stress-number diagram

TENSION TEST

INTRODUCTION

The mechanical properties of a material may be defined as those properties of a material associated with its elastic and inelastic reactions when force is applied. These properties are of prime interest to the engineer, arid the results of tests to determine these properties are used for various purposes.

Firstly, they may be used in the selection of material for a particular purpose, or for deciding the size-or shape of a component of a particular material so that it shall be sufficiently strong to fulfill its purpose.

Secondly, they may be used for quality control. Samples taken from different batches of allegedly the same material are tested and a batch should be rejected if the test results fall outside acceptable limits.

The most widely quoted mechanical properties are those determined by a tensile test. Results of tensile tests are tabulated in handbooks and, through the use of failure theories, these data can be used to predict failure of parts subject to more general stress state. Theoretically, this is a goodtest because of the apparent simplicity with which it can be performed and because the uniaxial loading condition resulting in a uniform stress distribution across the cross section of the test specimen. In actuality, a direct tensile load is difficult to achieve (because of misalignment of thespecimen grips) and some bending usually results. this is not serious when testing ductile materialsin which local yielding can redistribute the stress so uniformity exists. However, in brittle materialslocal yielding is not possible and the resulting non uniform stress distribution will cause failure ofthe specimen at a load considerably different from that expected if a uniformly distributed load was applied.

STRESS STRAIN CURVE

The tension test is conducted by applying an increasing load (at constant rate of strain) to the specimen of specific geometry on an apparatus similar to that shown schematically in **Figure (1).**

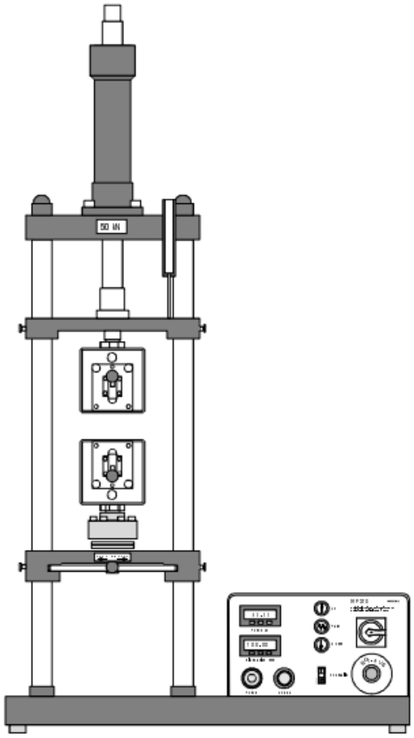


Fig (1) schematic illustration of tensile testing

When a load, **P**, is applied to a material, it deforms. When the load is applied in such a manner that the specimen is being pulled apart, this deformation results in an elongation or strain over a specified gage length. The result is a plot of coordinate load- elongation points, producing a curve of the form in **Figure (2)**

