POLITEKNIK MALAYSIA
TUANKU SYED SIRAJUDDIN

MATERIALS SCIENCE AND ENGINEERING

Material Testing

MOHD FADHLI AHMAD
MOHD HILMI ARIFFIN
YAP TEK HONG

MATERIALS SCIENCE AND ENGINEERING
(MATERIAL TESTING)
POLYTECHNIC SYLLABUS

TEAM OF WRITERS

LEAD EDITOR	MOHD FADHLI AHMAD
TEAM MEMBERS	MOHD HILMI ARIFFIN
	YAP TEK HONG
COVER DESIGNER	YAP TEK HONG
CONTENT REVIEWER	MASNIZA YUSOF
PROOF READER	DR. RASHDAN RASHID

Politeknik Tuanku Syed Sirajudddin (PTSS)
Pauh Putra, 02600 Arau, Perlis
No. Tel : 04-988 6200
No. Fax : 04-988 6300
www.ptss.edu.my

Diterbitkan oleh:
Politeknik TuankuSyed Sirajudddin (PTSS)
Pauh Putra, 02600 Arau, Perlis
eISBN : 978-629-7514-19-2

Cataloguing-in-Publication Data

Perpustakaan Negara Malaysia

A catalogue record for this book is available from the National Library of Malaysia

eISBN 978-629-7514-19-2

Acknowledgement

We wish to express our sincere gratitude to The Almighty Allah swt for establishing us to complete this book (MATERIALS SCIENCE AND ENGINEERING : MATERIAL TESTING). We are also grateful to Politeknik Tuanku Syed Sirajuddin for giving us the opportunity to write this e-book.

We also wish to express our appreciation to the numerous parties who have enabled the realization of this book, including the Mechanical Engineering Department, Politeknik Tuanku Syed Sirajuddin, Perlis, and all parties involved in the publication process, directly or indirectly.

We would like to thank our friends and colleagues for their assistance, guidance, and constant support during the publication of this book. We would also like to thank our family members who provided encouragement, patience, and support. We also like to thank everyone who gave us the chance to explore the hidden talent inside us to become authors, which might be left deep within us without our knowledge of this world. Besides that, we would like to express our appreciation to our colleagues, contributors, and authors of sources of information who have directly or indirectly inspired us to complete this e-book. Finally, we would wish readers happy reading and apologize for any omissions and errors. We hope that this module will be beneficial to all.

Preface

The 1st edition of the Material Testing specifically based on Malaysia Polytechnic syllabus. The scope is intended to give adequate coverage to mechanical engineering students of Malaysia Polytechnic. This textbook includes on chapter 8. The content emphasizes on technique used to determine the physical and mechanical properties of raw materials and components. Although every care has been taken to check mistakes and misprints, yet it is difficult to claim perfection. Any error, omissions and suggestions for the improvement will be brought to our notice, acknowledged and incorporated in the next edition.

MOHD FADHLI AHMAD
MOHD HILMI ARIFFIN
YAP TEK HONG

Table of Contents

Table of Contents

Table of Contents

1.0 MATERIAL TESTING

1.1 Introduction

- Material testing is the technique used to determine the physical and mechanical properties of raw materials and components.
- This process analyses material characteristics and the operating performance of the raw material and the finished product.
- The measurement of the characteristics and behavior of such substances as metals, ceramics, plastics, or composites under various conditions.
- The data thus obtained can be used to specify the suitability of materials for various applications, e.g., building or automobile construction, machinery, engines, tooling, etc.

- Materials Testing is performed for a variety of reasons and can provide a wealth of information about the tested materials, prototypes or product samples.
- The data collected during testing and the final test results can be very useful to engineers, designers, production managers and others.

1.2 Definition

- Material testing is the determination of the properties of a substance in comparison with a standard or specification.

Material Testing

1.3 Purposes Of Materials Testing

- Materials are tested for one or more of the following purposes:
  - i. To measurement of the characteristics and behavior of such substances as metals, ceramics, or plastics under various conditions.
  - ii. To predict the manufacturing outcome.
  - iii. To access numerically the fundamental mechanical properties of ductility, malleability, toughness etc.
  - iv. To check chemical composition.
  - v. To determine suitability of a material for a particular application.
  - vi. To determine data i.e. force deformation (or stress) values to draw up sets of specifications upon which the engineer can base his design.
  - vii. To determine the surface defects in raw materials or processed parts.

1.4 Significance Of Material Testing

i. To determine the material properties, and

ii. To determine the integrity of the material or component

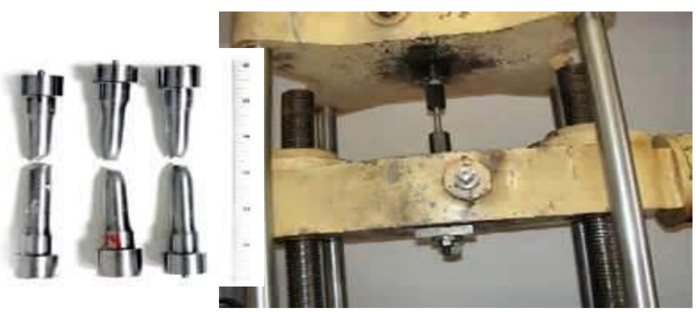
1.5 Classification of Tests

- Test on materials may be classified to two categories:
  - i. Destructive tests (DT)
  - ii. Non-destructive tests (NDT)

Material Testing

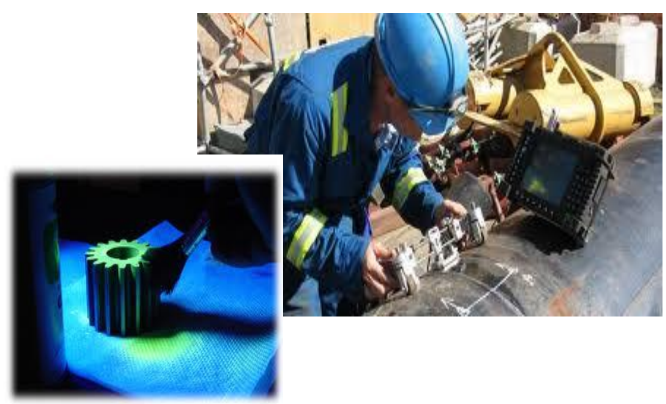
1.6 Destructive Tests (DT)

- In destructive testing, the tests are carried out to the specimen's failure, in order to understand a specimen's structural performance.
- In this testing, the component or specimen either breaks or remains no longer useful for further use.
- The purpose of destructive testing is to determine the mechanical properties of materials.
- Example : Tensile test, impact test, torsion test, etc.



1.7 Non-Destructive Tests (NDT)

- Non-Destructive tests is a analysis techniques used to evaluate the properties of a material without causing damage.
- In this testing, a component does not break and so even after being tested it can be used for the purpose for which it was made.
- The purpose of non-destructive testing is to revealing defects in components that could impair their performance when put in service
- Example : radiography, ultrasonic inspection etc.



1.8 Differences Between Destructive And Non-destructive Testing

No.	Destructive test	Non-destructive Test
i	Used for finding out the properties of the material.	Used for finding out defects of materials.
ii	Load is applied on the material.	Load is not applied on the material.
iii	Due to load application, material gets damaged.	No load applications, so no change for material damage.
iv	Special equipment's are required.	No requirement of special equipment's.
v	Expensive.	Non expensive.
vi	Skill is required	Less skill.

1.9 Advantages & Limitations Of Destructive Tests (DT)

Advantages

- Provides a direct and reliable measurement of how a material or component will respond to service conditions.
- Provides quantitative results, useful for design.
- Does not require interpretation of results by skilled operators.
- Usually finds agreement as to meaning and significance of test results.

Disadvantages

- Applied only to a sample; must show that the sample is representative of the group.
- Tested parts are destroyed during testing.
- Usually, cannot repeat a test on the same item or use the same specimen for multiple tests.
- May be restricted for costly or few-in-number parts.
- Hard to predict cumulative effect of service usage.
- Difficult to apply to parts in use; if done, testing terminates their useful life.
- Extensive machining or preparation of test specimens is often required.
- Capital equipment and labor costs are often high.

Material Testing

1.10 Advantages & Limitations of Non-destructive Tests (NDT)

Advantages

- Can be performed directly on production items without regard to cost or quantity available.
- Can be performed on 100% of production lot or a representative sample.
- Different tests can be applied to the item, and a test can be repeated on the same specimen.
- Can be performed on parts that are in service; the cumulative effects of service life can be monitored on a single part.
- Little or no specimen preparation is required.
- The test equipment is often portable,
- Labor costs are usually low.

Disadvantages

- Results often require interpretation by skilled operators.
- Different observes may interpret the test results differently.
- Properties are measured indirectly, and results are often qualitative or comparative.
- Some test equipment requires a large capital investment.

Exercise 1

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. The two types of tests on materials are:

a) ______________________________

b) ______________________________

2. The main purpose of conducting the Destructive Testing is :

____

____

3. State one weakness of the Non-Destructive Testing:

____

____

4. Following are the advantages of destructive testing except

a) Able to determine the mechanical properties

b) A test piece has a limit of a size

c) Require a higher load

d) Effective and reliable

5. Following are the characteristics of the destructive testing except

a) The test-piece is damaged

b) Sampling is not required

c) Require a higher load

d) To determine the mechanical properties

Tutorial 1

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. Define material testing.
2. Explain five purposes of materials testing.
3. Classify two types of material testing. State three differences between these testing. Also

2.0 PRINCIPLES OF DESTRUCTIVE TESTS

2.1 Principle Of Destructive Tests (DT)

- Destructive testing also call as mechanical test.
- In this test, the properties of materials are characteristic usually subjected to load and deformation.
- Therefore, the properties of materials under the action of load and deformation so produced under various environments become an important engineering consideration.
- Thus, in destructive testing, the component or specimen, after being destructively tested, either breaks or remains no longer useful for further use.
- There are many tests to measure mechanical properties, but we shall discuss some of the important and common tests, such as hardness test and impact test.

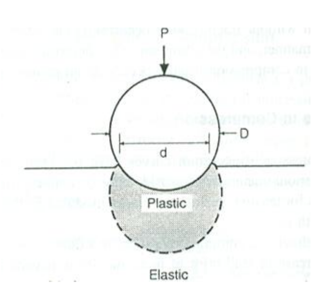
- The following important information given by hardness and impact test as given below:

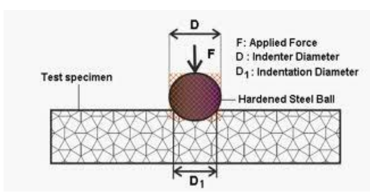
Hardness test	Impact test
• Wear resistance, indentation, scratch resistance or cutting ability of material.	• Toughness of material under shock loading condition

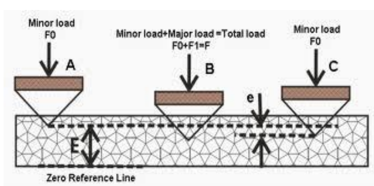
Material Testing – Hardness Test

2.2 Hardness Test

- In engineering, hardness is most commonly defined as the resistance of a material to indentation.
- Indentation is the pressing of a hard round ball or point against the material sample with a known force, so that a depression/impression is made.
- The depression, or indentation, results from plastic deformation under the indenter.







