Rohini College of Engineering and Technology
(Autonomous)

DEPARTMENT OF MECHANICAL ENGINEERING

OML351
INTRODUCTION TO NON-DESTRUCTIVE TESTING

UNIT I INTRODUCTION TO NDT & VISUAL TESTING

NDT Versus Mechanical testing, Overview of the Non Destructive Testing Methods for the detection of manufacturing defects as well as material characterisation. Relative merits and limitations, various physical characteristics of materials and their applications in NDT. Visual inspection –Unaided and aided.

INTRODUCTION

What is NDT?

- ✓ NDT stands for Non-Destructive Testing.
- ✓ As its name implies, non-destructive testing means testing of materials without destroying them.
- ✓ A non-destructive test is an examination of an object which will not produce any kind of damageor destruction to the sample.
- ✓ **Definitions:** Some of the commonly used definitions of NDT are given below:

(i) Non-destructive testing is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection or test is completed, the part can still be used.
(ii) "NDT is an examination that is performed on an object of any type, size, shape or material to determine the presence or absence of discontinuities or to evaluate other material characteristics".
(iii) NDT is a procedure which covers the inspection and/or testing of any material, component or assembly by means which do not affect its ultimate serviceability.
(iv) NDT is the examination of an object with the technology that does not affect the object's future usefulness.
(v) NDT means the use of non-invasive techniques i) to determine the integrity of a material, component or structure, or ii) to qualitatively measure some characteristics of an object.
(vi) NDT refers to technology that allows a component to be inspected for serviceability, without impairing its usefulness.

- ✓ The other terms commonly used for NDT are Non-Destructive Evaluation (NDE) and Non-Destructive Inspection (NDI).
- ✓ The NDT methods are becoming popular because these can be carried out without damaging the parts in use.

Objectives of NDT

- ❖ NDT can have several objectives which includes:
  - Materials sorting;
  - Materials characterization; Property monitoring (for process control);
  - Thickness measurement;
  - Defect detection/location; and
  - Defect characterization.
- ❖ However, the major task of NDT is to detect and identify the range of defects. Defects can include production flaws such as heat treatment cracks, grinding cracks, inclusions (of many types), voids (pores), and fatigue cracks (generated during service)

Uses of NDT methods

The NDT methods are most commonly used to achieve the following purposes:

1. Flaw detection and evaluation.
2. Leak detection.
3. Location measurement.
4. Dimensional measurements.
5. Structure and microstructure characterisation.
6. Estimation of mechanical and physical properties.
7. Stress-strain and dynamic response measurement.
8. Material sorting.
9. Chemical composition determination.

INTRODUCTION TO MATERIALS TESTING

Purposes of Materials Testing (Why are Materials tested?)

Materials are tested for one or more of the following purposes:

(i) To determine and evaluate various properties of materials both quantitatively and qualitatively.
(ii) To detect and evaluate the surface or sub-surface defects in raw materials or processed parts.
(iii) To check chemical composition.
(iv) To determine suitability of a material for a particular application.
(v) To predict the strength and serviceability of the materials.

Properties of Engineering Materials

- ✓ There are many thousands of different engineering materials available today. But they can be placed into one or other of the following categories:
  1. Metals,
  2. Polymers,
  3. Ceramics and inorganic glass, and
  4. Composites.
- ✓ All materials exhibit many different properties and qualities. The properties of material provide a basis for predicting its behaviour under various conditions.
- ✓ An engineer must have wide knowledge of materials and their properties so that he may select a suitable material for his product.
- ✓ Some of the most important properties of materials are grouped, as shown in Table below

Table. Material properties and qualities

S.No	Properties	Qualities
1	Physical properties	Colour, density, melting point, size, shape, surface, finish, dampingcapacity, specific gravity, porosity, structure.
2	Chemical properties	Corrosion resistance, atomic weight, equivalent weight, valency, molecular weight, acidity, alkalinity, atomic number, chemical composition.
3	Mechanicalproperties	Strength, elasticity, plasticity, ductility, brittleness, hardness, toughness, stiffness, resilience, creep.
4	Electrical properties	Resistivity, conductivity, capacitivity, dielectric constant, dielectricstrength.
5	Magnetic properties	Relative permeability, reluctivity, retentivity, susceptibility, hysteresis, coercive force.
6	Thermal properties	Specific heat, thermal capacity, thermal conductivity, thermal stresses, thermal fatigue, thermal shocks, latent heat.
7	Technologicalproperties	Malleability, machinability,castability, formability, weldability.
8	Aesthetic properties	Appearance, texture and ability to accept special finishes.
9	Economic properties	Raw material and processing costs, availability.
10	Other properties	Optical, acoustical, and physiochemical properties

CLASSIFICATION OF MATERIALS TESTS

The materials test may be grouped into two classes as:

1. Destructive tests, and
2. Non-destructive tests.

Destructive Tests

- ✓ In this type of testing, the component or specimen to be tested is destroyed and cannot be reused. After being destructively tested, the component or specimen either breaks or remains no longer useful for future use.
- ✓ As the name suggests, destructive testing (DT) includes methods where the component or specimen is broken down in order to determine physical and mechanical properties such as strength, toughness and ductility.
- ✓ Destructive testing is generally more suitable and economical for mass produced objects, as the cost of destroying a small number of pieces is negligible. It is usually not economical to do destructive testing where only one or very few items are to be produced.
- ✓ **Examples of destructive tests:** Destructive testing methods include mechanical testing, macro and micro testing as well as material analysis and metallographic examinations. Some of the commonly used destructive tests include:
    - i) Tensile test
    - ii) Compression test
    - iii) Shear test
    - iv) Hardness test
    - v) Impact test
    - vi) Fatigue test
    - vii) Creep test
    - viii) Bending test
    - ix) Torsion test

Non-Destructive Tests

- ➢ In this type of testing, the component or specimen to be tested is not destroyed and can be reused after the test.
- ➢ As its name implies, non-destructive testing means testing of components or specimens without destroying them.
- ➢ As defined already, non-destructive testing (NDT) is the process of inspecting, testing, or evaluating materials, components sub-assemblies for discontinuities or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection or test is completed, the part can still be used.

Applications of NDT:

The non-destructive tests are used:

- ▪ To ensure product integrity and reliability.
- ▪ To control manufacturing processes.
- ▪ To lower production costs.
- ▪ To maintain a uniformity in quality level.

- ➢ NDT tests can be performed on part:
    - (i) during manufacture, or
    - (ii) after manufacture, or
    - (iii) even on parts that are already in service.
- ➢ **Features of NDT:**
    - ▪ Using NDT, an entire production lot can be inspected, or selected samples can be inspected.
    - ▪ Also different tests can be applied to the same item, either simultaneous or sequentially, and the same test can be repeated on the same specimen for additional verification.
    - ▪ It may be added that the NDT equipment is often portable. This permits the use of NDT methods for on-site testing in most locations.
- ➢ Because NDT does not permanently alter the specimen being inspected, it is a high valuable technique that can save both time and money in product evaluation, trouble shooting, and research.
- ➢ Non-destructive tests make components more reliable, safe and economical.
- ➢ **Objectives of NDT:** The main objectives of non-destructive tests include:

    (i) To detect internal or surface flaws.

    (ii) To measure the dimensions of the specimen.

    (iii) To determine a material's structure or chemistry.

Basic elements of non-destructive testing:

The four basic elements in any non-destructivetesting are as follows.

i) Source or probing medium • Source can be some probing medium that can be used to inspect the specimen undertest. • The source/probing medium can be liquid penetrant, magnetic particle, ultrasonic wave, radiations, etc. • This probing medium must be changed or modified as a result of which the discontinuities with the specimen can be studied.
ii) Detector • A sensitive detector or sensor which is capable of detecting the changes in the probing medium.
iii) Recorder • A recorder or indicator is used to indicate or record the response from the detector.
iv) Interpretation • Various means of interpreting the recorded results through peaks, graphs, bar diagrams,etc.

- **Non-destructive testing methods:** There are number of NDT methods are being employed in practice. Some of the most commonly used NDT methods are:

1. Visual inspection	6. Ultrasonic testing
2. Liquid penetrant testing	7. Acoustic emission testing
3. Magnetic particle testing	8. Radiographic testing
4.Thermography	9. Laser testing
5. Eddy current testing	10. Leak testing

Comparison between Destructive and Non-Destructive Tests

Table presents the comparison between destructive and non-destructive tests, highlighting their advantages and limitations.

Table. Destructive tests Vs. Non-destructive tests

S.No.	Comparison Item	Destructive Tests	Non-Destructive Tests
1	Definition	In this type of testing, the component or specimen to be tested is destroyed and cannot bereused after the test.	In this type of testing, the component or specimen to be tested is not destroyed and can be used after the test.
2	Examples	i) Tensile test ii) Compression test iii) Shear test iv) Hardness test v) Impact test vi) Fatigue test vii) Creep test viii)Bending test ix) Torsion test x) Chemical analysis, etc	i) Visual inspection ii) Liquid penetrant test iii)Magnetic particle testingiv)Thermography v) Eddy current vi) Ultrasonic testing vii)Acoustic emission testing viii)Radiographic testing ix) Leak testing x) Laser testing, etc
3	Suitability	DT is generally performed when the component or specimen can no longer be used in service or is readily replaceable.	NDT can be performed on component or specimen which is in service.