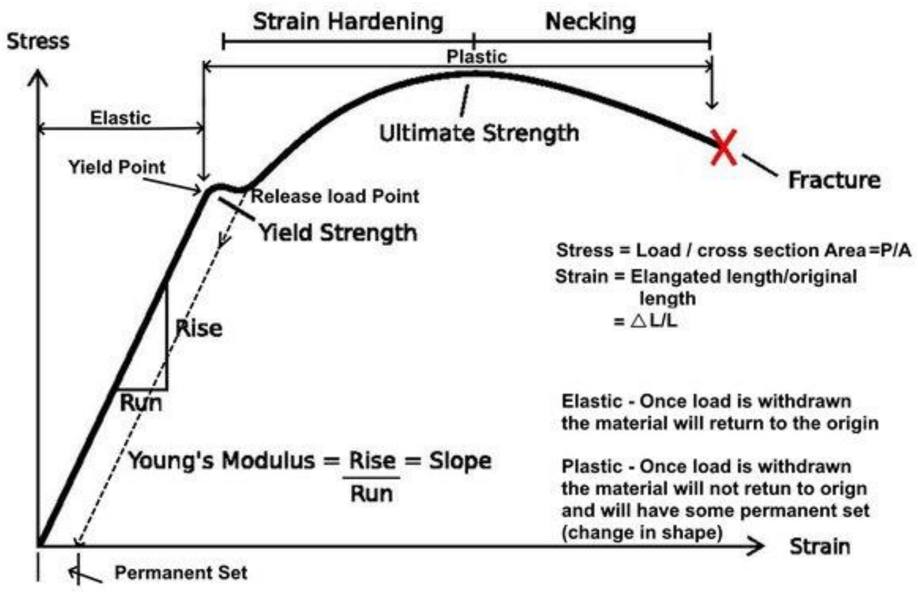


Fig (2) Engineering stress-strain diagram

Since characteristics loads will differ with different size specimens and elongation will vary with different gage lengths, it becomes desirable to remove the size effects and establish a plot that is characteristic of the materials response to the test conditions. If the load is divided by the original cross-sectional area and the elongation is divided by the original gage length, thesize effects are eliminated, and the plot becomes known as an Engineering stress-strain diagram, as shown in **figure (2).**

$$stress = \sigma = \frac{P}{A_0}$$

$$strain = \varepsilon = \frac{\Delta L}{L_0}$$

This curve is simply a Load elongation curve with the Scales of both axes modified to remove size effects.

Up to a certain stress, strain is directly proportional to stress, the Stress. At which this proportionality ceases to exist is the proportional Limit. Up to this limit. the material obeys **Hooks law** which states that stress-is directly proportional to Strain. The proportionality constant is known as **Young's modulus of elasticity**, **E**. As a measure of **stiffness**, it indicates the ability of a given material, for a given cross section, to resist deflection when loaded.

$$E = \frac{\sigma}{\varepsilon}$$

In the elastic region, if the applied load is removed, the specimen will return to its original length. Thus, from zero up to a certain point, the behavior is elastic and the maximum stress for which truly elastic behavior exists is called the elastic limit, $\boldsymbol{\sigma}_e$

The amount of energy that a unit volume of material can absorb within the elastic range is called the resilience or, in quantitative terms, the **modulus of resilience, U_R**. This energy is potential energy and is therefore released whenever a member is unloaded.

$$U_R = \int_0^{\varepsilon_e} \sigma \, d\varepsilon = \frac{1}{2}\frac{\sigma_e^2}{E}$$

Beyond the elastic limit, increases in Strain do not require proportionate increase in stress. in some materials, a point may be reached where additional strain occurs without any increase in stress, fills point being known as the yield point or yield point stress. Most materials do not have a well-defined yield point, but have a stress-strain curve of the form shown in **Figure (3).**

For such materials the elastic, to-plastic transition is defined by the offset yield Strength (0.1 % or 0.2%) Offset yield strength is then determined by drawing a line parallel to the elastic line, displaced by the offset Strain, and reporting the point where it intersects the stress-strain curve. (**see Figure (3)**)