- Some specific characteristic of the indentation, such as its size or depth, is taken as a measure of hardness.
- There are 3 general types of hardness measurements depending upon the manner in which the test is conducted. These are:
    i. Scratch hardness
    ii. Indentation hardness
    iii. Rebound hardness

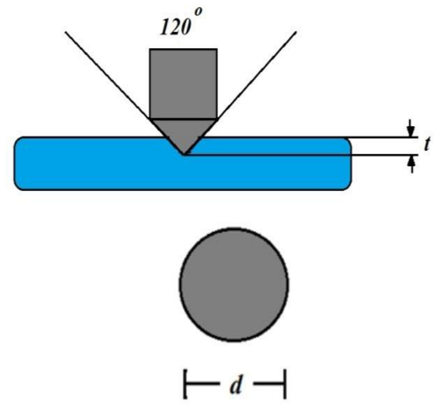
2.3 Scratch Hardness

- Scratch hardness determines scratching and abrasion ability of a metal when scratched by standard substance.
- The standard substances are either minerals or files.
- Some minerals have been given hardness numbers from 1 to 10 on the Mohs scale. The hardness of the metal is determined to find, by trial, which mineral scratch a smooth surface of substance and which mineral can be scratched by the substance.
- Another method to determine the abrasion or scratch hardness is by the use of files. The material to be tested is either rubbed/filed against a standard file or vice versa and it is noted whether or not a visible cut is produced. A visible cut on the metal surface is produced if the hardness is produced if the hardness is lower than that of the file.

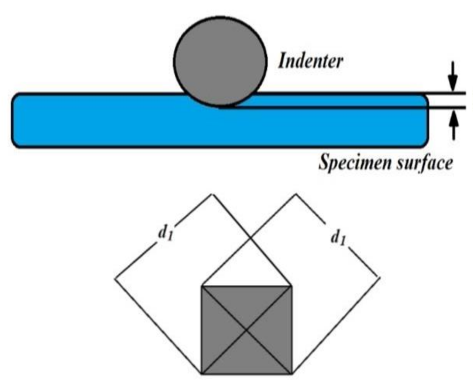
Material Testing – Hardness Test

2.4 Indentation Hardness

- Another type of hardness, which is more commonly used, is called indentation hardness.
- The method gives quantitative values and materials even a small change in hardness can be distinguished.
- The hardness values obtained can be correlated with other properties like tensile strength, wear resistance, etc.
- All the indentation hardness testing methods are based on the principle of forcing a hard material, called an indenter, against a flat surface of the metal, whose hardness is to be measured, under a fixed load.
- Depending upon its hardness, the metal resists deformation, and finally an impression is made by the indenter on the surface of the metal.
- The diameter or the depth of impression determines the hardness of the material, and after the measurement it could be converted into a relative quantitative value.



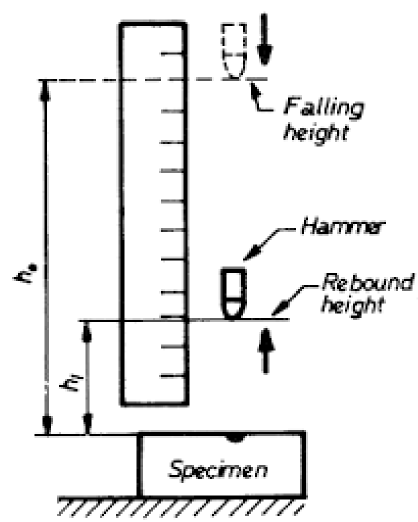
- A large number of indentation hardness tests have been invented/created and used.
- Some of these which find wide commercial application are Brinell, Rockwell and Vickers hardness testers.
- These devices of hardness measurement differ in the shape, size and type of indenter, the load applied, and the method of measuring the diameter or depth of the impression.



Material Testing – Hardness Test

2.5 Rebound Hardness

- This hardness tester in entirely different in principle from other machines, such as Brinell, Rockwell and Vickers.
- This test measures the rebound of a weight that dropped onto the specimen. The machine consists essentially of an anvil or a firm rest on which the specimen is placed, a vertical glass tube with a certain long, and a small cylindrical weight that drops through the tube onto the surface of the specimen from which it rebounds upward. A scale on the tube measures the height of the rebound. At the top of the tube is a mechanism for releasing the weight.
- The weights is provided with a bluntly pointed diamond at the bottom.
- The effect of dropping the weight upon the specimen is to indent the specimen slightly.
- The harder the specimen, the less it is indented and the higher the rebound.
- This test is subject to error on measuring the height of rebound accurately.
- The rebound hardness testing is particularly employed for hardness measurement on large work pieces or for applications in which visible or sharp impressions in the test surface cannot to tolerated, especially to assess the properties of rubber-type materials.
- The rebound hardness is measured using a Shore Scleroscope.



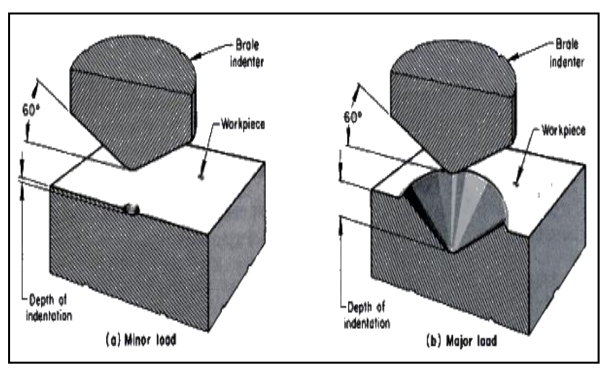
- There are many hardness tests to measure the hardness properties, but we shall discuss some of the important and common tests, such as Rockwell and Vickers hardness test.

Material Testing – Rockwell Hardness Test

2.6 Rockwell Hardness Test

- The Rockwell test machine is a rapid action direct-reading machine. The Rockwell scale is a hardness scale based on the indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload (before). There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, where A is the scale letter.
- Stanley P. Rockwell invented the Rockwell hardness test.

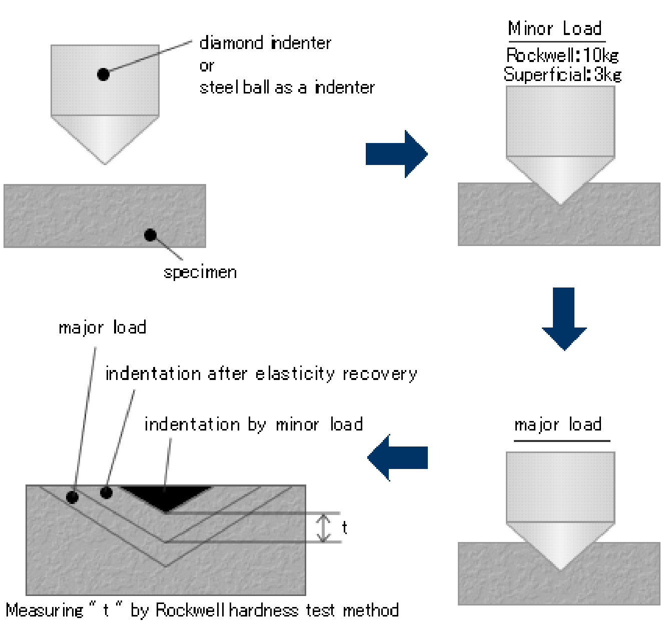
- He was a metallurgist for a large ball bearing company and he wanted a fast non-destructive way to determine if the heat treatment process they were doing on the bearing races was successful.
- The only hardness tests he had available at time were Vickers, Brinell and Scleroscope.
- The Vickers test was too time consuming, Brinell indents were too big for his parts and the Scleroscope was difficult to use, especially on his small parts.
- To satisfy his needs he invented the Rockwell test method.
- This simple sequence of test force application proved to be a major advance in the world of hardness testing.
- It enabled the user to perform an accurate hardness test on a variety of sized parts in just a few seconds.



Material Testing – Rockwell Hardness Test

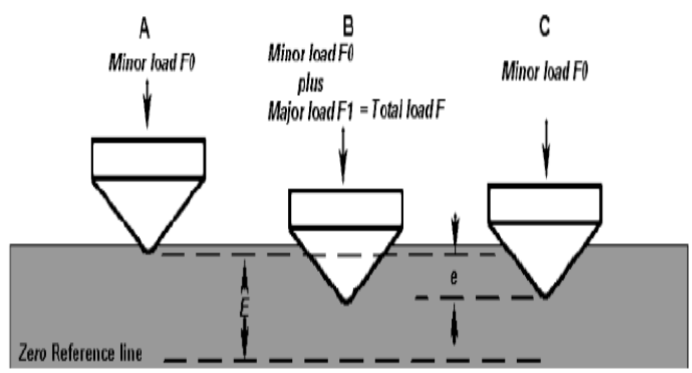
2.6.1 Types Of Rockwell Tests

- There are two types of Rockwell tests:
  - i. Rockwell: the minor load is 10 kgf, the major load is 60, 100, or 150 kgf.
  - ii. Superficial Rockwell: the minor load is 3 kgf and major loads are 15, 30, or 45 kgf.
- In both tests, the indenter may be either a diamond cone or steel ball, depending upon the characteristics of the material being tested.



2.6.2 Principle Of Rockwell Tests

- 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 Fo 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.

Material Testing – Rockwell Hardness Test

- When equilibrium has again been reach, 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.

HR = E – e

where:

Fo = preliminary minor load in kgf

F1 = additional major load in kgf

F = total load in kgf

e = permanent increase in depth of penetration due to major load F1 measured in units of 0.002mm

HR = Rockwell hardness number

E = Is the constant determined by the form of the indenter. For the diamond cone indenter is 100, for the steel ball 130.