4	Advantages	1. Provides a direct and reliable measurements. 2. Provides quantitative measurements. 3. Result interpretation is easy. 4. Can be performed without very high skilled personnel. 5. Correlation between test measurements and material properties is direct.	1. Tests are done directly on theobject. 2. 100% testing (or representative samples) on actual components canbe performed. 3. Different NDT methods can be applied on the same component and hence many or all properties of interest can be examined. 4. A non-destructive test can be repeated on the same specimen. 5. Can be performed on componentswhich are in service. 6. Little or no specimen preparationis required. 7. The test equipment is oftenportable. 8. Labour costs are usually low. 9. Most NDT methods are quick.
5	Limitations	1. Tests are performed only to a sample and the sample may not be a representative of the group. 2. Tested parts are destroyed during testing. 3. Usually cannot repeat a test on the same specimen. 4. Usually cannot use the same specimen for multiple destructive testing. 5. May be restricted for costly or few in-number parts. 6. Difficult to predict cumulative effect of service usage.	1. Measurement is indirect. 2. Reliability is to be verified. 3. Measurements are often qualitative or comparative. 4. Result interpretation is oftendifficult. 5. Skilled personnel are required fortesting and result interpretation. 6. Different observers may interpretthe test results differently. 7. Some test equipment requires alarge capital investment.

OVERVIEW OF DESTRUCTIVE TESTS

The overview of major destructive tests is briefly presented below.

Tensile Test

- The tensile test is one of the most widely used of the mechanical tests.
- A tensile test of a material is performed on ductile materials to determine tensile properties suchas:
  (i) Limit of proportionality,
  (ii) Yield point or yield strength,
  (iii)Maximum tensile strength,
  (iv) Breaking strength,
  (v) Percentage elongation, (vi) Percentage reduction in area, and (vii) Modulus of elasticity.
- The tensile test is usually carried out with the help of a 'Universal Testing Machine' (UTM).

Arrangement

- The material to be tested, also known as a specimen, is machined to standardized dimensions, as shown in fig
- A typical specimen has a diameter of 12.6 mm and gauge length of 50 mm.

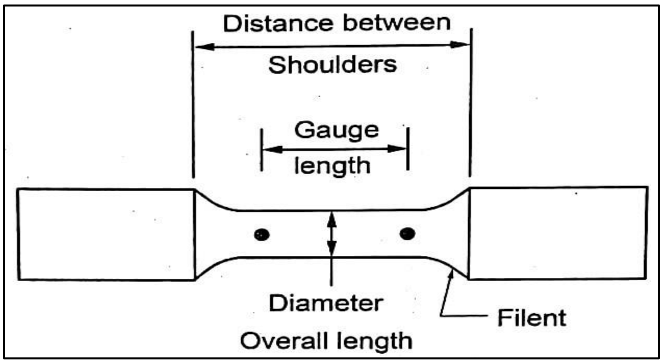


Figure. Standard tension specimen

❖ A schematic working arrangement of a universal testing machine is shown in Fig.

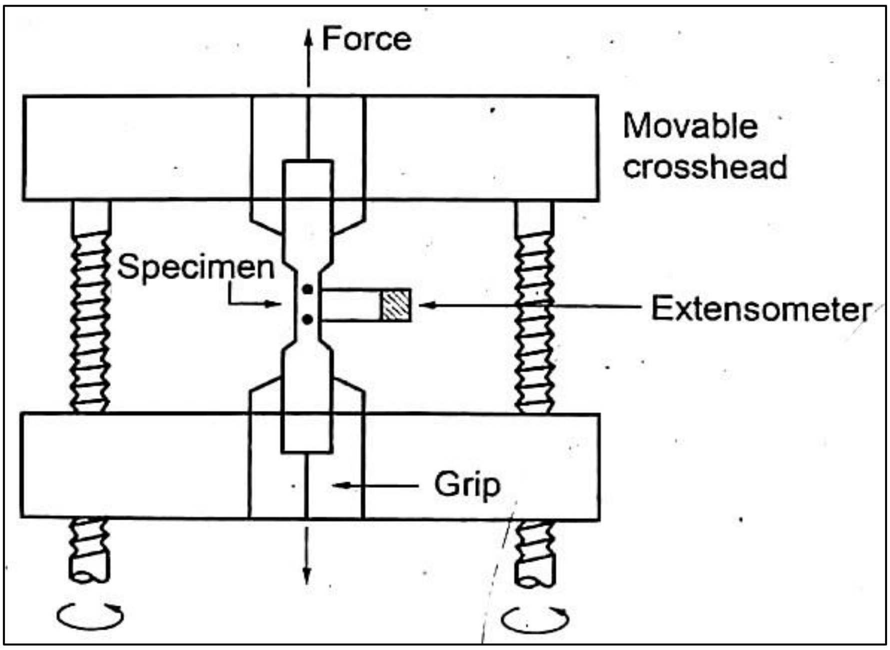


Figure. Universal testing machine

Schematic arrangement of a UTM.

❖ The specimen is elongated by the moving cross head; load cell and extensometer measure themagnitude of the applied load and the elongation respectively.

Testing Procedure

✓ The specimen to be tested is fastened to the two end-jaws of the UTM. Now the load is applied gradually on the specimen by means of the movable cross head, till the specimen fractures.

✓ During the test, the magnitude of the load is measured by the load measuring unit (load cell). A strain gauge or extensometer is used to measure the elongation of the specimen between the gauge marks when the load is applied.

✓ Then the different values of load and elongation at different intervals are recorded and tabulated.By using the tabulated data, the stress-strain curve can be plotted.

Compression Test

✓ The compression test is conducted in a manner similar to the tensile test, except that the force iscompressive.

✓ Since brittle materials are unsuitable for tension test, therefore they are tested for compression.

✓ Brittle materials such as cast iron, concrete, mortar, brick and ceramics are commonly tested incompression.

✓ The compression test is also conducted on a universal testing machine.

Hardness Tests

- ✓ **Hardness defined:** Hardness may be defined as the ability of a material to resist scratching,abrasion, cutting or penetration.
- ✓ The hardness test is performed on material to know its resistance against indentation andabrasion.

Types of Hardness Tests

The three most commonly used hardness tests are:

1. Brinell hardness test,
2. Vickers hardness test
3. Rockwell hardness test.

Basic Common Principle

The three hardness tests have the same basic principles as below:

- ✓ An indenter is pressed into the surface of the material by a slowly applied known load, and theextent of the resulting impression is measured mechanically or optically.
- ✓ A large impression for a given load and indenter indicates a soft material, and a small impressionindicates a hard material.

1. Brinell Hardness Test

- In the Brinell test, a hardened steel ball indenter is forced into the surface of the metal to be tested. The diameter of the hardened steel (or tungsten carbide) indenter is 10 mm. Standard loads range between 500 kg and 3000 kg in 500 kg increments. During a test, the load is maintained constant for 10 to 15 seconds.

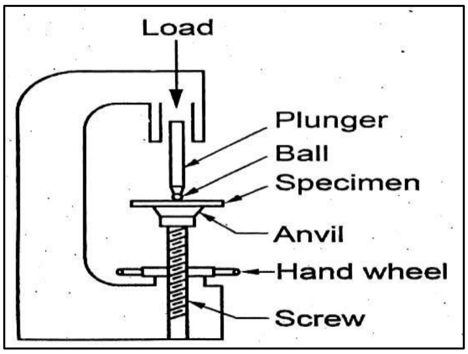


Figure. A Brinell hardness testing machine

- The Brinell's Hardness test is performed by pressing a steel ball, also known as indenter, into the specimen, as shown in figure

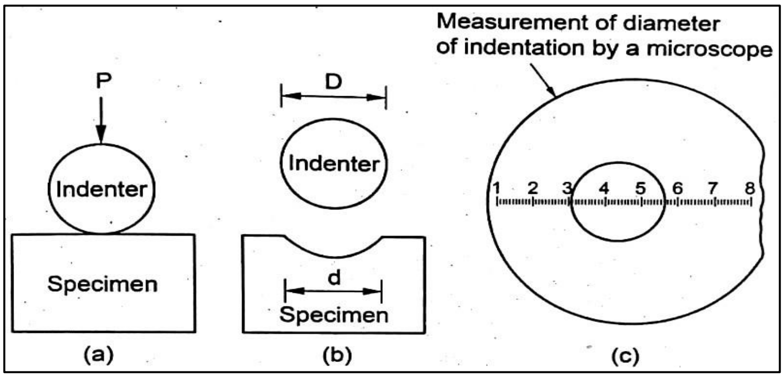


Figure. Brinell hardness test

- The diameter of the resulting impression is measured with the help of a calibrated microscope.

Vickers Hardness Test

- The Vickers hardness test is similar to the Brinell test, with a square-based diamond pyramid beingused as the indenter.
- As in the Brinell test, the indenter is forced into the surface of the material under the action of a static load for 10 to 15 seconds.
- The standard indenter is a square pyramid shape with an angle of 136° between opposite faces. This angle was chosen because it approximates the most desirable ratio of indentation diameter to ball diameter in the Brinell hardness test.
- An advantage of the Vickers test over the Brinell test is that the accuracy is increased in determining the diagonal of a square as opposed to the diameter of a circle, as shown in Figure.