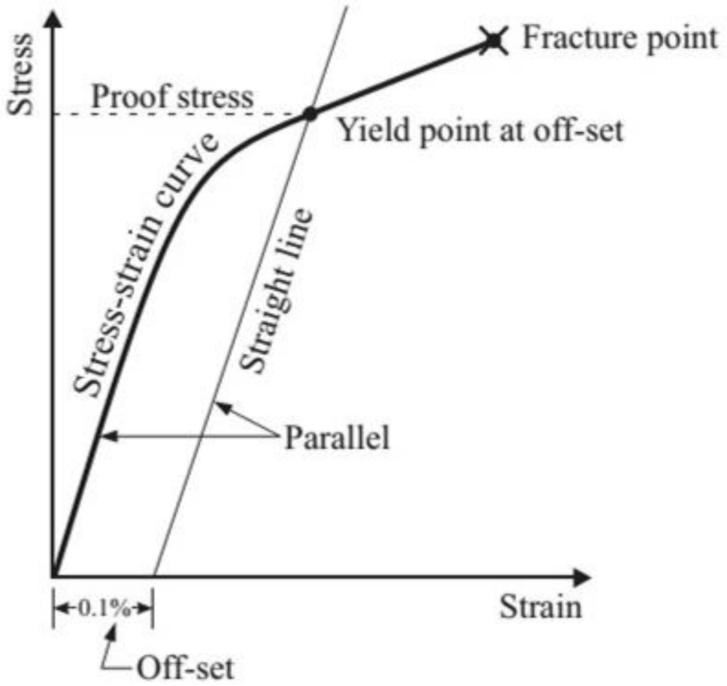
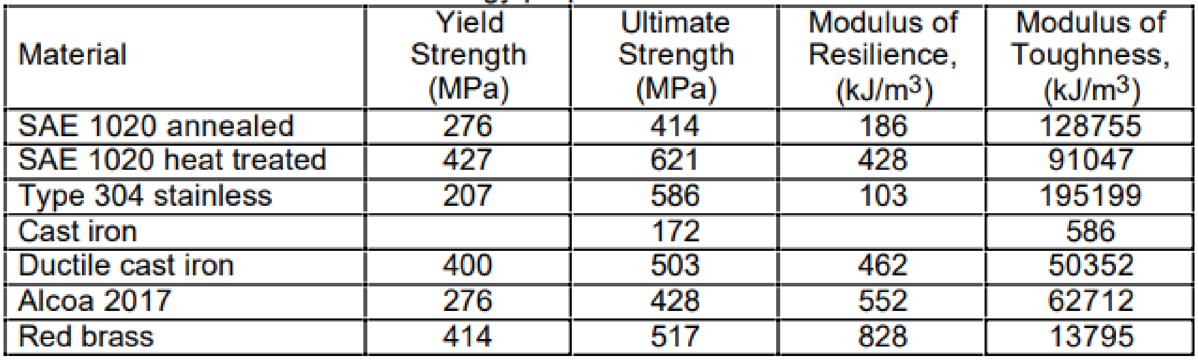


Fig (3) a stress-strain curve for materials do not havea well-defined yield point showing the offset method for determining yield strength.

Toughness is defined as the work per unit volume to fracture a material and is commonly expressed as the **modulus of toughness, UT** . It is given by the total area under the stress- strain curve, it is often approximated by **(2/3)($\varepsilon_m \sigma_m$)** that is (2/3) of the product of maximum tensile strength and maximum tensile strain This quantity is important in selecting materials for applications where high over loads are likely to occur and large amounts of energy must be absorbed. Also, this value is an important parameter in ranking materials for resistance to abrasion or cavitations. Both these wear applications involve tearing piece of metal from a parent structure and hence are related to the toughness of the material (Typical values are given in **Table (1)**).

Table 1 Energy properties of materials in tension



Material	Yield Strength (MPa)	Ultimate Strength (MPa)	Modulus of Resilience, (kJ/m^3)	Modulus of Toughness, (kJ/m^3)
SAE 1020 annealed	276	414	186	128755
SAE 1020 heat treated	427	621	428	91047
Type 304 stainless	207	586	103	195199
Cast iron		172		586
Ductile cast iron	400	503	462	50352
Alcoa 2017	276	428	552	62712
Red brass	414	517	828	13795

The extent to which a material exhibits plasticity is significant in evaluating its suitability to certain manufacturing processes. This ability of a material to deform plastically without fracture is known as **ductility**. It could be measured by either a length change or an area change. The percent elongation, which is the percent strain to fracture is given by:

$$\%\, elongation = \frac{L_f - L_0}{L_0} \times 100\%$$

Where L_f is the length between gage marks at fracture.