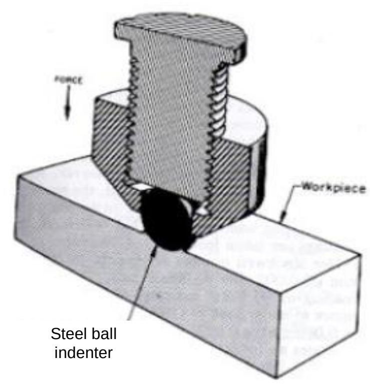
Material Testing – Rockwell Hardness Test

2.6.3 Types Of Rockwell Hardness Indenter

- There are 2 types of indenter used in this testing:
    i. steel ball indenter
    ii. diamond cone indenter

2.6.3.1 Steel Ball Indenter

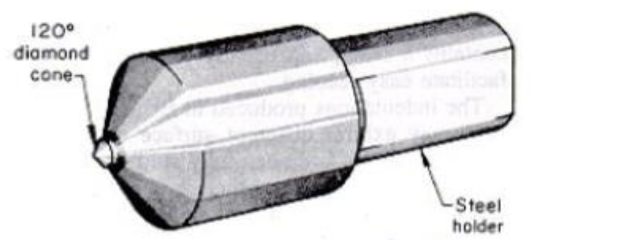
- Size : Diameter 1/16” (1.588mm), 1/8” (3.175mm), ¼” (6.350mm) and ½” (12.70mm).
- Most materials are tested using hardened steel ball indenters.
- Used for scales HRB, HRE, HRF, HRG, HRH and HRK.



2.6.3.2 Diamond Cone Indenter

- Size : Angle of 120°
- A 120°
- diamond cone indenter with a slightly rounded point is used for testing very hard materials.
- Used for scale HRA, HRC and HRD

Steel ball indenter



Material Testing – Rockwell Hardness Test

2.6.4 Load For Hardness Testing

- There are 3 main types of Rockwell hardness testing load and the applying of the load are depends on the types of Rockwell testing used and types of materials tested:
    i. preliminary load (minor load)
    ii. additional load (major load – minor load)
    iii. Total load (major load)
- In Rockwell: the minor load is 10 kgf, the major load is 60, 100, or 150 kgf.
- In Superficial Rockwell: the minor load is 3 kgf and major loads are 15, 30, or 45 kgf.

2.6.5 Rockwell Hardness Scales

- The Rockwell scale characterizes the indentation hardness of materials through the depth of penetration of an indenter, loaded on a material sample and compared to the penetration in some reference material.
- The Rockwell scale involves the application of a minor load followed by a major load, and then noting the hardness value directly from a dial.
- The regular Rockwell scales and typical materials for which these scales are applicable.

Scale Symbol	Indenter	Major Load, kgf	Typical Applications
A	Diamond	60	Cemented carbides, thin steel, and shallow case-hardened steel (Extremely hardness material, eg tool steels)
B	1/16" ball (1.588-mm)	100	Copper alloys, soft steels, aluminum alloys, malleable iron (softer materials, eg. Cu alloys, Al alloys, mold steel)
C	Diamond	150	Steel, hard cast irons, pearlitic malleable iron, titanium, deep case-hardened steel, and other materials harder than HRB 100 (Hard materials, eg: hard cast irons, alloy steels)
D	Diamond	100	Thin steel and medium case-hardened steel and pearlitic malleable iron
E	1/8" ball (3.175-mm)	100	Cast iron, aluminum and magnesium alloys, bearing metals
F	1/16" ball (1.588-mm)	60	Annealed copper alloys, thin soft sheet metals
G	1/16" ball (1.588-mm)	150	Phosphor bronze, beryllium copper, malleable irons. Upper limit is HRG 92, to avoid possible flattening of ball.
H	1/8" ball (3.175-mm)	60	Aluminum, zinc, lead
K	1/8" ball (3.175-mm)	150	Bearing metals and other very soft or thin materials. Use smallest ball and heaviest load that do not give anvil effect.
L	1/4" ball (6.350-mm)	60	
M	1/4" ball (6.350-mm)	100	
P	1/4" ball (6.350-mm)	150	
R	1/2" ball (12.70-mm)	60	
S	1/2" ball (12.70-mm)	100	
V	1/2" ball (12.70-mm)	150	

Material Testing – Rockwell Hardness Test

2.6.6 Duration / Time For Hardness Testing

Load	Duration / time
The dwell time for preliminary load	Shall not exceed 3 s
The dwell time for additional load	1 to 8 s
While maintaining the preliminary test load remove the additional test load in accordance with:	For material which, under the conditions of the test, show no time-dependent plasticity, remove additional load within 3s after the total test load is applied.
	For material which, under the conditions of the test, show some time-dependent plasticity, remove additional load within 5 to 6s when using diamond cone indenter and within 6 to 8s when using steel ball indenter after the application of the total test load begins.
	In special cases where the material, under the conditions of test, shows considerable time-dependent plasticity, remove additional load within 20 to 25s after application of the total test load begins.

2.6.7 Precautions

- Successive impressions should not be superimposed/overlapped on one another nor be made too close together when making hardness determinations. (≥ 3 indentation diameter)
- Nor should a measurement be made too close to the edge, or on a specimen so thin that the impression comes through the other side. (≥ 1mm or ≥ 2.5 indentation diameter)
- The care required in preparing the surface is grater for Rockwell than for the Brinell test because of smaller Rockwell impression. (Thickness = 10 times depth of indentation)
- The surface of the specimen should be flat and free from spring action. (surfaces roughness ≤ 0.2 ɥm)
- Since impression is small it is desirable to take several readings in order to get a representative value of hardness.

2.6.8 Advantages

- Rapid test, usually less than 10 seconds.
- Direct reading, does not require any optical measurement results can be questioned. Rockwell hardness measurements can be made almost quickly as with the Shore scelroscope because they are read directly form the Instrument scale.
- Test machine is easy to operate.
- No need to make calculations to get the number of hardness.
- It is more flexible than the Brinell; a large number of combinations of indentors and loads make it more useful to test a wider range of materials.
- Rockwell testers are also fitted with a number of fixtures for testing different sizes and shapes of metal parts.

Material Testing – Rockwell Hardness Test

- Non-destructive, especially on finished components, usually components / parts that can be reused. Because of the small size of the Rockwell impression, the test is considered to be non-destructive for most applications.

2.6.9 Disadvantages

- Samples must be clean and have a place / smooth surface to get good results. The Rockwell test is limited by greater care required in preparation of samples but this is offset by its greater sensitivity as compared to brinell tester.
- Various scale tests required to cover to all limits for metal hardness.
- Exchange between the scale is dependent on the type of material.
- This test is not as reliably when compared with Brinell and Vickers tests because this test can not give a little difference in hardness.

2.6.10 Standard For Rockwell Hardness Test

- ASTM E 18 – 92
- BS 891: 1989

Exercise 2

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. Which hardness test is most widely used in the world?
   a) Brinell
   b) Vickers
   c) Shore
   d) Rockwell

2. Rockwell test utilizes ___________ a measure of hardness.
   a) Load
   b) Depth of indentation
   c) Diameter of indentation
   d) Time of loading

3. Diamond indenter is known as 'Brale indenter'.
   a) True
   b) False

4. What is a advantage of the Rockwell test?
   a) Fast speed
   b) Different scale
   c) Bigger size of indentation
   d) Different indenters

5. With the aids of sketches, explain the principle of Rockwell hardness test Scale B (HRB) .

Tutorial 2

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. In B-scale of Rockwell hardness testing, the shape of indenter used is:
   a. Diamond cone
   b. Steel ball
   c. Steel prism
   d. Any of the above

2. The load applied in C-scale of Rockwell hardness test is
   a. 60 kgf
   b. 100 kgf
   c. 120 kgf
   d. 150 kgf

3. The major load applied in A-scale of Rockwell hardness test is
   a. 60 kgf
   b. 100 kgf
   c. 120 kgf
   d. 150 kgf

4. What minimizes the amount of surface preparation in Rockwell test?
   a) Minor load
   b) Indenter surface
   c) Indenter geometry
   d) Heat-treatment

5. Hardened steel is tested on the C scale with ________ indenter and a _______ kg major load.
   a) Diamond, 100
   b) Diamond, 150
   c) 1.6 mm steel ball, 100
   d) 3.2 mm steel ball, 150

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

6. The Rockwell test is a rapid action direct-reading machine and used to determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload (before). Based on provided chart, list information's below when conducting the Rockwell hardness test Scale B (HRB):

    a) Types of indenter

    b) Size of indenter

    c) Minor load

    d) Additional load

    e) Total load

    f) The dwell time for preliminary load

    g) The dwell time for additional load

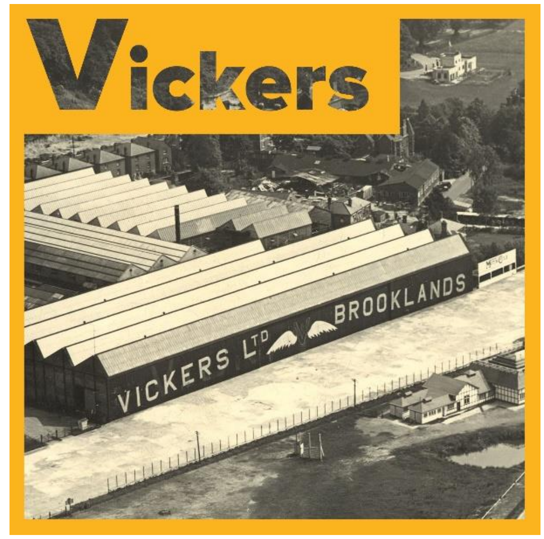
    h) The time for remove the additional test load while the preliminary test load is still maintained.

    i) Types of materials test by for this scale

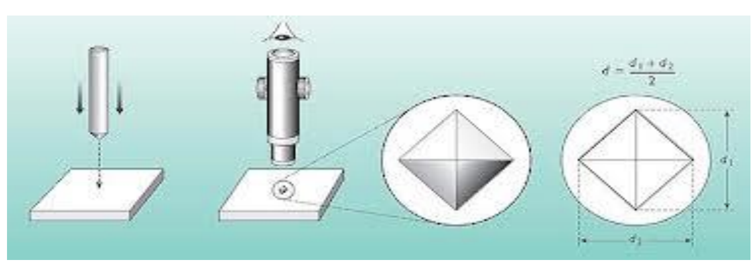
Material Testing – Vickers Hardness Test

2.7 Vickers Hardness Test

- The Vickers hardness test was developed and devised in the 1921 by engineers at Vickers, Ltd., i.e. Robert L. Smith and George E. Sandland in the United Kingdom, as an alternative to the Brinell method to measure the hardness of materials.
- The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source.
- It is the standard method for measuring the hardness of metals, particularly those with extremely hard surfaces: the surface is subjected to a standard pressure for a standard length of time by a pyramid-shaped diamond indenter. The diagonal of the resulting indention / size of an impression is measured under a microscope and the Vickers Hardness value read from a conversion table or by calculation.