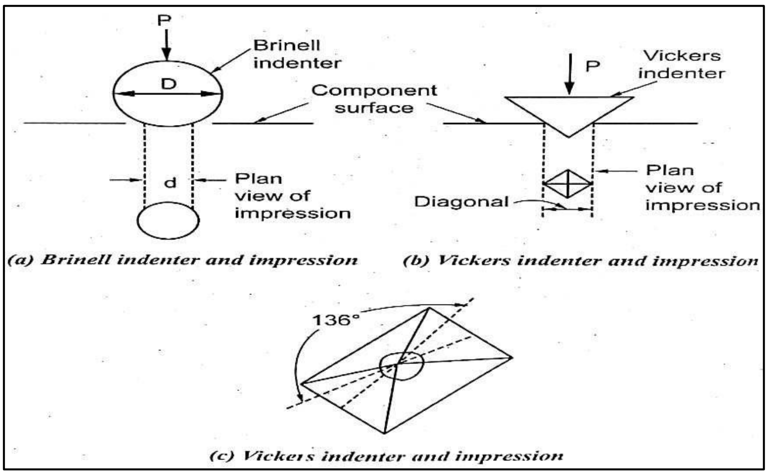


Figure. Brinell Vs. Vickers indenter and impression

- **Vickers hardness number:** The diamond-pyramid hardness number (DPH) or Vickers hardness number (VHN or VPH) is defined as the applied load divided by the surface area of indentation.

2. Rockwell Hardness Test

- The Rockwell hardness test is probably the most widely used methods of hardness testing.

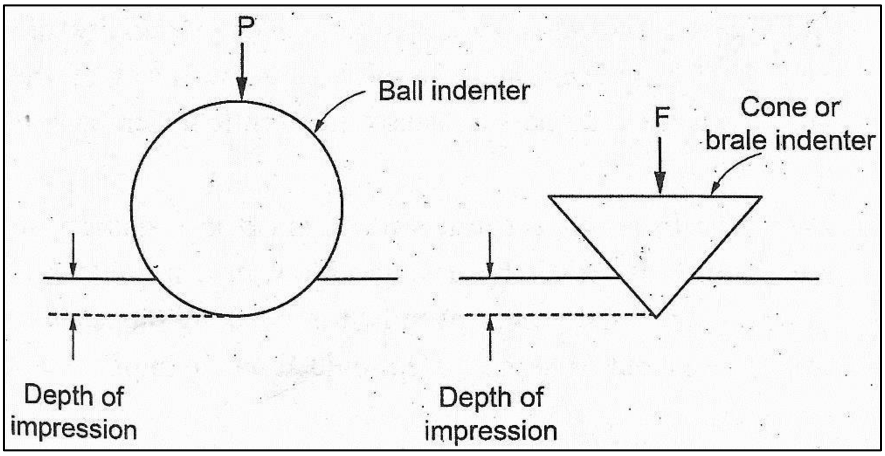


Figure. Rockwell Indenter

- The principle of the Rockwell test differs from that of the others is that of the depth of the impression is related to the hardness rather than the diameter or diagonal of the impression, as shown in Fig. Rockwell tests are widely used in industries due to its accuracy, and rapidity. In this test, the dial gives a direct reading of hardness; no need for measuring indentation diameter or diagonal length using the microscope.

Impact Tests

- The impact test is performed to study the behaviour of materials under dynamic load i.e., suddenly applied load.
- Impact strength defined: The capacity of a metal to withstand blows without fracture is known asimpact strength or impact resistance.
- The impact test indicates the toughness of the material i.e., the amount of energy absorbed by the material during plastic deformation.
- The impact test also indicates the notch sensitivity of a material. The notch sensitivity refers to the tendency of some normal ductile materials to behave like brittle materials in the presence ofnotches.
- Principle: In an impact test; a notch is cut in a standard test piece which is struck by a single blowin a impact testing machine. Then the energy absorbed in breaking the specimen can be measuredfrom the scale provided on the impact testing machine.
- The schematic arrangement of the impact testing machine is shown in Figure.

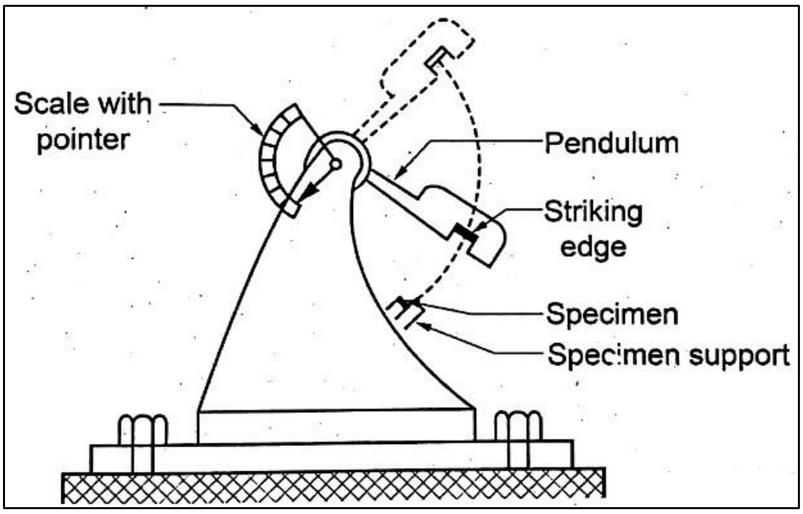


Figure. Impact testing machine

Types of Impact Tests

- Based on the types of specimen used on impact testing machine, the impact tests can be classifiedinto:
  1. Izod test, and
  2. Charpy test.
- It can be noted that the impact testing machines are designed so that both types of test can beperformed on the same machine with only minor adjustments.

1. Izod Test

- Izod test uses a cantilever specimen of size 75 mm x 10 mm x 10 mm, as shown in Fig. 1.8(a). TheV-notch angle is 45° and the depth of the notch is 2 mm.
- The Izod specimen is placed in the vise such that it is a cantilever, as shown in Figure

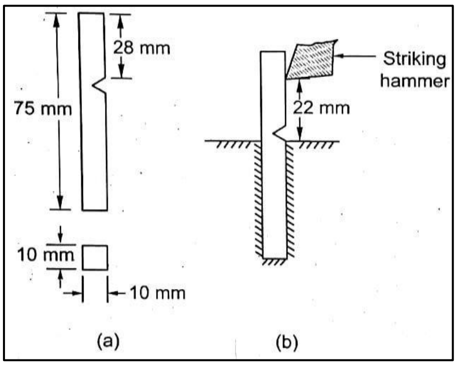


Figure. Specimen for Izod test

2. Charpy Test

- The Charpy test uses a test specimen of size 55 mm x 10 mm x 10 mm, as shown in Figure. The V-notch angle is 45° and the depth of the notch is 2 mm..
- The Charpy specimen is placed in the vise as a simply supported beam, as shown in Figure.

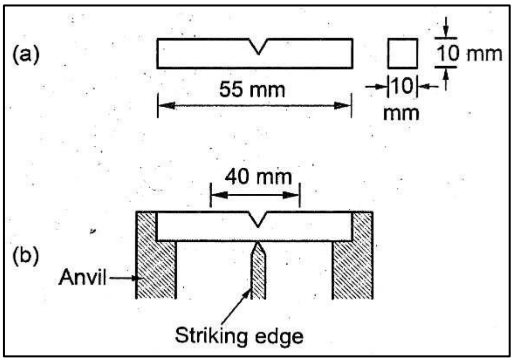


Figure. Specimen for Charpy test

Testing Procedure

The general procedure to conduct an impact test is given below:

1. The specimen is placed in the vice of anvil.
2. The pendulum hammer is raised to known standard height depending on the type of specimen to betested.
3. When the pendulum is released, its potential energy is converted into kinetic energy just before itstrikes the specimen.
4. Now the pendulum strikes the specimen. It may be noted that the Izod specimen is hit above the V-notch and the Charpy specimen will be hit behind the V-notch.
5. The pendulum, after rupturing the specimen, rises on the other side of the machine.

ENGINEERING BRIEF ON DISCONTINUITIES

What are Discontinuities?

- *Whenever there is a change in the homogeneity of properties within a material, it can invariably be attributed to the presence of **discontinuities** or **imperfections** within the material.*
- Engineering materials always possess some discontinuities, although they may be very small andthey may or may not be acceptable.
- **Examples of discontinuities include:**
  - Voids
  - Inclusions
  - Laps
  - Folds
  - Cracks
  - Porosity
  - Chemical segregation
  - Local change in microstructure
- Sharp transitions in surface homogeneity, continuity, and contour are also considered to be "discontinuities" on component surfaces. Geometric surface discontinuities include sharp angles,notches, gouges, scratches, galling, fretting, pitting, and welding undercut.
- Discontinuities in engineering structures are unacceptable when they degrade the performance or durability of the structure below the expectations of design and when they challenge the operability, reliability, and life of a component.
- Discontinuities are evaluated completely by determining their location, number, shape, size, orientation, and type.
- An understanding of the origin of discontinuities is useful in determining the type and features of discontinuities that may be expected in a component. Awareness of the characteristics, locations, and orientations of discontinuities is most helpful and sometimes critical in their detection and evaluation.