This quantity depends on the gage length used in measuring L as nonuniform deformation occurs in a certain region of the specimen during necking just prior to fracture, the gage length should always be specified. The percent reduction in area is a cross sectional area measurement of ductility

$$\%\,\text{Reduction Of}\ \ Area = \frac{A_0 - A_f}{A_0} * 100\ \%$$

Where *:*

A_o: is the original cross-sectional area
A_f: is the cross-sectional area at fracture

If the material fails with little or no ductility, it is said to be **brittle**. Thus brittleness can be viewed as the opposite of ductility. However, brittleness should not be considered as the lack of strength, but simply the lack of significant plasticity.

TRUE STRESS-STRAIN CURVE

The Stress-strain curve of **Figure (2)** is a plot of engineering stress versus engineering strain.

The cross section of test specimen changes as the tension test proceeds, first uniformly and then nonuniformly after necking begins. The actual stress within the specimen should be based on the instantaneous cross sectional area and will be greater than the engineering stress:

$$\sigma_{\mathrm{T}} = \frac{F}{A} = \frac{FL}{A_0 L_0} = \frac{F}{A_0}(1+\varepsilon\ ) = \sigma\ (1+\varepsilon\ )$$

the determination of true strain is more complex. The definition of natural strain or logarithmic strain is expressed as:

$$\varepsilon_{\mathrm{T}} = \int_{L_0}^{L} \frac{\mathrm{d}L}{L} = \ln\left(\frac{L}{L_0}\right) = \ln(1+\varepsilon\ )$$

These two definitions of true Strain are equivalent in the plastic range where the material volume can be considered constant $AL= A_oL_o$. Note that in the elastic range the change in volume ΔV per unit volume is given by the bulk modulus B:

$$B = \frac{E}{3(1-2v)}$$

We can easily convert from engineering values to true values using:

$$\varepsilon_T = ln(1+\varepsilon)$$
$$\sigma_T = \sigma(1+\varepsilon)$$

Where

$$\frac{A_o}{A} = \frac{L}{L_0} = 1+\varepsilon$$

σ and ε are the engineering stress and strain at particular load.

Figure (4) shows the true stress-strain curve. It should be noted that the true stress of the material continues to rise through the test even after necking. In the elastic range, the relation between stress and strain is simply:

$$\sigma_{T}=E\varepsilon_{T}$$

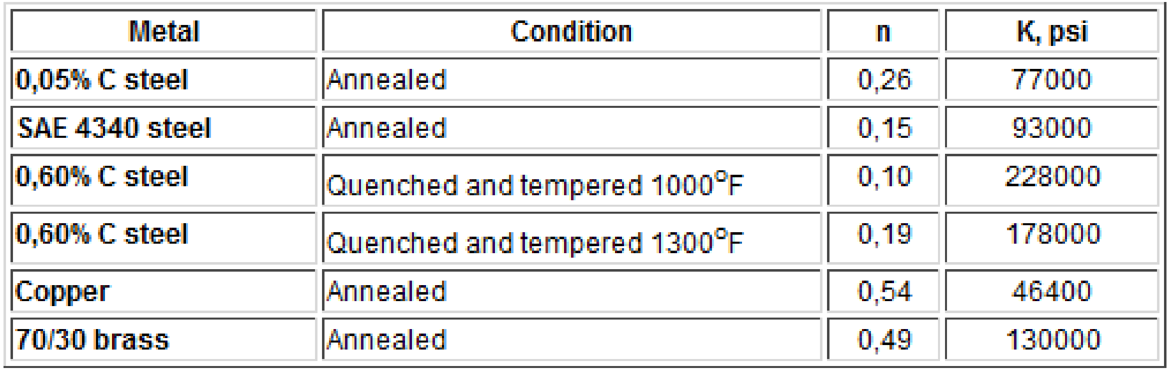
But in the plastic region

$$\sigma_T = \sigma_0 \varepsilon_T{}^m$$

Where σ_0 is a strength coefficient and m is an exponent often called the strain-hardening coefficient.