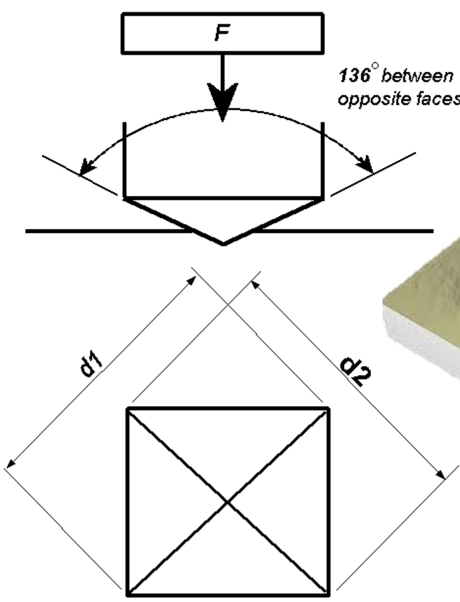
- The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness, and also has one of the widest scales among hardness tests.
- The unit of hardness given by the test is known as the Vickers Pyramid Number (HV) or Diamond Pyramid Hardness (DPH).

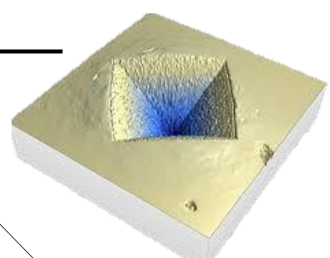


Material Testing – Vickers Hardness Test

2.7.1 Principle of Vickers Hardness Test

- An indenter, comprising a diamond in the form of a right pyramid with a square base and a specified angle between opposite faces at the vertex and mounted in a suitable holder, is forced into the material with a test force F.



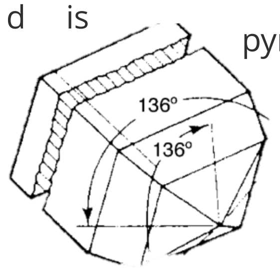


- The two diagonals, d1 and d2, of the indentation left in the surface of the material after removal of the load, are measured in two directions at right angles and their arithmetic d is calculated.

- The area of the sloping surface of the indentation is calculated from the mean diagonal, d, the indentation being considered as a right pyramid with a square base of diagonal, d and a vertex angle of 136o.
- The Vickers hardness is a number proportional to the quotient obtained by dividing the test force by the calculated sloping surface area of the indentation.

2.7.2 Type of Indenter

- The Vickers hardness test uses a square-base diamond pyramid as the indenter.
- The included angle between opposite faces of the pyramid is 136°.
- This angle was chosen because it approximates the most desirable ratio of indentation diameter to ball diameter in the Brinell hardness test.
- Because of the shape of the indenter, this is frequently called the diamond-pyramid hardness test (DPH).



Material Testing – Vickers Hardness Test

2.7.3 Load/Force And Hardness Scales For HV Hardness Testing

- Based on the BS 427 : 1990, the forces applied in this test are as table below:

Correlated values of force and hardness scale		
Hardness scale	Load symbol, f (kg)	Test force, F (N)
HV 1	1	9.807
HV 2.5	2.5	24.52
HV 5	5	49.03
HV 10	10	98.07
HV 20	20	196.1
HV 30	30	294.2
HV 50	50	490.3
HV 100	100	980.7

- Convenient loads to use for some common materials are:

Material	Load symbol, f (kg)
Steels and cast irons	30
Copper alloys	10
Pure copper, aluminium alloys	5
Pure aluminium	2.5
Lead, tin ,tin alloys	1

2.7.4 Duration / Time For Hv Hardness Testing

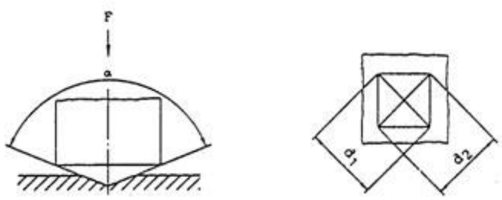
- The standard dwell time of 10 s to 15s.
- Maintain the full force for the standard dwell time of 10 s to 15 s.

2.7.5 Calculation of Vickers Hardness Values

- After making indentation on a flat surface, Vickers hardness can be calculated using the following equation:

Material Testing – Vickers Hardness Test

- First:
  - Two diagonals, d1 and d2 from the indentations will stay on the surface of the material after removal of the load, the measurement was measured in two directions at right angles to the conditions and mean diagonal of impression, d is calculated: -



Vickers principle

$$\text{Mean diagonal of impression, d} = \frac{d_1 + d_2}{2}$$

- Second:
  - Surface area of the indentation, made with a pyramid-shaped diamond indenter type a square base is given by: -

$$\text{Area, A} = \frac{d^2}{2\text{Sin}\frac{\theta}{2}}$$

- The Vickers hardness number, HV is given by:

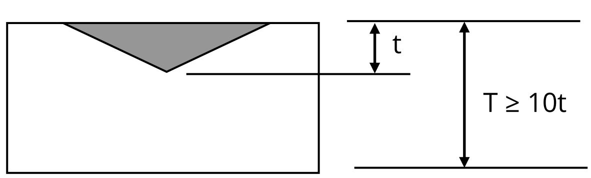
$$\text{HV} = \frac{\text{Applied load, f(kg)}}{\text{Surface area of impression, A(mm}^2)} = \frac{f}{\left[\frac{d^2}{2\text{Sin}\frac{\theta}{2}}\right]} = \frac{f}{\left[\frac{d^2}{2\text{Sin}\frac{136^o}{2}}\right]} = \frac{2f\text{Sin}68^o}{d^2} = \frac{1.8544f}{d^2}$$

Where:
HV = Vickers Hardness
f = Applied load (kg),) (f = 0,102 x F)
d = Average of the two diagonals of the indentations, d1 and d2 (mm)
θ = Angle between the opposing faces of the pyramid indenter peak (in degrees, 136°)

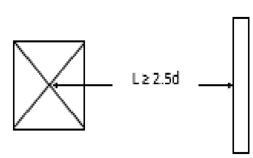
Material Testing – Vickers Hardness Test

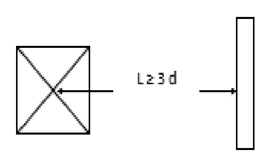
2.7.6 Precautions

- Testing machine
    - After indirect verification the testing machine shall not be removed. No parts of the machine shall be changed with the exception of the indenter. In particular the same measuring microscope shall be used.
- Test piece
    - The test piece shall have such a surface finish as to permit accurate measurement of the diagonal of the indentation. (test surface, Ra = 0.1ųm)
- Test piece thickness
    - No deformation shall be visible at back of the test piece after the test. The thickness of the test piece shall be not less than 10 times the depth of the indentation:



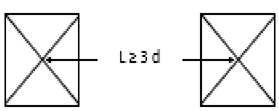
- Location of indentations
    - The distance between the centre of any indentation and the edge of the test piece shall be at least 2.5 times the mean diagonal of the indentation in the case of steel, copper and copper alloys; and at least 3 times the mean diagonal of the indentation in the case of light metals, lead and tin and their alloys.

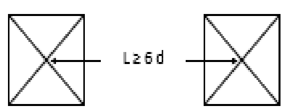




Material Testing – Vickers Hardness Test

- The distance between the centres of two adjacent indentations shall be at least 3 times the mean diagonal of the indentation in the case of steel, copper and copper alloys; and at least 6 times the mean diagonal of the indentation in the case of light metals, lead and tin and their alloys. If 2 adjacent indentations differ in size, the spacing shall be based on the mean diagonal of the larger indentation.





2.7.7 Advantages

- The advantage of Vicker's over brinell is chiefly in greater precision in measurement of the diagonal of the square as compared to the diameter of the circular brinell impression.
- The Vicker's tester can also be used for testing harder materials because it uses a diamond.
- One scale covers the entire hardness range.
- A wide range of test forces to suit every application.
- Non-destructive, sample can normally be used.

2.7.8 Disadvantages

- Vicker's hardness testers are much more complicated and expensive than either Rockwell or Brinell machines.
- The main drawback of the Vickers test is the need to optically measure the indent size. This requires that the test point be highly finished to be able to see the indent well enough to make an accurate measurement.
- Slow. Testing can take 30 seconds not counting the sample preparation time.

2.7.9 Standard For Vickers Hardness Test

- ASTM E 92 – 82 (Reapproved 1987)
- BS 427: 1990

Exercise 3

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. What is the angle of indenter in Vicker's hardness test?
   a) 96 degrees
   b) 110 degrees
   c) 136 degrees
   d) 150 degrees

2. How is the Vicker's hardness number defined as?
   a) $1.8544PD^2$
   b) $1.8544P\ 1/D^2$
   c) $8.544P\ 1/D^2$
   d) $8.544PD^2$

3. What is the load that the Vickers hardness test can carry?
   a) 10 kg
   b) 120 kg
   c) 150 kg
   d) 3000 kg

4. ___________ Indenter is used in Vickers hardness test.
   a) Hardened steel ball
   b) Diamond ball
   c) Diamond pyramid
   d) Tungsten carbide

5. Which of the following is an advantage of the Vickers test?
   a) Rough surface preparation
   b) Cheaper
   c) Accurate readings
   d) Large floor-standing machine

Tutorial 3

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. In a Vickers hardness test, the load is 5 kg is used, resulting in a 0,298 mm indentation diagonal length of the average value. Determine the Vickers hardness number for the material.

2. Indentation hardness test using a Vickers diamond test with a load of 30 kg, made on a metal sample and the results for the average diagonal length of the following was recorded:

   First impression: 0,527 mm
   Second impression: 0,481 mm
   Third impression: 0,497 mm

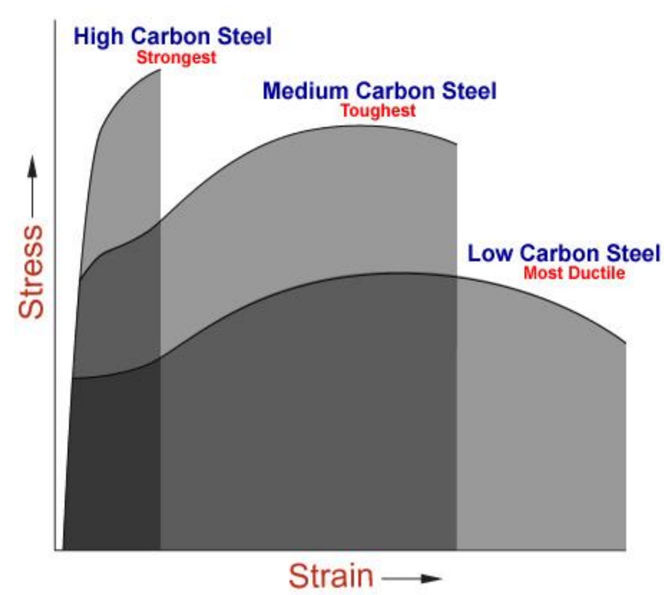
   Calculate the number of diamond hardness of the material

3. The average length of the diagonal of a Vickers diamond indentation made on an aluminium sample using a load of 2.5 kg is 0.362mm.
   a. What is the hardness of aluminium?
   b. What is the size of the diamond indentation that will be made on the same material if the load of 5 kg will be used?