Types of Discontinuities

Discontinuities can be divided into three general categories based on the stage in processing at which they are introduced as:

1. Inherent discontinuities,
2. Processing discontinuities, and
3. Service-induced discontinuities.

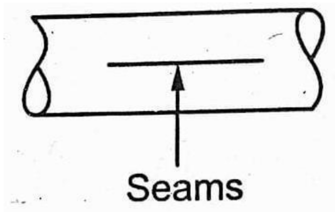
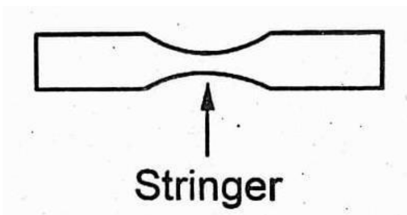
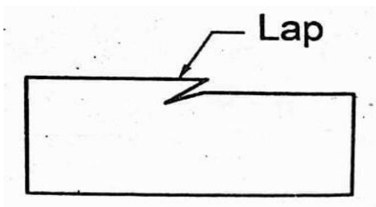
Inherent Discontinuities

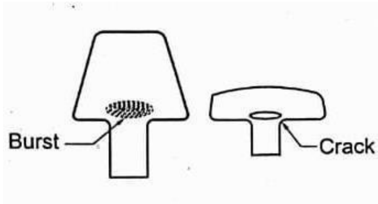
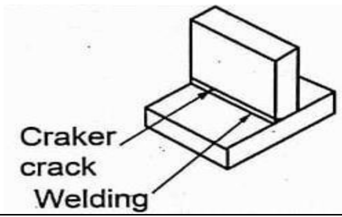
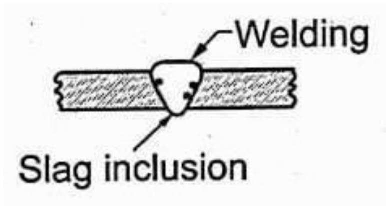
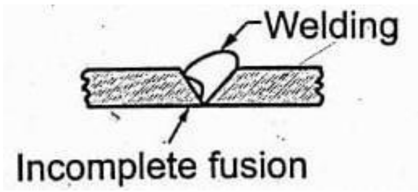
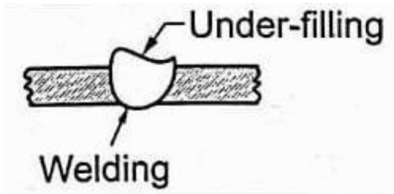
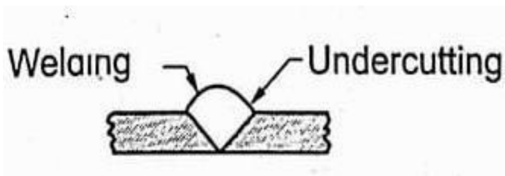
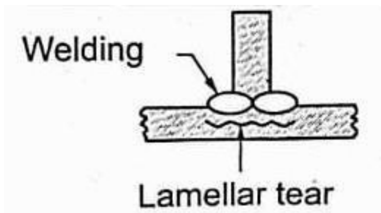
- ✓ An "inherent discontinuity" is one that is generated in the original production of an alloy stock material.
- ✓ Inherent discontinuities are usually formed when the metal is molten. There are two further sub classifications:
    - o Inherent wrought discontinuities relate to the melting and solidification of the original ingot before it is formed into slabs, blooms, and billets.
    - o Inherent cast discontinuities relate to the melting, casting and solidification of a cast article.

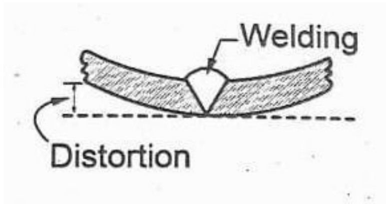
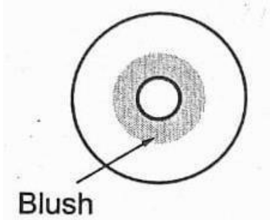
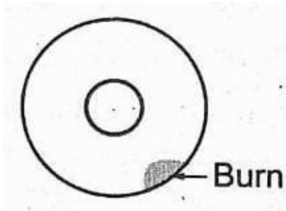
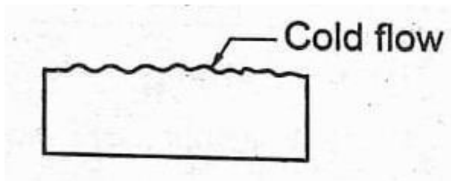
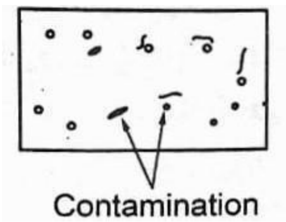
Processing Discontinuities

- ❖ Processing discontinuities are usually related to the various manufacturing process such as machining, forming, extruding, rolling, welding, heat treating, and plating.
- ❖ During the manufacturing process, many discontinuities that were subsurface will be made opento the surface by machining, grinding, etc.
- ❖ For instance, discontinuities generated during welding are called "welding discontinuities". Any discontinuities caused by casting may be called "casting discontinuities," and discontinuities generated in forging obviously would be "forging discontinuities".
- ❖ Table illustrates some of the common processing discontinuities.

<u>Processing discontinuities</u>

Fabrication and Processing Discontinuities		
1	**Seams:** These are surface discontinuities and appears as longitudinal scratches or folds in the material.	
2	**Stringers:** These are non metallic inclusions in slabs or billets that are thinned and lengthened in direction of rolling.	
3	**Laps:** These are discontinuous the irregular contours caused by the folding of metal in a thin plate on the surface at forged product.	

4	**Forging bursts or cracks:** It occurs when a material is forged at a temperature at which it can't withstand at high internal stress.	
	Welding Defects	
5	**Crater crack:** When a welding arc is broken, a crater will form if adequate molten metal is available to fill the arc cavity.	
6	**Slag inclusion:** It occurs when compound such as oxides, fluxes and electrode coating material that are trapped in the weld zone.	
7	**Incomplete fusion:** It occurs, when depth of welded joints is insufficient.	
8	**Under-filling:** It occurs when joints are notfilled property.	
9	**Undercutting:** It occurs due to melting awayof the base metal.	
10	**Lamellar tears:** It occurs due to shrinkage of the restrained members in the structure during cooling.	

11	**Distortion and wrapping:** They to occur differential due thermal expansion and contraction of different regions of the welded assembly.	
	Miscellaneous Processing Discontinuities	
12	**Blush:** It causes due to shear stress between molecules during injection and may be due to small gate or fast injection speed.	
13	**Burn:** It is a discoloration usually or dark, depending severity. black, brown yellow/brown upon the severity	
14	**Cold flow:** It is a wavy or streaked appearance on part surface. Looks like a fingerprint or small waves like waves on the surface of water.	
15	**Contamination:** Foreign particles embedded in the part.	

Service-Induced Discontinuities

- The discontinuities that are created during the use of a component are called "service-induceddiscontinuities".
- Service discontinuities are related to the various service conditions, such as stress, corrosion,fatigue and erosion.
- The discontinuities may after the local stress distribution and, in addition, may affect themechanical or chemical (corrosion resistance) properties.
- Table presents some of the common service induced discontinuities.

<u>Service-induced discontinuities</u>

1. Wear

- ✓ It is the undesired removal of material caused by contacting surface through mechanical action.
- ✓ The different types of wear are abrasive, erosive, grinding, gouging, adhesive and fretting.

2. Corrosion
✓ It is the deterioration of a metal resulting from electrochemical reactions with its enrolment. ✓ It may be noted that wear is mechanical in origin, whereas corrosion is chemical in origin. ✓ The different types of corrosion are galvanic, uniform, crevice and erosion.
3. Fatigue cracking
✓ Fatigue can cause the failure of a material or component under repeated, fluctuating stresses. ✓ The main types of fatigue are mechanical fatigue and thermal fatigue.

Discontinuity vs. Defect vs. Flaw

Though the terms discontinuity, defect, and flaw are used interchangeably in practice, technically theycan be differentiated as below.

- ✓ Discontinuity is a lack of continuity or cohesion; it is an intentional or unintentional interruption in the physical structure or configuration of a material or component.
- ✓ Flaw is an imperfection or discontinuity that may be detectable by non-destructive testing and isnot necessarily rejectable.
- ✓ Defect is one or more flaws whose aggregate size, shape, orientation, location, or properties do not meet specified acceptance criteria and are rejectable.
- ✓ In other words, if the discontinuities turn out to be rejectable according the criteria specified in the applicable documents, then these as termed as 'defects'.
- ✓ *A discontinuity will survive a field fast while a defect won't*. For example, a crack on a water pipe would be a defect since the water will leak while an acceptable profile could pass as a discontinuityas long as the pipe doesn't leak.

OVERVIEW OF NON-DESTRUCTIVE TESTING METHODS

The overview of commonly used non-destructive testing methods is briefly presented below.

Visual Inspection

What is it?

- ❖ Visual inspection is the simplest, fastest, and most widely used non-destructive testing method.
- ❖ Visual inspection is carried out with the naked eye (unaided) or using some optical aids (aided) such as mirrors, magnifying glasses, and microscopes.

Definition:

Visual Inspection is commonly defined as "the examination of a material, component, or product for conditions of non-conformance using light and the eyes, alone or in conjunction with various aids".

- ✓ Visual inspection often also involves shaking, listening Feeling and sometimes even smelling the component being inspected.
- ✓ Visual inspection is commonly employed to support/compliment other NDT methods.
- ✓ Digital detectors and computer technology have made it possible to automate some visual inspections. This is known as **machine vision inspection.**

Characteristic Detected (Applicability)

The visual inspection is commonly used:

(i) To detect surface characteristics such as finish, scratches, cracks or color.
(ii) To check stain in transparent
(iii) To inspect corrosion.