Typical values for σ_0 and m are given in **Table (2).**

Table (2): material constants m and σ_0 for different sheet material.



Metal	Condition	n	K, psi
0,05% C steel	Annealed	0,26	77000
SAE 4340 steel	Annealed	0,15	93000
0,60% C steel	Quenched and tempered 1000°F	0,10	228000
0,60% C steel	Quenched and tempered 1300°F	0,19	178000
Copper	Annealed	0,54	46400
70/30 brass	Annealed	0,49	130000

Taking the Logarithms of both sides of the last two equations we get:

$$log(\sigma_T) = log(E) + log(\varepsilon_T)$$
$$log(\sigma_T) = log(\sigma_0) + mlog(\varepsilon_T)$$

From this we conclude that the elastic portion of the line is the same for all materials, having a slope of unity. If this line is extrapolated at a value of strain of one corresponds to a stress value equal to E.The plastic portion is a straight line of slope m. The stress σ_0 is the true stress corresponding to a truestrain of unity .

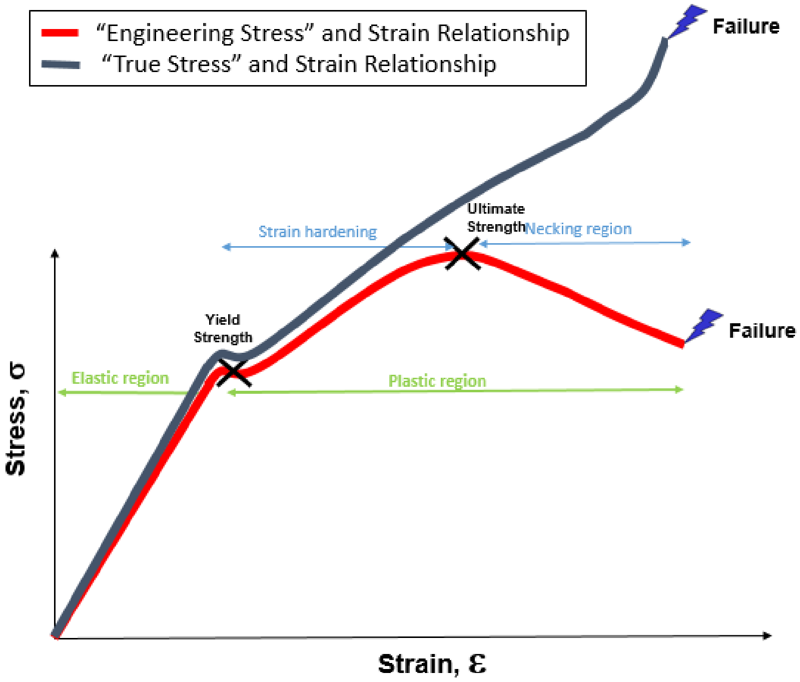


Fig (4) *The True Engineering stress curve versus the Engineering Stress curve*

LABORATORY SHEET

Objectives

To determine the strength and several elastic and plastic properties of various materials, to observe the behavior of the material under static load, and to study the fracture.

Apparatus:

Universal Testing Machine, Enables compressive and tensile testing. The machine can be operated by using a hand pump or with a motorized unit (**Figure (1)).**

Test Specimen:

Test specimens (**Figure (7))** used may be either cut from flat sheet stock or turned from round stock. The specimens are designed to produce uniform uniaxial tension in the central test portion and assure reduced stresses. In the sections that are gripped.