Material Testing – Impact Test

2.8 Impact Test

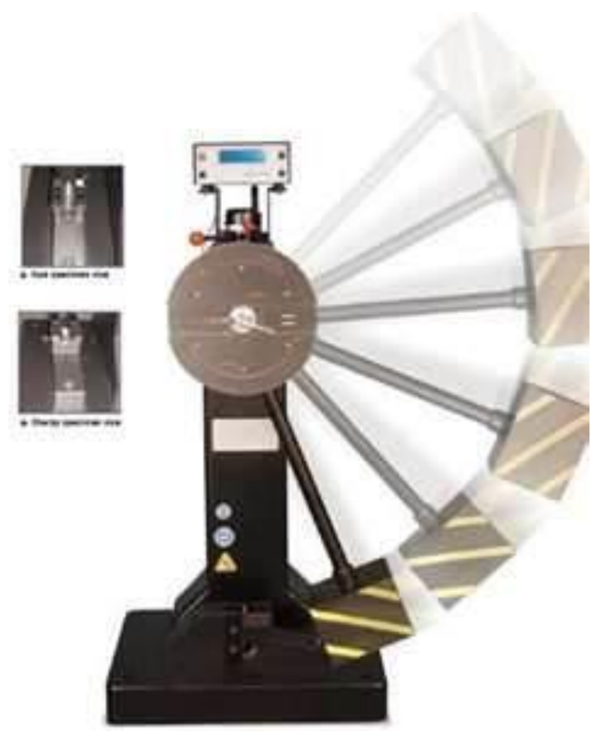
- The strength of a material is the critical stress required to initiate failure.
- Strength is not only mechanical parameter that determines the usefulness of a material for a specific application.
- Some glasses are as strong as steel, but nobody would recommend the use of glass for car bumpers!
- The reason is that steel can absorb a large amount of energy before it fails whereas glass can not.
- The parameter describing the ability of a material to absorb energy is toughness.
- We commonly categorize fracture as being either ductile or brittle.
- Little energy is required to fracture brittle materials, such as glass, polystyrene, and some of the cast iron.
- Conversely, tough materials, such as rubber and many steels, absorb considerable /large amounts of energy in the fracture process.
- Brittle fracture requires energy to separate atoms and expose new surfaces along the fracture path.
- Ductile failure requires not only the energy just mentioned but much more additional energy to deform plastically the material ahead of the fracture.
- One measure of the toughness is the area of the stress-strain curve. The unit for toughness are therefore the product of stress and strain $(\mathrm{N/m^2}\ (\frac{\mathrm{m}}{\mathrm{m}}) = \mathrm{joules/m^2})$.

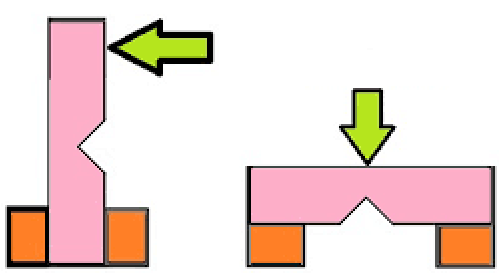


Material Testing – Impact Test

2.8.1 Purpose of Impact Tests

- Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force.
- The test measures the impact energy, or the energy absorbed prior to fracture.

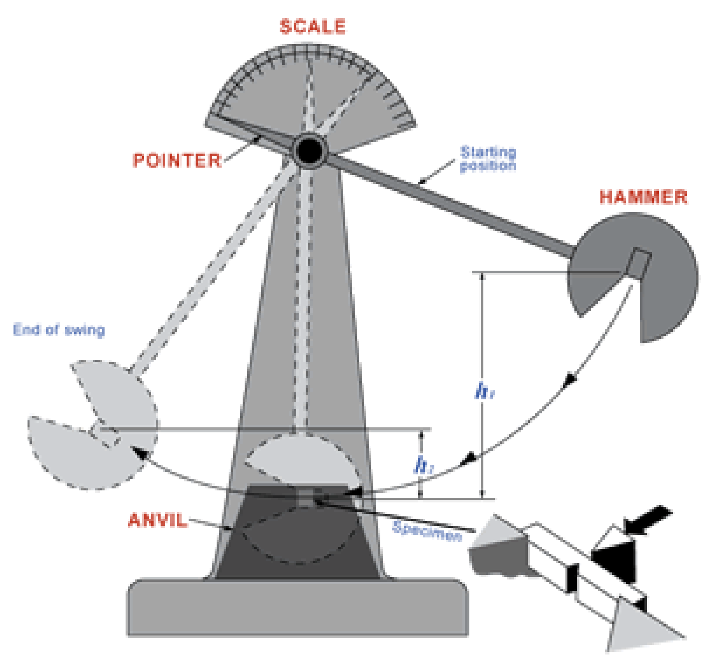




(a) Izod Test (b) Charpy Test

2.8.2 Principle of Impact Tests

- The general principle of the tests is that a test specimen, containing a milled notch, is struck by a fast moving hammer and the energy that is absorbed in fracturing the test-piece is measured; OR
- Impact tests consist of striking a suitable specimen with a controlled blow and measuring the energy absorbed in bending or breaking the specimen. The energy value indicates the toughness of the material under test.

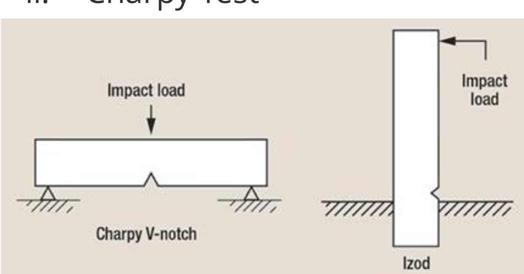


Material Testing – Impact Test

- The machine has a hammer which is suspended /hanged like a pendulum, a vice for holding the specimen in the correct position relative to the hammer and a dial for indicating the energy absorbed in carrying out the test in joules (J).
- If there is maximum overswing, as there would be if no specimen was placed in the vice, then zero energy absorption is indicated.
- If the hammer is stopped by the specimen with no overswing, then maximum energy absorption is indicated.
- Intermediate reading are the impact values (J) of the materials being tested (their toughness or lack of brittleness)

2.8.3 Type of Impact Tests

- The most common methods of measuring impact energy are the:
  - i. Izod Test
  - ii. Charpy Test



2.8.3.1 Izod Tests

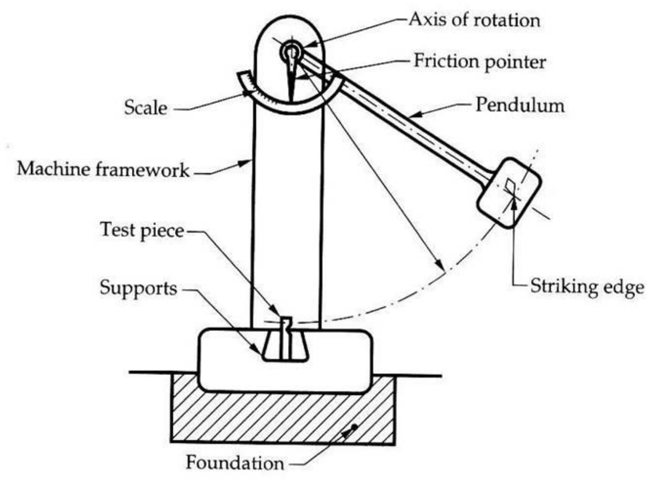
- Izod impact strength testing is an standard method of determining impact strength.
- A notched sample is generally used to determine impact strength.
- The test is named after the English engineer Edwin Gilbert Izod (1876–1946), who described it in his 1903 address to the British Association, subsequently published in Engineering. (Izod, Gilbert, 'Testing brittleness of steel', Engineering, 25 September 1903, pp. 431-2)
- Impact is a very important phenomenon in governing the life of a structure. For example, in the case of an aircraft, impact can take place by a bird hitting a plane while it is cruising, or during take off and landing the aircraft may be struck by debris present on the runway, and as well as other causes.
- An arm held at a specific height (constant potential energy) is released. The arm hits the sample and breaks it. From the energy absorbed by the sample, its impact strength is determined.

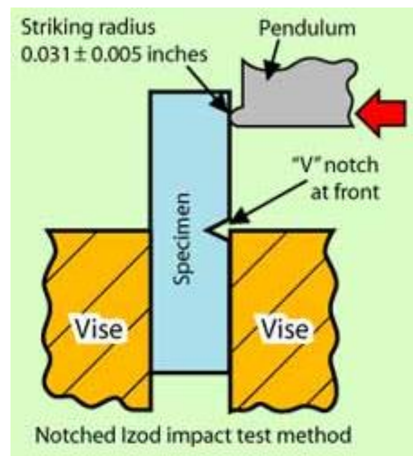
Material Testing – Impact Test

- The Izod impact test differs from the Charpy impact test in that the sample is held in a cantilevered beam configuration as opposed to a three-point bending configuration.

2.8.3.1.1 Principle Of Izod Test

- The test uses a cantilever test piece of 10 mm x 10 mm section specimen having standard 45° notch 2 mm deep.
- This is broken by means of a swinging pendulum which is allowed to fall from a certain height to cause an impact load on the specimen.
- The angle rise of the pendulum after rupture of the specimen or energy to rupture the specimen is indicated on the graduated scale by a pointer.
- The energy required to rupture the specimen is the function of the angle of rise.





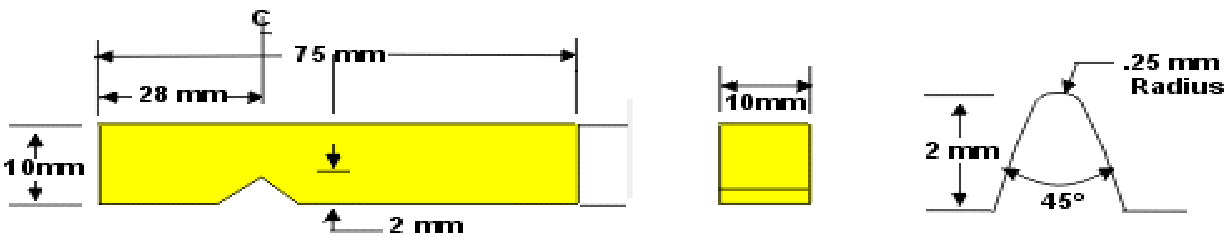
Notched Izod impact test method

2.8.3.1.2 Izod Test Specimen

- Izod test (standard specimen)
  1. A detail of notch
  2. section of test piece
  3. position of striker

Material Testing – Impact Test

- The Izod impact test differs from the Charpy impact test in that the sample is held in a cantilevered beam configuration as opposed to a three-point bending configuration.