Principle

- ✓ Seeing believes and the art of seeing is the visual inspection technique.
- ✓ Visual testing requires adequate illumination of the test surface and proper eye-sight of the tester.
- ✓ The test specimen is illuminated and the test surface is observed and examined. Wherever required, the optical aids such as mirrors, magnifying glasses, microscopes, video cameras and computer-vision systems can be employed.

Advantages

Some of the advantages of visual testing are as follows:

- ❖ Simple and easy to use.
- ❖ Relatively inexpensive.
- ❖ Testing speed is high.
- ❖ Testing can be performed on components in-service.
- ❖ Permanent records are available when latest equipment is used.

Limitations

Some of the limitations of visual testing are as follows:

- ❖ The test results depend on skill and knowledge of tester.
- ❖ Limited to detection of surface flaws.
- ❖ Eye resolution is weak.
- ❖ Eye fatigue.

Applications

Typical applications of visual inspection include:

- ❖ Checking of the surface condition of the component.
- ❖ Checking of alignment of muting surfaces.
- ❖ Checking of shape of the component.
- ❖ Checking for evidence of leaking
- ❖ Checking for internal side defects.

Liquid Penetrant Testing

- ❖ Liquid penetrant method is an effective method of detecting surface defects in metals and other non-porous material surfaces.
- ❖ It detects flaws that are open to the surface e.g., cracks, seams, laps, lack of bond, porosity, cold shut etc.
- ❖ It can be effectively used for the inspection of:
  i) Ferrous metals,
  ii) Non-ferrous metals, and
  iii) Non-porous, non-metallic materials such as ceramics
- ❖ This method is widely used for testing of non-magnetic materials.

Characteristics Detected (Applicability) Liquid penetrant testing is widely used:

- ❖ To locate cracks, porosity, and other defects that breaks the surface as a material and has enough volume to trap and hold the penetrant material.
- ❖ To inspect large areas very efficiently and will work on most non-porous materials.

Principle

- ❖ The principle of liquid penetrant tests is that the liquid penetrants are drawn into surface flaws such as cracks or porosities by capillary action. Then the developer material in conjunction with visual inspection reveals the surface flaw.
- ❖ In this testing, "penetrant' and 'developer' are used.
  - **Penetrant** is a liquid capable of testing the entire surface and being drawn into the openings. Usually brightly colour eddies or fluorescent materials are used as penetrants.
  - **Developer** is an absorbent material capable of drawing traces of penetrants from the defects back onto the surface.
- ❖ Illustrates a typical sequence of operations for liquid penetrant inspection to detect the presence of surface flaw in a work piece.

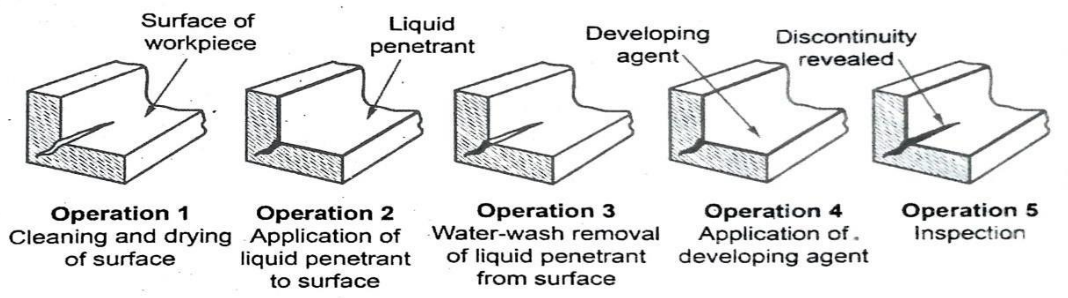


Figure. Principle of Liquid Penetrant Testing

Advantages

Some of the advantages of liquid penetrant testing are as follows:

(i) Sample and easy to use.
(ii) Inexpensive and versatile.
(iii) Highly portable.
(iv) Highly sensitive to fine, tight discontinuities.
(v) Applicable to variety of materials.
(vi) Applicable to complex shapes.
(vii) Large surface areas or large volumes of parts/materials can be inspected rapidly and at low cost.

Limitations

Some of the limitations of liquid penetrant testing are as follows:

- ✓ It can only detect flaws that are open to the surface.
- ✓ It cannot be used on porous and very rough surfaces
- ✓ Surface preparation (before testing) is critical contaminants can mask defects. So test surface must free of all dirt, oil, grease, paint, rust, etc.
- ✓ Deformed surfaces and surface coatings may detection.
- ✓ it is required to remove all penetrant materials after test
- ✓ Chemical handling precautions are necessary (toxicity, fire, waste)

Applications

Typical applications of liquid penetrant testing are:

- ✓ Inspection of tools and dies.
- ✓ Inspection of tanks, vessels, reactors, piping, dyers, and pumps in the chemical, petrochemical, food, paper, and processing industries.
- ✓ Inspection of diesel locomotive, truck, and automobile parts (such as axles, wheels, gears, crankshaft, cylinder blocks, connecting rods, cylinders, transmissions, and frames).
- ✓ Inspection of field drilling rigs, drill pipe, castings, and drilling equipment.
- ✓ Inspection of aircraft engine parts, propellers, wing fittings, castings and so on.

Magnetic Particle Testing

What is it?

- ✓ Magnetic particle testing is used for the testing of materials which can be easily magnetized.
- ✓ This method is capable of detecting surface and subsurface flaws such as cracks and inclusions**.**
- ✓ This method can be used for testing of ferromagnetic materials (such as Iron, steel, nickel, and cobalt alloys).
- ✓ The nonferrous metals (such as aluminium, magnesium, copper, lead, tin, and titanium) and the ferrous (but not ferromagnetic) austenitic stainless steel cannot be inspected using this method.
- ✓ It is a relatively simple, inexpensive and rapid technique. It is free from any restrictions as to size, shape, composition, and heat treatment of a ferromagnetic specimen.

Characteristics Detected (Applicability)

- ✓ The magnetic particle testing method is used extensively to detect surface and near surface cracks, voids, inclusions, or materials or geometry changes in ferromagnetic parts and materials.

Principle

- ✓ Illustrates the basic principle of magnetic particle testing method.
- ✓ Magnetic particle inspection is based on the principle that ferromagnetic materials, when magnetized, will have a distorted magnetic field in the vicinity of flaws and defects.
- ✓ The flaws and defects are revealed by the application of minute magnetic particles (such as dry iron powder or iron powder in suspension as a liquid).
- ✓ The magnetic particles are strongly attracted to surface regions where the flux is concentrated.
- ✓ This would create a visual indication approximating the size and shape of the flaw. The parts have to the demagnetized and cleaned after inspection.

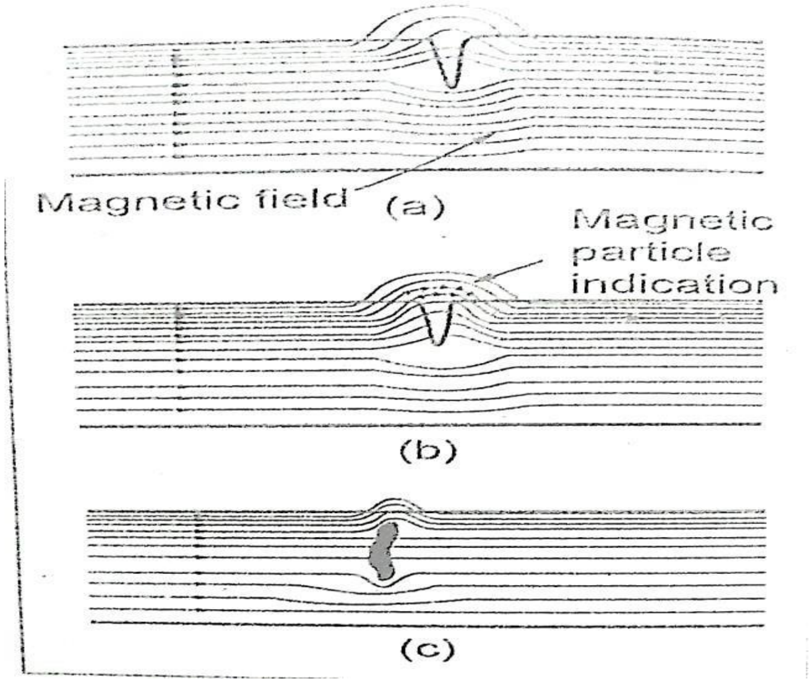


Figure. Principle of Magnetic Particle Testing

(a) Magnetic field showing disruption by a surface cru
(b) Magnetic particles are applied and are preferentially attracts to field leakage
(c) Subsurface defects can also produce surface detectable disruptions if they are sufficiently close to the surface

Thus the three procedural steps involved are:

(a) Magnetizing the test specimen.
(b) Applying magnetic particles on the test specimen, and
(c) Locating the defects.

Advantages

Some of the advantages of magnetic particle testing are as follows:

- ✓ It is relatively simple and fast.
- ✓ It can reveal both surface and subsurface flaws and inclusions.
- ✓ It is portable.
- ✓ Applicable to complex geometries.
- ✓ Applicable to any size of the component, as long as it can induce uniform magnetic fields within the piece.

Limitations

Some of the limitations of magnetic particle testing are as follows:

(i) Applicable only to ferromagnetic materials.
(ii) Alignment of the flaw and the field affects the sensitivity so that multiple inspections with different magnetizations may be required.
(iii) Can only detect defects at or near surfaces.
(iv) After testing, the part must be demagnetized and cleaned.
(v) High current source is required.
(vi) Paint or other nonmagnetic coverings adversely affect sensitivity.