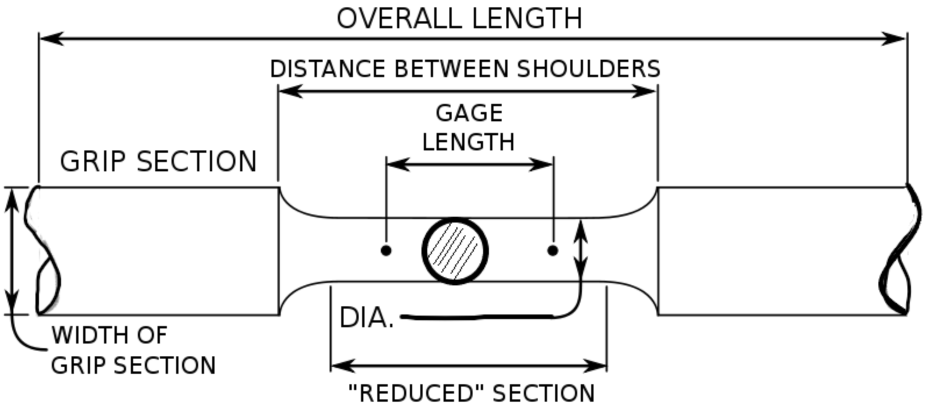


Fig (7) Test specimen

Procedure

1. Measure the dimensions of the test specimen: thickness and width- diameter, and gage length.
2. Mark the gage length.
3. Locate the test specimen between the grips. Attach the dial gage (or extensometer) for elongation
   measurement. Switch on the load meter.
4. Start applying load at specified increments of deflection until fracture.
5. Record deflection and load at each increment.
6. Repeat the test for other specimens

Table (3.1) geometrical properties and dimensions

Material	**Gage length (mm)**	**Diameter (mm)**	**Cross sectional area (mm^2)**

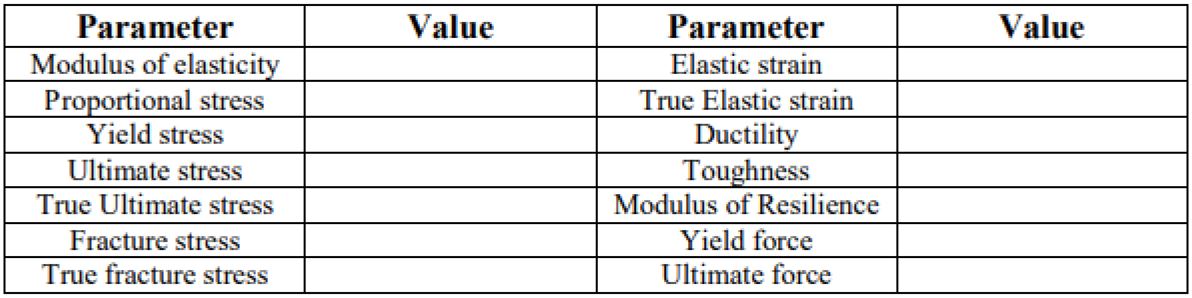
Requirements:

1. Complete Table(3.2).

Table-3.1 Data collected from the experiment and calculated results

F(KN)	δL	stress(F/Ao) (KPa)	strain (δL/Lo)

2. Plot engineering stress-strain curve for each specimen. Find and locate:



Parameter	**Value**	**Parameter**	**Value**
Modulus of elasticity		Elastic strain	
Proportional stress		True Elastic strain	
Yield stress		Ductility	
Ultimate stress		Toughness	
True Ultimate stress		Modulus of Resilience	
Fracture stress		Yield force	
True fracture stress		Ultimate force	

Discussion and Conclusions:

1. What is stress? How does it differ from load or force?

2. What is strain? How it is normally expressed?

3. Why is a plot of stress versus strain is preferable to one of load versus elongation?

4. Is stress proportional to strain for all stress values? Explain?

5. What is the significance of the modulus of elasticity of a material to a designer:

6. What is resilience? Where might it be important? Give example(s).

7. At what point on the stress strain curve does necking occur?

8. What is the difference between ductile and brittle response in a material?

9.Although true stress-strain curves are more difficult to determine than their engineering counterpart, they more accurately reflect material properties. Why?

10. What are the expected sources of uncertainties?

11.Suggest any method to improve the experiment?