2.8.3.2 Charpy Tests

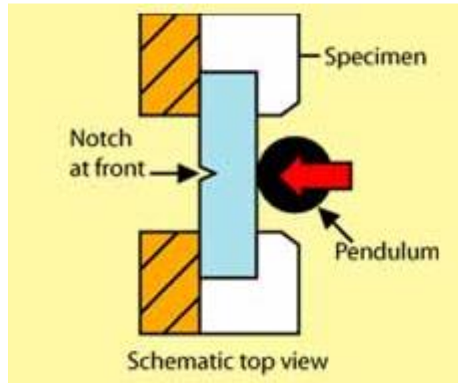
- The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture.
- This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition.
- It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply.
- A disadvantage is that some results are only comparative.

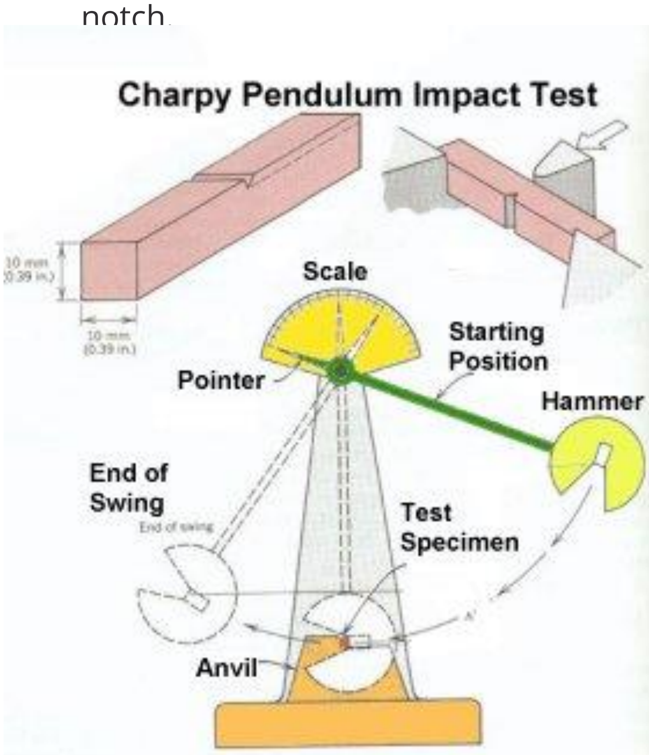
- The test was developed around 1900 by S. B. Russell (1898, American) and G. Charpy (1901, French).The test became known as the Charpy test in the early 1900s due to the technical contributions and standardization efforts by Georges Charpy. The test was pivotal/important in understanding the fracture problems of ships during WWII.
- Today it is used in many industries for testing materials used in the construction of pressure vessels and bridges and to determine how storms will affect materials used in them.

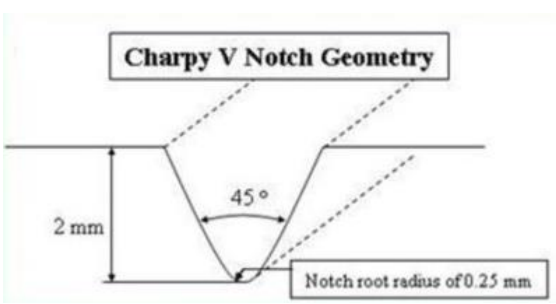
Material Testing – Impact Test

2.8.3.2.1 Principle of Charpy Tests

- This test is more common than Izod test and it uses simply supported test piece of 10 mm x 10 mm section.
- The specimen is placed on supports (supported as a beam) or anvil so that the blow of striker is opposite to the notch.

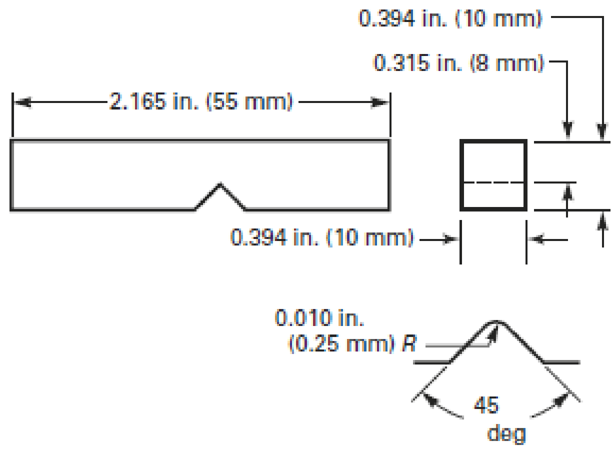






2.8.3.2.2 Charpy Test Specimen

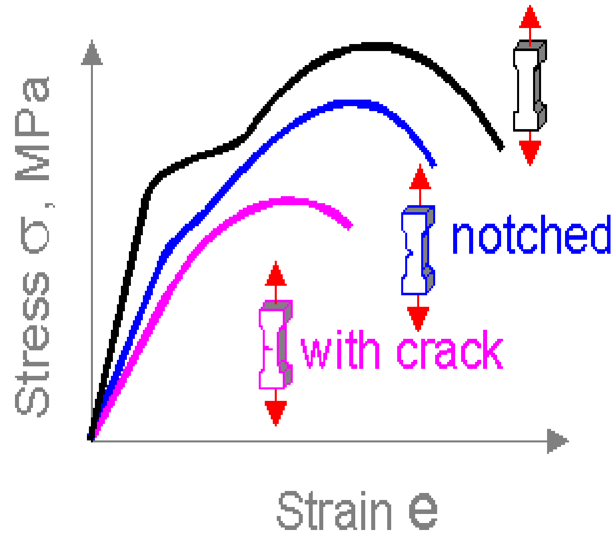
- Izod test (standard specimen)
    - i. A detail of notch
    - ii. section of test piece
    - iii. position of striker



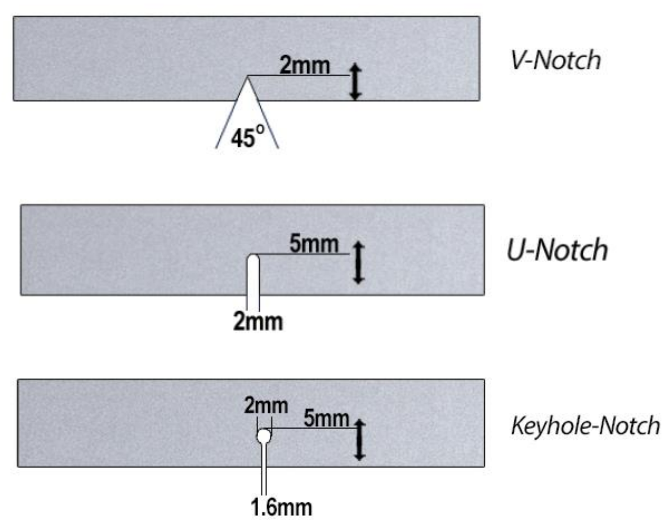
Material Testing – Impact Test

2.8.3.3 Types Of Notch

- The notch serves as a stress concentration zone and some materials are more sensitive towards notches than others. The notch depth and tip radius are therefore very important.
- Both tests are use a notched specimen, useful information can be obtained regarding the resistance of the material to the spread of a crack which may originate from a point of stress concentration such as sharp corners, undercuts, sudden changes in section, and machining marks in stressed components.
- Such points of stress concentration should be eliminated during design and manufacture.
- Notches caused by poor machining, fabrication, or design cause stresses to be concentrated, will reducing the toughness of the material.
- The notch sensitivity of a material can be evaluated by comparing the absorbed energies of notched versus un-notched specimens.



- The absorbed energies are much lower in notched specimens if the material is notch sensitive, as in ductile cast iron.
- There are several types of notch:
  i. U notch
  ii. Keyhole notch
  iii. V notch



Exercise 4

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1) The tendency of a ductile material to act as brittle is known as _________
   a) Compaction
   b) Brazing
   c) Tempering
   d) Toughness

2) The ability of a material to absorb energy during plastic deformation is known as
   a) ductility
   b) creep
   c) fatique
   d) toughness

3) Which of the following material has the high impact energy
   a) Cast iron
   b) Low carbon steel
   c) Medium carbon steel
   d) High carbon steel

4) Tough materials will ____________ large amounts of energy in the fracture process.
   a) Reflect
   b) Absorb
   c) Rebound
   d) Destroy

5) If the hammer is stopped by the specimen with no overswing, is indicates that.....
   a) maximum energy absorption.
   b) minimum energy absorption.
   c) zero energy absorption.
   d) lack of brittleness.

Tutorial 4

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force.
   a) Define the principle of impact test.
   b) With the aid of diagrams, explain the principle of:
      i. Izod test
      ii. Charpy test

3.0 PRINCIPLES OF NON-DESTRUCTIVE TESTS

3.1 Principle Of Non-Destructive Tests (NDT)

- Non-destructive (NDT) testing is the use of physical methods which will test materials, components and assemblies for flaws in their structure without damaging their future usefulness.
- NDT is concerned with revealing flaws in the structure of a product, but cannot predict where flaws will develop due to the design itself.
- Non-destructive testing also refers to the use of testing techniques that do not alter any of the properties of the tested product.
- These properties could be its strength, integrity, appearance, corrosion resistance, conductivity, wear resistance, toughness and so on.
- NDT analysis technique widely used by industry to evaluate the properties of a material, component, structure or system for characteristic differences or welding defects and discontinuities without causing damage to the original part.
- There are several techniques used in NDT for the collection of various types of data, each requiring its own kind of tools, training, and preparation.
- Some of these techniques might allow for a complete volumetric inspection of an object, while others only allow for a surface inspection.
- In a similar way, some NDT methods will have varying degrees of success depending on the type of material they're used on.
- Here are the five most commonly used NDT techniques:

1. Visual Inspection (VT)
2. Dye Penetrant Inspection (DPI)
3. Magnetic Particle Inspection (MPI)
4. Ultrasonic Testing (UT)
5. Radiography Testing (RT)

Material Testing – Visual Inspection

3.2 Visual Inspection (VT)

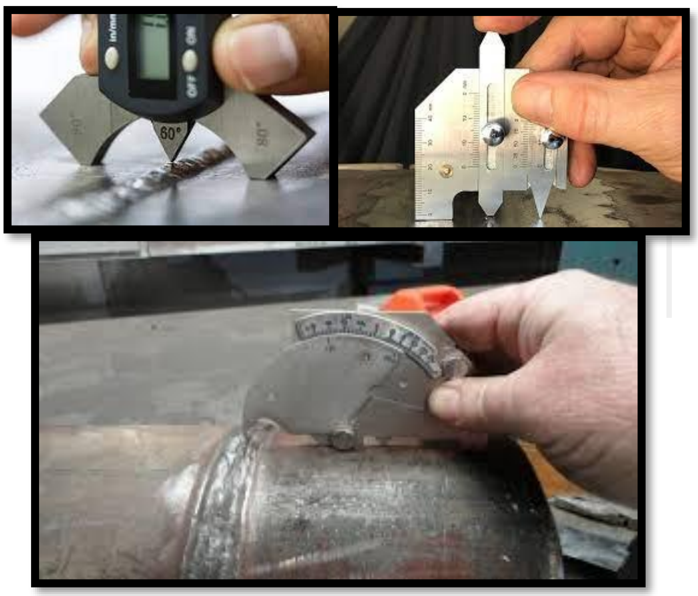
- Visual inspection (VT) is the most popular and the most widely used of the non-destructive inspection techniques.
- Completed welds should be checked according to the plans and the specifications.
- The most common welds that need to be inspected in the field are fillet welds. Fillet welds are designed based on their leg sizes.
- If the leg is under the specified dimension, then the strength required is less than what the joint was designed for. The throat of the weld should be checked also.