Applications

Typical applications of the magnetic particle testing method include:

(i) Inspection of fans and blowers in thermal power plants.
(ii) Inspection of weld cracks.
(iii) Inspection of connecting rods.
(iv) Underwater inspections such as offshore structural welds, pipeline inspection and ship structures.

Thermography Testing

What is it?

- ✓ Thermography testing is a non-destructive testing (NDT) imaging technique that allows the visualization of heat patterns on an object
- ✓ Thermography is also called as **thermal imaging or infrared (IR) thermography.**
- ✓ Thermography enables the thermal profile of material c component to be presented in a graphic form which allows a working temperature assessment to be derived From this, variations in the material or component temperature are identified, using which the flaws/defects can be detected.
- ✓ Thermal inspection involves using contact and or non-contact type heat sensing devices to detect temperature changes.

Principle

- ✓ The basic principle of thermal inspection involves the measurement or mapping of surface temperatures when heat flows from, to, or through a test object. Temperature differentials on a surface, or changes in surface temperature with time, are related to heat flow patterns. These heat flow patterns can be used to detect flaws of the test object.
- ✓ For example, during the operation of a heating system, a hotspot detected at a joint in heating duct may be caused by a hot air leak.
- ✓ Usually, when the temperature differentials are greater, then the imperfection/flaw will be larger and closer to the surface.
- ✓ Detects in the work piece, such as cracks, deboned regions in laminated structures, and poor joints, cause a change in thermal distribution. Using the temperature differentials and heat flow patterns, the defects are detected.

Advantages

Some of the advantages of thermography testing are as follows:

- ✓ It can be carried out during normal operating conditions without stopping the system.
- ✓ The non-contact test method can be used from a safe distance.
- ✓ Visual picture of the components can be identified.
- ✓ Permanent record is possible.
- ✓ The results are available in real time and there is little or no processing needed.
- ✓ IR cameras are relatively cays to use.
- ✓ It can detect conditions of the equipment and defects before they become serious problems.
- ✓ The exact location of the defective zone can be easily

Limitations

Some of the limitations of the thermography testing are as follows:

- ✓ Interpretation of results needs a certain experience and knowledge.
- ✓ Higher accuracy on detection of defects can be difficult due to varying emissivity of the different materials.
- ✓ Comparatively cost of the equipment is high

Applications

Typical applications of the thermography testing include.

- Detection of defects in composites
- Inspection of impact damages in CFRP (carbon fibre reinforced polymer) panels.
- Detection of cracks in turbine components.
- Detection of corrosion in air craft parts.
- Inspection of drilling induced defects in laminates.
- Inspection of motors and rotating equipment.
- Inspection of surface cracks in method structures.
- Inspection of bearings wears due to misalignment.

Eddy Current Testing

What is it?

- Eddy Current Testing (ECT) is an electromagnetic non-destructive testing technique.
- This method can be used only on all electrically conducting materials.
- The eddy current testing is also known as inductive testing.

Characteristics Detected (Applicability)

This method is widely used to:

- To detect surface defects (seams laps, cracks, voids and inclusion).
- To sort dissimilar metals.
- To measure or identify properties such as electrical conductivity, magnetic permeability, grain size, hardness, and physical dimensions.
- To measure the thickness of a nonconductive coating on a conductive metal (or the thickness of a nonmagnetic metal coating on a magnetic metal).
- To measure case hardening depth.

Principle

- ✓ The eddy current tearing works on the basis of electromagnetic induction
- ✓ In this method, eddy currents are induced in a test object by bringing it close to on alternating current carrying coil. These eddy currents are normally parallel to the coil winding. The defects in the test object impede and change the direction of eddy currents and cause changes in the electromagnetic field. These changes affect the inspection coil, the voltage of which is monitored to determine the presence of defects.

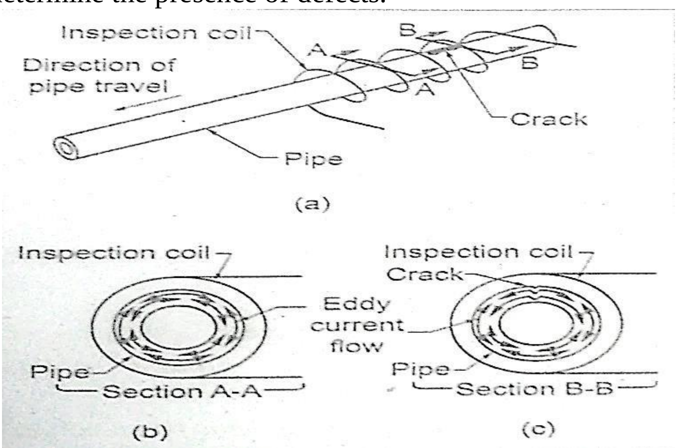


Figure. Principle of Eddy Current Testing

Advantages

Some of the advantages of eddy current testing are as follow.

- It can detect both surface and near-surface IR-regulations.
- It is quick to use and provides immediate results of inspection.
- It is versatile, as it can detect flaws, variations in alloy or heat treatment, variations in plating or coating thickness, wall thickness and crack depth.
- No physical contact required.
- It can be automated

- Low cost and portable.
- Pre- and post-treatment of the test object is not required.

Limitations

Some of the limitations of eddy current testing are as follows:

- ✓ Response is sensitive to a number of variables, so interpretation may be difficult.
- ✓ Only applicable to conductive materials, such as metals.
- ✓ Reference standards are needed for comparison.
- ✓ Highly skilled operators are required to perform inspection.
- ✓ It is not reliable on carbon steel for the detection of sub-surface flaws and also not suitable for large areas.
- ✓ Its depth of penetration is limited to 8 mm.
- ✓ Constant separation distance between coils and specimen is required for good results.
- ✓ No permanent record.

Applications

Typical applications of eddy current testing include:

- ✓ Detection and measurement of flaws in steering mechanisms, airplane landing gears, engine parts, reactor and steam generator turbines, aircraft wheels, aircraft wing structures, condenser pipes, turbine blades, etc.
- ✓ Detection and determination of the severity of various surface cracks, (stress, hardening. grinding, etc) weld seams, laps, pits, scabs, porosity, voids and inclusions.
- ✓ Measurement of coating and plating thickness.
- ✓ Detection and measurement of flaws in seamless, hot-rolled steel tubes; welded tubes; fastener holes, etc.
- ✓ Measurement of dimensional differences in machines, formed, or stamped parts.
- ✓ Determination of the hardness and depth of case hardening in bearing rings and other parts.

Ultrasonic Testing

What is it?

- ✓ Ultrasonic testing is one of the popular non-destructive testing methods,that uses the sound energy to determine the integrity of the test objects.
- ✓ Even from early days, sound has been used to provide indication of product quality. A cracked bell will not ring but a fine crystal goblet will have a clear ring when tapped lightly. This basic phenomenon is employed in ultras testing.
- ✓ In ultrasonic testing the very short range, high frequency ultrasonic waves (whose range lies between 0.5-20 MHz) are used for detection of surface and sub-surface flames in the test objects.
- ✓ The ultrasonic waves are usually generated by the piezoelectric effect which converts electrical energy to mechanical energy. A quartz crystal is used for this purpose.

Characteristics Detected (Applicability)

The ultrasonic testing method is used:

- ✓ For detection of flaws in materials.
- ✓ For measurement of thickness.
- ✓ For the determination of mechanical properties and grain structure of materials.

Principle

- ✓ In ultrasonic inspection, an ultrasonic beam travels through the test object. An internal defect, such as crack, interrupts the beam and reflects back a portion of the ultrasonic energy. The amplitude of the energy reflected, and the time required for return, indicates the presence and location of any flaws in the test object.
- ✓ Illustrates as typical simple ultrasonic inspection of a float plate.
- ✓ The ultrasonic inspection employs sending separate probes namely transducer and receiving transducer.
- ✓ Depicts the plot of sound intensity or transducer voltage versus time showing the initial pulse and echoes from the bottom surface and intervening defect.

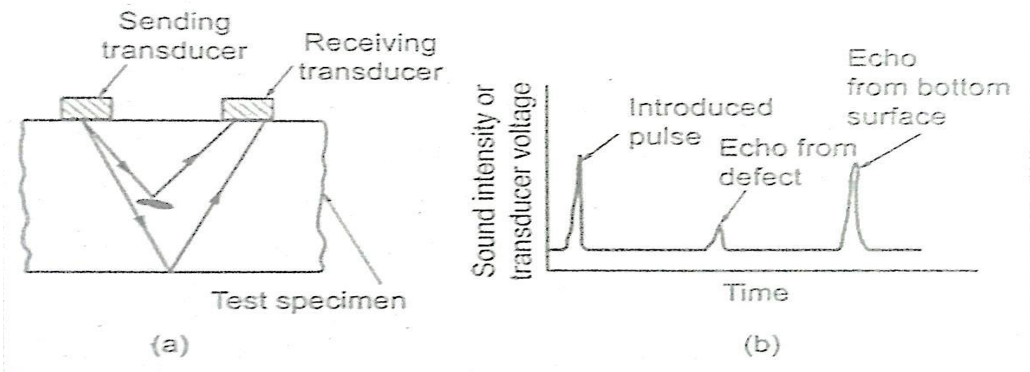


Figure. Ultrasonic inspection of a flat plate

Advantages

Some of the advantages of ultrasonic testing are as follows:

- ✓ High sensitivity, greater accuracy than other methods in determination of internal defects.
- ✓ High-speed test with immediate test results.
- ✓ Portable device.
- ✓ It can be automated and recorded.
- ✓ High penetration in most important materials (upto 60 ft in steel).
- ✓ It indicates both flaw size and location. (viii) It requires access to only one surface of the test object.
- ✓ It presents no radiation or safely hazard.