3.2.1 Principles of VT

- Visual testing can generally be used to inspect a component's surface quality, evaluate the alignment of mating surfaces, and look for leaks.
- Aside from being used extensively in the mining industry, visual testing is also widely used in contemporary manufacturing.
- A visual inspector can identify dangerous flaws or impurities that can impact on how a manufactured item is utilized in the future using.
- It is vital to test items before they are sold or utilized, and there are many other industries where materials are tested before they are allowed for use in public.
- For instance, material engineers require the assistance of inspectors in gathering data about the quality of their welding jobs, and the survivability and integrity of the material.
- Besides studying industrial components, inspectors also examine things that the general public frequently uses, such stairways and guardrails. Inspectors can ensure that safe parts reach the market by looking at these components, ensuring that both customers and consumers benefit from structurally sound, high-quality products.
- Other sectors that require routine visual inspections as part of their maintenance processes (and even root cause analysis) include aerospace, chemical refineries, food and beverage, oil and gas, power and utilities, maritime operations, pharmaceuticals, and research and troubleshooting

Material Testing – Visual Inspection

3.2.2 Essential Steps in VT



1. This step entails compiling detailed operating instructions, guidelines and procedures as well as a list of the products, machinery, and other items that require inspection.
2. The product is cleaned and prepared for visual examination.
3. The object is then checked thoroughly for potential defects, flaws and inconsistencies.
4. The defects identified in the asset, component or material are assessed for compliance with set standards.
5. The final step involves reviewing the results of the visual inspection and deciding whether to accept or reject the product.

3.2.3 Advantages of VT

- It is the most affordable or lowest-cost non-destructive testing method. The reason is that an inspector can conduct a visual inspection with little to no equipment.
- It is a portable testing method. Since this NDT technique requires very few to no tools or equipment, it is considered an easy and convenient testing method.
- It requires very little part preparation. The component being examined usually doesn't need to undergo many part preparations.

3.2.4 Disadvantages of VT

- It requires rigorous training. Contrary to the belief that it's easy to train others to become visual inspectors, technicians need to undergo rigorous inspector training.
- It is limited to the detection of surface defects. Since visual testing is surface - oriented, an inspector may overlook internal problems or significant flaws.
- It requires extensive knowledge and experience. The accuracy of the evaluation depends greatly on the expertise of the inspector.

Exercise 5

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1) Which among the following is not a type of Non-destructive testing?
   a) compression test
   b) visual testing
   c) ultrasonic testing
   d) radiography testing

2) Which of the following nondestructive testing methods are limited to the detection of surface discontinuities?
   a) Visual inspection and dye penetrant inspection
   b) Dye penetrant inspection and magnetic particles inspection
   c) Magnetic particles inspection and ultrasonic testing
   d) Ultrasonic testing and radiography testing

3) Visual non-destructive testing is limited to:
   a) small, easily handled parts
   b) non-ferrous materials
   c) dimensional defects
   d) surface defects

4) Probably the most basic inspection technique is visual testing. which of items would a visual inspector most likely not used to carry out his duties?
   a) Measuring devices
   b) Flash Light
   c) Magnifying glass
   d) Rubber mallet

5) Which of the following would have an effect on the sensitivity of a direct visual test?
   a) corrosion on the surface
   b) size of the area to be examined
   c) shape of the part or component
   d) the type of material, such as carbon steel versus stainless steel

Tutorial 5

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. Visual inspection (VT) is the most popular and the most widely used of the non-destructive inspection techniques.
   a) Define the principle of visual inspection.
   b) Briefly explain the essential step in visual inspection.
   c) State 3 (THREE) limitation in visual inspection process.

Material Testing – Dye Penetrant Inspection

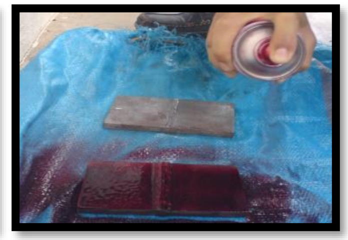
3.3 Dye Penetrant Inspection (DPI)

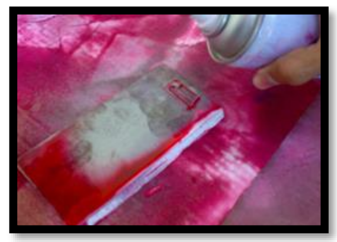
- Dye Penetrant Inspection (DPI), also called Liquid Penetrant Inspection (LPI) or Penetrant Testing (PT), is one of the oldest and simplest NDT methods where its earliest versions dates back to the 19th century.
- Liquid penetrant inspection is used to detect surface-connected discontinuities such as cracks from fatigue, quenching, and grinding, as well as fractures, porosity, incomplete fusion, and flaws in joints.

3.3.1 Principles of DPI

- Liquid (or dye) penetrant inspection is an extension of visual inspection and is used for detecting surface-breaking flaws, such as cracks, laps and folds, on any non-absorbent material's surface.
- DPI is based upon capillary action, where low surface tension fluid penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component by dipping, spraying, or brushing.

3.3.2 Essential Steps in VT





1. Surface preparation - clean surface from oil, dirt, grease or any contaminants.
2. Application of penetrant – color contrast or fluorescent.
3. Removal of excess penetrant – wipe in one direction slowly.
4. Development – reveal the defect.
5. Observation and inspection – mark, measure, etc.

3.3.3 Advantages of DPI

- High sensitivity (small discontinuities can be detected).
- Few material limitations (metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected).

Material Testing – Dye Penetrant Inspection

- Rapid inspection of large areas and volumes.
- Suitable for parts with complex shapes.
- Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
- Portable (materials are available in aerosol spray cans)
- Low cost (materials and associated equipment are relatively inexpensive).

3.3.4 Disadvantages of DPI

- Only surface breaking defects can be detected.
- Only materials with a relatively nonporous surface can be inspected.
- Pre-cleaning is critical since contaminants can mask defects.
- Metal smearing from machining, grinding, and grit or vapor blasting must be removed.
- The inspector must have direct access to the surface being inspected.
- Surface finish and roughness can affect inspection sensitivity.
- Multiple process operations must be performed and controlled.
- Post cleaning of acceptable parts or materials is required.
- Chemical handling and proper disposal is required

Material Testing – Magnetic Particles Inspection

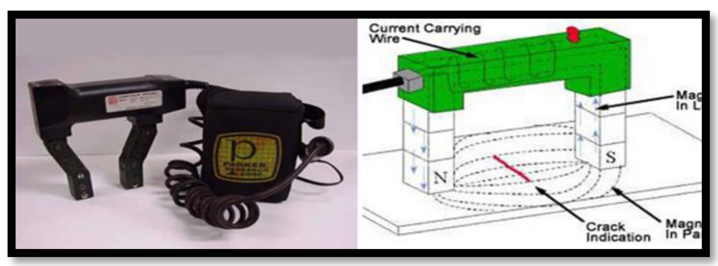
3.4 Magnetic Particles Inspection (MPI)

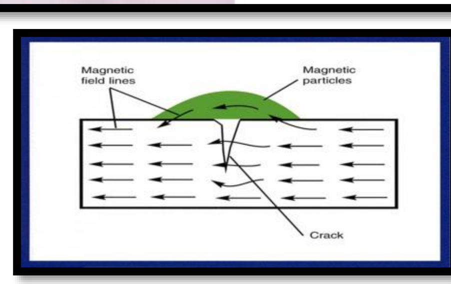
- Magnetic particle inspection (often abbreviated MT or MPI) is a nondestructive inspection method that provides detection of linear flaws located at or near the surface of ferromagnetic materials. It is viewed primarily as a surface examination method.
- Magnetic Particle Inspection (MPI) is a very effective method for location of surface breaking and slight sub-surface defects such as cracking, pores, cold lap, lack of sidewall fusion in welds in magnetic materials.

3.4.1 Principles of MPI

- There are many different techniques. The most versatile technique is using a 110v AC hand held electromagnetic yoke magnet, a white strippable paint as contrast background and a magnetic "ink" composed of iron powder particles in a liquid carrier base.
- The area is magnetized with the yoke magnet. In the event of a surface or slightly sub surface defect being present, the lines of magnetic force will deform around the defect.
- The magnetic ink is applied and the iron powder particles will bridge the gap caused by the defect and give a visible indication against the white contrast background.
- Magnetic Particle Inspection (MPI) provides very good defect resolution and is used extensively on welded fabrications in magnetic material, Castings, Locating fatigue cracks in items subject to cyclical stress.

3.4.2 Essential Steps in MPI





1. Surface preparation - clean surface from oil, dirt, grease or any contaminants.
2. Magnetizing– magnetized the part.
3. Spray fluorescent magnetic particle – for fluorescent method.

4. Spray white paint and the black iron magnetic particle – for Non fluorescent method.
5. Observation and inspection – Wear safety google under UV light for fluorescent method.

3.4.3 Advantages of MPI

- Can find both surface and near sub-surface defects
- Some inspection formats are extremely portable and low cost
- Rapid inspection with immediate results
- Indications are visible to the inspector directly on the specimen surface
- Can detect defects that have been smeared over
- Can inspect parts with irregular shapes (external splines, crankshafts, connecting rods, etc.)High sensitivity (small discontinuities can be detected).
- Few material limitations (metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected).
- Rapid inspection of large areas and volumes.
- Suitable for parts with complex shapes.
- Indications are produced directly on the surface of the part and constitute a visual expensive).

3.4.4 Disadvantages of MPI

- The specimen must be ferromagnetic (e.g. steel, cast iron)
- Paint thicker than about 0.005" must be removed before inspection
- Post cleaning and post demagnetization is often necessary
- Maximum depth sensitivity is typically quoted as 0.100" (deeper under perfect conditions)
- Alignment between magnetic flux and defect is important

Exercise 6

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1) The total time the penetrant is in contact with the part surface is called the:
   a) Penetrant dwell time
   b) Developer time
   c) Emulsifier time
   d) Penetrant evaporation time

2) The advantage that liquid penetrant testing has over an unaided visual inspection is that:
   a) The actual size of the discontinuity can be measured
   b) The depth of the defect can be measured
   c) The cause of the impact can be seen
   d) It makes defects easier to see for the inspector

3) Which of the following is a disadvantage of DPI?
   a) Only surface breaking flaws can be detected
   b) Surface finish and roughness can affect inspection sensitivity
   c) Post cleaning is required
   d) All of the above

4) A volume of space where there is a change in magnetic energy is called:
   a) A magnetic field
   b) A magnetic dipole
   c) A magnetic pole
   d) A magnetic domain

5) A location where a magnetic field can be detected exiting or entering a material is called:
   a) A magnetic pole
   b) A magnetic field
   c) A flux field
   d) Polarity

Tutorial 6

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. Dye penetrant inspection (DPI) are designed to detect surface-connected discontinuities such as cracks from fatigue, quenching, and grinding, as well as fractures, porosity, incomplete fusion, and flaws in joints.
   a) Define the principle of dye penetrant inspection .
   b) With the aid of diagrams, explain the principle dye penetrant inspection.

2. Magnetic particle inspection provides detection of linear flaws located at or near the surface of ferromagnetic materials.
   a) State 3 (THREE) advantages and disadvantages of magnetic particle inspection.

3.5 Ultrasonic Testing (UT)

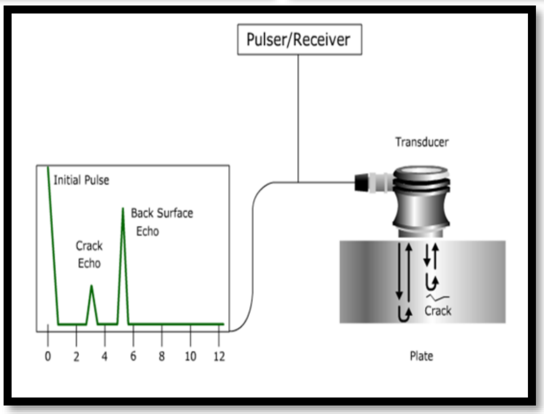
- Ultrasonic nondestructive testing, also known as ultrasonic NDT or simply UT, is a method of characterizing the thickness or internal structure of a test piece through the use of high frequency sound waves.
- The frequencies, or pitch, used for ultrasonic testing are many times higher than the limit of human hearing, most commonly in the range from 500 KHz to 20 MHz
- In industrial applications, ultrasonic testing is widely used on metals, plastics, composites, and ceramics.
- Ultrasonic technology is also widely used in the biomedical field for diagnostic imaging and medical research.

3.5.1 Principles of UT

- High frequency sound waves are very directional, and they will travel through a medium until they encounter a boundary with another medium, at which point they reflect back to their references.
- By analyzing these reflections it is possible to measure the thickness of a test piece, or find evidence of cracks or other hidden internal flaws
- There are two methods of receiving the ultrasound waveform, reflection and attenuation.
- In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object. The diagnostic machine displays these results in the form of a signal with an amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection.
- In attenuation mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium. Imperfections in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence. Using the couplant increases the efficiency of the process by reducing the losses in the ultrasonic wave energy due to separation between the surfaces.

Material Testing – Ultrasonic Testing

3.5.2 Essential Steps in UT



1. Calibration – Ensure equipment are accurate.
2. Couplant / Oil – smoothen surface area to be inspected.
3. Probe (normal/twin) – use correct probe according to thickness of material
4. Observation and inspection – Read the graph and compare to actual data, use the right settings.

3.5.3 Advantages of UT

- Ultrasonic testing is completely nondestructive.
- The test piece does not have to be cut, sectioned, or exposed to damaging chemicals.
- Access to only one side is required, unlike measurement with mechanical thickness tools like calipers and micrometers.
- There are no potential health hazards associated with ultrasonic testing, unlike radiography.
- When a test has been properly set up, results are highly repeatable and reliable.

3.5.4 Disadvantages of UT

- Ultrasonic flaw detection requires a trained operator who can set up a test with the aid of appropriate reference standards and properly interpret the results.
- Inspection of some complex geometries may be challenging. Ultrasonic thickness gages must be calibrated with respect to the material being measured.
- Applications requiring a wide range of thickness measurement or measurement of acoustically diverse materials may require multiple setups.
- Ultrasonic thickness gages are more expensive than mechanical measurement devices.

Material Testing – Radiographic Testing

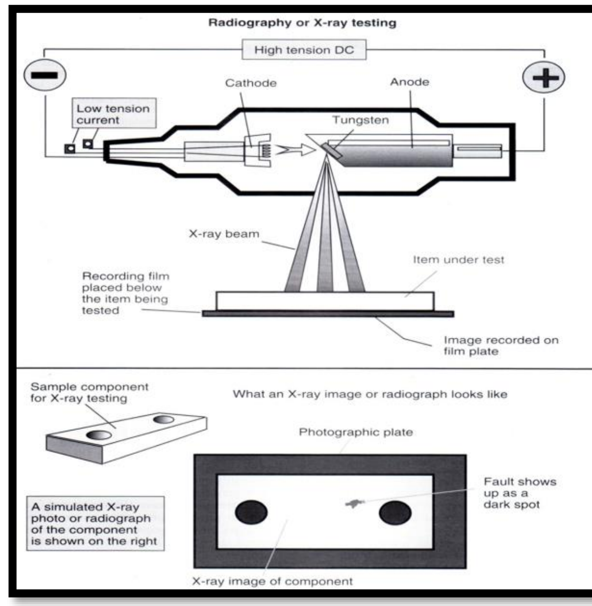
3.6 Radiographic Testing (RT)

- Radiographic Testing (RT or X-ray or Gamma ray) is a non-destructive testing (NDT) method that examines the volume of a specimen.
- Radiography (X-ray) uses X-rays and gamma-rays to produce a radiograph of a specimen, showing any changes in thickness, defects (internal and external), and assembly details to ensure optimum quality in your operation

3.6.1 Principles of RT

- RT usually is suitable for testing welded joints that can be accessed from both sides, with the exception of double-wall signal image techniques used on some pipe.
- Although this is a slow and expensive NDT method, it is a dependable way to detect porosity, inclusions, cracks, and voids in weld interiors.
- RT makes use of X-rays or gamma rays. X-rays are produced by an X-ray tube, and gamma rays are produced by a radioactive isotope.

3.6.2 Essential Steps in RT



1. The x-ray are released by heating the cathode.
2. They are then accelerated by the D.C. current and directed onto the piece by the tungsten anode.
3. The x-rays then pass through the test piece onto an x-ray film which displays the results.
4. The x-rays cannot pass through the faults as easily making them visible on the x-ray film.
5. All discontinuities are detected by viewing the weld shape and variations in the density of the processed film.
6. This permanent film record of weld quality is relatively easy to interpret

Material Testing – Radiographic Testing

3.6.3 Advantages of RT

- Volumetric inspection.
- Can detect surface and subsurface flaws.
- Permanent records.
- Good quality control method.

3.6.4 Disadvantages of RT

- Equipment can be bulky and heavy.
- Radiation hazards.
- Testing area needs to be controlled access.
- Equipment relatively time consuming and expensive.
- Access may be required to both sides of object.
- May not detect critical flaws.
- Results require interpreting by experienced person.
- Gamma results inferior to X-ray results.
- Gamma less sensitive thanX-ray especially on thin materials.
- Not suitable for certain configuration such as tee joint.

Exercise 7

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1) Which of the following could influence the behavior of a transducer?
   a) Electrical construction
   b) Material construction
   c) Mechanical construction
   d) All of the above

2) The material of the reference standard used to setup for a flaw inspection:
   a) Can be made from similar material as long as the velocity is the same
   b) Should be the same material being inspected
   c) Must have the same impedance values as the base material
   d) Can only be used once

3) Couplant displaces the__________ and makes it possible to get more sound energy into the test specimen.
   a) Surface rust
   b) Surface blemishes
   c) Sound energy
   d) Air

4) X-rays and Gamma rays are a form of:
   a) Light
   b) Particle radiation
   c) Electromagnetic radiation
   d) Both B and C

5) Which of the following is not a strength of radiographic inspection?
   a) It is not limited to material type
   b) It can be used to inspect assembled components
   c) It can detect surface and subsurface features
   d) Access to both side of the test sample is required

Tutorial 7

SELF ASSESSMENT: TEST YOUR KNOWLEDGES....

Instruction : Answer all the question.

1. Ultrasonic testing is a method of characterizing the thickness or internal structure of a test piece through the use of high frequency sound waves.
   a) Define the principle of ultrasonic testing.
   b) With the aid of diagrams, explain the principle of ultrasonic testing

2. Radiographic testing produce a radiograph of a specimen, showing any changes in thickness, defects and assembly details to ensure optimum quality in your operation.
   a) Briefly explain the principle of radiography testing.
   b) State 3 (THREE) advantages and disadvantages of radiographic testing .

REFERENCES

Callister, William D., Jr., Rethwisch, David G., Materials Science And Engineering : An Introduction 10th Edition. | Hoboken, NJ : Wiley

Raj, B., Jayakumar, T., & Thavasimuthu, M. (2002). Practical Non-destructiveTesting. New Delhi: Narosa Publishing House.

B K Agrawal. (2000). Introduction to Engineering Materials. New Delhi: TataMcGraw-Hill Publishing Company Limited.

Dowling. (1993). Mechanical Behavior of Materials. New Jersey, US: Prentice-Hall.

Jacobs,Kilduff. (1994). Engineering Materials Technology. New Jersey, US: Prentice-Hall.

K.G. Budinski & M.K Budinski. (1999). Engineering Materials (6th ed.).New Jersey, US: Prentice-Hall.

R.L.Timings. (1998). Engineering Materials (2nded.). Singapore: Longman.

V.B. John. (1995). Bahan Kejuruteraan. Kuala Lumpur: UTM. (Diterjemah oleh: Jasmi Hashim).

Verno John. (1997). Pengenalan Kepada Bahan Kejuruteraan. Skudai: UTM. (Diterjemah oleh: Ani Idris & Jasmi Hashim).

e ISBN 978-629-7514-19-2

9 786297 514192

POLITEKNIK TUANKU SYED SIRAJUDDIN

(online)