Limitations

Some of the limitations of ultrasonic testing are as follows

(i) Surface must be accessible to transmit ultrasound.
(ii) Rough and uneven scanning surfaces can reduce the effectiveness of the test.
(iii) A couplant is required to promote the transfer of sound energy into the test specimen. Trained and experienced operators are required.
(iv) Defect orientation affects defect detestability.
(v) Unfavourable geometry of the test object causes problems.

Applications

Typical applications of ultrasonic testing method include.

(i) Inspection of large castings and forging, for internal soundness, before carrying out expensive machining operations.
(ii) Inspection of moving strip or plate for laminations as regards its thickness.
(iii) Routine inspection of locomotive axles and wheel pins for fatigue cracks.
(iv) Inspection of rails for bolt-hole breaks without dismantling rail-end assemblies.

Acoustic Emission Testing

What is it?

- ✓ The Acoustic Emission (AE) test is a Non-Destructive Test (NDT) method generally used to detect and locate imperfections in mechanically loaded structures and components.
- ✓ The acoustic emission testing is based on the fact that solid materials emit sonic or ultrasonic acoustic emissions when they are mechanically or thermally stressed to the point where deformation or fracturing occurs. By detecting these sounds through the use of electronic devices, the flaws can be detected.
- ✓ The acoustic emission in the sound form is to the cars visual inspection is to the eyes.

Characteristics Detected (Applicability)

The acoustic emission is used:

1. To detect and locate imperfections to mechanically loaded structures and components.
2. To detect the formation of cracks in materials during production operations.

Principle

- ✓ Almost all materials will emit high frequency sound (acoustic emissions) when stressed, deformed, or undergoing structural changes, such as the formation or growth of a crack or defect. These emissions can now be detected and provide an indication of dynamic change within the material.
- ✓ Illustrates the process of generation and detection of acoustic emissions.

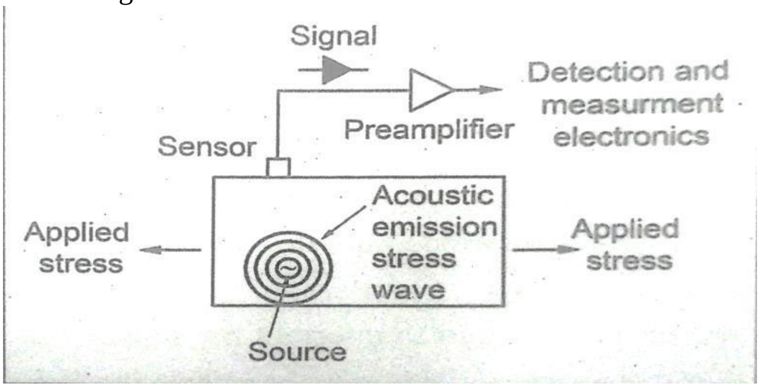


Figure. Principle of Acoustic Emission Testing

BASIC PRINCIPLE OF THE ACOUSTIC EMISSION METHOD

- ✓ Sudden movement at the source produces a stress wave (acoustic emissions), which radiates out into the structure and excites a sensitive piezo electric transducer.
- ✓ As the stress is the material is increased, many of these emissions are generated. The signals from one or more sensors are amplified and measured to produce data for display and interpretation

Advantages

Some of the advantages of acoustic emission testing method are as follows:

- ✓ The entire structure can be monitored with near instantaneous detection and response.
- ✓ In this method, only 'active' flaw scan be detected.
- ✓ Defects inaccessible to other methods can be detected.
- ✓ It can be performed in severe environments.
- ✓ Real time evaluation and remote scanning is possible.
- ✓ Less intrusive.
- ✓ Less geometry sensitive.

Limitations

- ✓ Some of the limitations of acoustic emission testing method are as follows:
- ✓ Only growing flaws can be detected (i.e. the mere presence of defects is not detectable).
- ✓ There is no indication of the size or shape of the flaw.
- ✓ Influence of ambient noise and attenuation of signals may result in poor output.
- ✓ Sophisticated data processing devices are required.
- ✓ Poor repeatability.
- ✓ Experience is required to interpret the signals.
- ✓ Size and shape of the component affects the strength of the emission signals that reach the detector.

Applications

Typical applications of acoustic emission testing method are as follows:

- ✓ AE testing is employed in many industries such as refineries, pipelines, power generation, structural, and aircraft.
- ✓ AE testing and evaluation is also used by offshore oil platforms and paper mills.
- ✓ Structures frequently tested using AE method include bridges, tunnels, towers, tanks, pipes, cranes and heavy industrial equipment.

Radiography Testing

What is it?

- ✓ Radiography testing is one of the most important, versatile and widely accepted of all the non-destructive examination methods.

- ✓ The radiographic testing method is commonly used for the detection of internal flaws such as cracks and porosity in many different materials and configuration.
- ✓ In radiography testing, X-ray or gamma ray is used to determine the internal soundness of the metal: hence it is also called as X-ray or **gamma ray testing**.
- ✓ Radiographic inspection employs the same principles and techniques as those of medical X-rays

Characteristics Detected (Applicability)

The radiography testing method is used:

- ✓ To inspect almost any material for surface and sub-surface defects.
- ✓ To locate and measure internal features:
- ✓ To confirm the location of hidden parts in an assembly.
- ✓ To measure the thickness of materials.

Principle

- ✓ Radiography uses an X-ray or gamma ray as a source of radiation which passes through the test object and is captured on film or digital device.
- ✓ After processing the film, an image of varying density is obtained. Using the image, possible imperfections are identified through density changes.

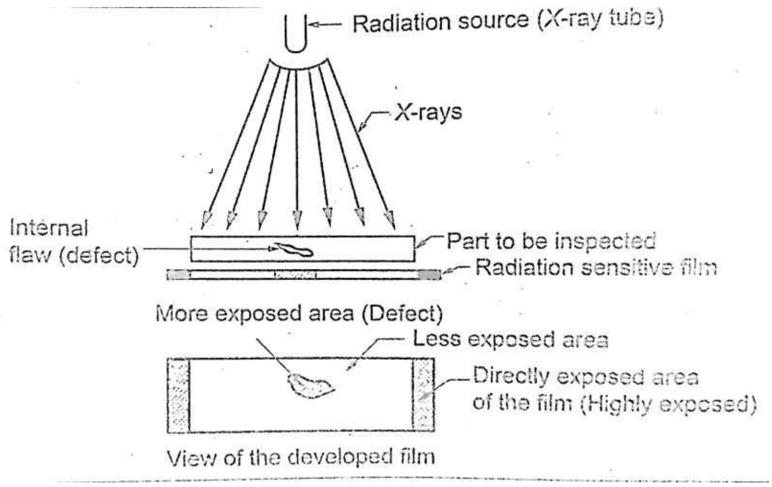


Fig. Principle of Radiography Testing

Advantages

Some of the advantages of radiography testing method are as follows:

- ✓ Wide variety of materials can be inspected.
- ✓ Minimum surface preparation is required.
- ✓ Sensitivity to changes in thickness, corrosion, voids and cracks.
- ✓ Both surface and sub surface defects can be detected.
- ✓ Provides permanent record of inspection.
- ✓ It can inspect complex shapes and multi-layered structures without disassembly.

Limitations

Some of the limitations of radiographic testing method are as follows:

- ✓ Most costly of the NDT methods (as it involves expensive equipment, film and processing).
- ✓ Access to both sides of the specimen is required.
- ✓ It cannot detect planar defects readily.
- ✓ Orientation of the specimen is critical to assess the defects.
- ✓ Determination of flaw depth is impossible without additional angled exposures.
- ✓ Extensive operator training and skill required.
- ✓ Additional safety measures are essential to present radiation hazard for personnel.

Applications

- ✓ Typical applications of radiography testing method include:
- ✓ Detection of internal discontinuities such as shrinkage, cracking and porosity in castings.
- ✓ Verification of integrity of internal components.
- ✓ Determination of the quality of welded sections and pipes.

- ✓ Identification of the extent of corrosion
- ✓ Inspection of variety of non-metallic parts.
- ✓ Locating discontinuities in assemblies, fabricated structured

VISUAL INSPECTION

INTRODUCTION

What is it?

- ✓ Visual inspection is the simplest, fastest and by far the most commonly used destructive testing method.
- ✓ As the name suggests, visual inspection relies primarily on good eyesight and can be carried out with the naked eye known as an aided visual inspection) or using some optical s known as aided visual inspection) such as mirrors, glasses and microscopes.

Definition:

- ✓ Visual inspection is commonly defined as "the examination of a material, component, or product for conditions of non-conformance using light and the eyes, alone or in conjunction with various aids"
- ✓ Visual inspection often also involves shaking, listening, feeling, and sometimes even smelling the component being inspected.

Other NDT Methods Rely on Visual Testing

- ✓ Visual testing is inherently part of all other NDT test method. Visual inspection is commonly employed compliment/support other NDT methods.
- ✓ Other NDT methods require visual intervention to interpret images obtained while carrying out the examination. At some point, all NDT methods fall back on visual testing.
- ✓ For example, liquid penetrant Testing uses dyes that rely on Inspector's ability to visually identify surface indications

Characteristics Detected (Applicability)

- ✓ The visual testing is commonly used:
- ✓ To detect surface characteristics such as finish, scratches, Cracks, colour, wear and corrosion.
- ✓ To check alignment of mating surfaces.
- ✓ To check shape of the components.
- ✓ To check for evidence of leaking.
- ✓ To check for internal side defects.

BASIC PRINCIPLE OF VISUAL INSPECTION

Principle

- ✓ Seeing is believing and the art of seeing of visual inspection
- ✓ Techniques. Visual testing requires adequate illumination of the test surface and proper eye-sight of the tester. The test specimen is illuminated and the test surface is observed and examined.
- ✓ Whenever required, the optical aids such as mirrors. Magnifying glasses, microscopes, video cameras and computer-vision systems can be employed. The surface of the specimen should be adequately cleaned before bang inspected
- ✓ The following three basic requirements form basis for correct application of visual testing:
  - Good eye sight/vision of the inspector,
  - Good lighting conditions, and
  - Experienced and judgement of the inspector.

Advantages of Visual Inspection

Some of the advantages of visual testing are as follows:

(i) Simple and easy to use.
(ii) Relatively inexpensive.
(iii) Testing speed is high.
(iv) Testing can be performed on components which are in-service.
(v) Permanent records are available when latest equipment is used.
(vi) Almost all materials can be inspected.

Limitations of Visual Inspection

Some of the limitations of visual testing are as follows:

1. Limited to detection of surface flaws.
2. The test results depend on skill and knowledge of tester.
3. Eye resolution is weak
4. Eye fatigue.

TYPES OF VISUAL TESTING

Visual testing can be classified on the basis of use of aids used

(i) Unaided or direct visual testing, and

(ii) Aided visual testing.

Unaided or Direct Visual Testing

- ✓ As the name suggests, the unaided visual testing is carried out with naked eye (and without using any optical aids).
- ✓ The most important instrument is visual testing in the human eye.

Eye

- ✓ The human eye is the most fascinating and valuable tool in NDT.
- ✓ It has greater precision and accuracy than many of the sophisticated cameras. It has unique focusing capabilities and has the ability to work in conjunction with the human brain s that it can be trained to find specific details or characteristics in a test specimen.
- ✓ It has the ability to differentiate and distinguish between colors and their tones/shades characteristics as well.
- ✓ The human eye is capable of assessing many visual characteristics and identifying various types of discontinuities
- ✓ The eye can perform accurate inspections to detect size, shape, color, depth, brightness, contrast, and texture.

Aided Visual Testing

- ✓ As the name suggests, the aided visual testing is carried out with the aid of optical aids (such as magnifying glasses microscopes, boroscopes, fiberscopes) and a variety of other optical imaging and image enhancement tools.
- ✓ The optical aids are mainly used in usual testing for:
  - (i) magnification of defects which cannot be detected
  - (ii) Assisting in the inspection of defects;
  - (iii) Permitting visual checks or areas not accessible to unaided eye.

EQUIPMENT USED IN VISUAL INSPECTION

The optical aids used in practice for visual testing include:

1. Mirrors (small, angled mirrors)
2. Magnifying glasses, eye loupes, multilane magnifiers measuring magnifiers.
3. Microscopes (optical and electro)
4. Borescopes
5. Fiberscopes and videoscopes
6. Telescopes
7. Periscopes
8. Optical comparators
9. Optical Flats (for surface flatness measurement)
10. Phographic records
11. Closed-Circuit television (CCTV)Systems
12. Machine Vision System
13. Image enhancement(Computer analysis and enhancement)

The Brief Description of the basic optical aids used in visual testing is given below.

Magnifying Mirrors

- ✓ When inspecting areas not easily accessible, a magnifying mirror can be used.
- ✓ Depending on the test specimen, the mirror can be of any size (from the small dentist's mirror which can be stuck into small openings to a much larger mirror).

Magnifying Glass

- ✓ A magnifying glass can be used for closer inspection of Suspicious looking areas
- ✓ It generally consists of a simple lens for lower power magnification and double or multiple lenses for high demagnification.

Microscopes

- ✓ The simple microscope consists of a convex lens. The obi is placed between lenses and focus length of lens, so that erect, virtual and magnified image is formed. The size of image of an object depends upon the angle subtended at eye by the object (known as the visual angle).

Borescopes (or Endoscopes)

- ✓ Borescopes are optical instrument designed for remote Viewing of objects. They are used to inspect the inside of narrow tube, bore, or chamber.
- ✓ Borescopes is a precision optical instrument with built Illumination.
- ✓ Borescopes also called as ‘endoscopes’ or ‘end probe consist of superior optical systems and high intensity light sources.
- ✓ Some borescopes provide magnification option, zoom control or accessories.
- ✓ Because of the variety of applications and multitude o inspection needs, boroscopes are manufactured in rig extended, flexible, and micro designs.
- ✓

Fiberscope and Video scopes

- ✓ Modern fiberscope and videoscopes, due to their small size And flexibility, can provide access to internal areas inaccessible to rigid borescopes.
- ✓ Using these, digital images can be captured and processed real time. With the aid of laser lights, the area and depth many surface defects can also be determined.

Telescopes

- ✓ Telescope is an instrument that collects radiation from distant object in order to produce an image of it.
- ✓ An optical telescope uses visual radiations
- ✓ The telescopes are used for providing visual examination of the inaccessible surfaces.

Optical Comparators

- ✓ Optical comparators are the magnifying devices for visual examination and measurement.
- ✓ A comparator produces 2D enlarged image of an object on a large ground-glass screen.
- ✓ Optical comparators project the image of small parts onto a large projection screen. The magnified image is then compared against an optical comparator chart, which is a magnified outline drawing of the work piece being gauged.

Periscopes

- ✓ Periscope is an instrument used for remote observation of inaccessible areas.
- ✓ In simple periscope, two right angle reflecting prisms are utilized in combination with a series of lenses.
- ✓ The periscopes are commonly used for remote visual inspection in hazardous situation such as radiations areas, toxic environment and for overhead viewing of areasinvolving obstacles.

APPLICATIONS OF VISUAL INSPECTION

Typical applications of visual inspection include:

(i) Inspection of cleaning in machines.
(ii) Checking for corrosion, erosion and deformities of machine components.
(iii) Checking for ruptures, cracks and wear of parts in the equipment.
(iv) Monitoring of manometers, press stats and temperatures.
(v) Monitoring of oil level, greasing and greasing apparatus.

Illustration of Some Applications of Visual Testing

Visual Testing of Welds

- ✓ The visual inspector performing weld inspection is required to perform tasks in accordance with the relevant codes & standards at all stages of welding i.e., before welding, during Welding, and after welding.
- ✓ While performing visual inspection of welds, the firs checking should take place without prior cleaning of the weld for rust and dirt. This is because; it is often easier to discover any crack formation when the seam has not been cleaned.

- ✓ After the initial inspection, a more thorough cleaning of the surface of the weld should be carried out.
- ✓ During the subsequent visual inspection, one should be aware that many irregularities in the weld may look like cracks. In such cases, the cleaned welds can be further investigated with dye penetrant or magnetic particle method or using other methods such as ultrasonic and radiography.

Visual Testing of Pumps

- ✓ For carrying out visual testing, dismantling of pumps should be done following the manufacturers, instruction manual.
- ✓ During the dismantling process, the following tasks may be performed:
  - Check impellers visually for signs of erosion Cavitations damage.
  - Diffuser elements for pumps to be visually inspected for erosion and cracks.
  - Sleeves and rings should be tested to verify their dimensions to be within tolerance limits.
  - Check the pump shaft to see its straightness by taking a dial test indicator testing.
  - Shaft bearing journals should be checked for correct Finish.
  - Bearing surfaces should be inspected for smoothness and Wear.
  - Pump casing should be visually inspected for erosion and Washout.
  - All sleeve bearings should be visually inspected for pitting, finish, scoring, and dimension.

Visual Testing of Hydraulic Systems

- ✓ The following points should be visually checked when the hydraulic system is stopped:
  - Check that the oil is clean and clear.
  - Check that the system is clean and dry
- ✓ The following points should be checked when the hydraulic system is in operation:
  - Listen for unusual noises from the motor, pump and Piping system.
  - Check that the oil is clean and clear (must not foam) and that the temperature is correct.
  - Check that the system is intact (no leaks) and that the Filter indicators are OK.
  - Check for possible draining of condensation.

Visual Testing of Belt Pulley

The following points should be visually checked when the system is stopped:

- Check for missing belts and screening.
- Check for belt tracks.
- Check that the belts are of equal length.
- Check that the pulleys are finished.
- Check belt tension by pushing the belt downward by Hand.
- Check the condition of the belts; possible cracks.

The following points should be visually checked when the System is in operation:

- Check for belt noise.
- Check for missing belts and screening.

Visual Testing of Forging Discontinuities

- ✓ Forgings are inspected visually to detect bursts, laps and cracks.
- ✓ It is helpful for the inspector to use a 5X to 10 X magnifier during visual inspections.
- ✓ A burst, normally an internal discontinuity, shows up during secondary processing of a large forging.