POLLACHI INSTITUTE OF ENGINEERING AND TECHNOLOGY
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sky is the limit

Degree/Branch: B.E Mechanical **Semester/Year: VII/IV**

Subject code/Name: OML751 TESTING OF MATERIALS

UNIT I

OVERVIEW OF NDT

1) What are the methods to examine the defects in the products?

1. Non-Destructive Testing
2. Non-Destructive Evaluation
3. Non-Destructive Inspection

2) Define: Non-Destructive Testing?

The method of testing or inspection of a component or material to detect the presence of any defect without damaging it is called Non-Destructive Testing.

3) What are the benefits of a Non-Destructive Testing of products?

i) They provide the information on the quality of the material or component without damaging. ii) Presence of defects can be detected both at the manufacturing stage as well as during service.

iii) this helps to prevent failure in service and results in not only financial saving but saving of human lives also.

4) What are the defects that can be identified by NDT techniques?

Both external defects such as cracks, discontinuities, marks, porosities and internal defects such as blow holes, porosities, welding discontinuities etc. can be identified by NDT techniques.

5)What are the advantages of Non-Destructive Testing over Destructive Testing?

Sl. No	Non-Destructive Testing(advantages)	Destructive Testing(limitation)

1.	Tests are made directly on the object.100% testing on actual components is possible.	Tests are not made directly on the objects. Hence correlation between the sample.
2.	In-service testing is possible	In-service testing is not possible
3.	Repeated checks over a period of time are possible.	Repeated checks over a period of time are not possible.

4.	Very little preparation is sufficient.	Preparation of the test specimen is costly.

8) Name some new methods of NDT?

i) Neutron radiography

ii) Acoustic emission

iii)Thermography

iv) Strain sensing

v) Microwave technique

vi) Holography

9) What are the factors to be considered for the choice of specific NDT methods?

i) Availability based on analysis

10) What is Visual Inspection?

A simple visual test can reveal gross surface defects thus leading to an immediate rejection of the component and consequently saving much time and money. They provide information on the quality of a material or component without damaging it.

11) What is the basic principle of Visual Inspection?

The basic procedure used in visual NDT involves illumination of the specimen with light, usually in the visible region. The specimen is then examined with eye or by light sensitive devices such as photocells.

12) What is the important tool in NDT method?

The most valuable NDT tool is the human eye. The eye has excellent visual perception. The sensitivity of the human eye varies for light with different wavelengths. Under ordinary conditions, the eye is most sensitive to yellowgreen light, which has a wavelength of 5560 A^0.

13) What is the prime importance of visual inspection?

For Visual Inspection, adequate lighting about 800-1000 lux is needed. The period of time during which a human inspector is permitted to work should be limited to not more than 2 hours on continuous basis to avoid errors due to decrease in visual reliability and discrimination.

14) What are the information which can revealed by Visual Inspection of a component?

a) The general condition of the component.

b) The presence or absence of oxide film or corrosive product on the surface.

c) The presence or absence of cracks, orientation of cracks and the position of cracks relative to the various zones in the case of welds

d) The surface porosity, infilled craters, contour of the weld beads, and the probable orientation of the interface between the fused weld bead and the adjoining parent metal.

15) What is the use of optical aid instruments in visual inspection?

a) To magnify defects that cannot be detected by the unaided eye.

b) To permit visual checks of areas not accessible to the unaided eye.

16) What is optical microscope?

An optical microscope is a combination of lenses used to magnify the image of a small object. The object is placed close to the lens to obtain as high a magnification as possible.

PART B 16 MARKS

1. Discuss briefly about the visual inspection and instruments used for visual inspection? (16)

Visual testing (VT) is the oldest and most common nondestructive testing (NDT) techniques. It is typically the first step in the examination process to inspect a variety of product forms including castings, forgings, machined components and weld elements, according to the NDT Training & Test Center.

Compared to other techniques, visual testing is low in cost and easy to apply, and often eliminates the need for further types of testing. Some of the industries that use VT include structural steel, automotive, petrochemical, power generation, and aerospace.

Visual Testing Defined

According to a report from the U.S. Department of Transportation Federal Aviation Administration, Visual Inspection Research Project Report on Benchmark Inspections, "Visual inspection is the process of examination and evaluation of systems and components by use of human sensory systems aided only by mechanical enhancements to sensory input such as magnifiers, dental picks, stethoscopes, and the like. The inspection process may be done using such behaviors as looking, listening, feeling, smelling, shaking, and twisting.

"It includes a cognitive component wherein observations are correlated with knowledge of structure and with descriptions and diagrams from service literature."

Other NDT Methods Rely on VT

Other NDT methods require visual intervention to interpret images obtained while carrying out the examination. At some point, all NDT methods fall back on VT.

Liquid penetrant testing, for example, uses dyes that rely on the inspector's ability to visually identify surface indications. Magnetic particle testing falls into a similar category. Radiographic techniques require that the technician use visual judgment to determine the soundness of the object being tested.

Visual testing often locates areas where other NDT techniques need to be applied, or areas where mechanical and optical aids may provide improved inspection.

Visual Testing Requirements

In its paper on visual testing, the American Welding Society (AWS) said that requirements for visual testing typically pertain to three areas:

- The inspector's vision;
- The amount of light falling on the specimen, which is measured using a light meter; and
- Whether the area being inspected is obstructed from view.

Mechanical and Optical Aids Used in VT

Mechanical or optical aids are often necessary to perform visual testing.

These include such items as:

- Boroscopes
- Magnifying glasses
- Micrometers
- Mirrors
- UV Lights

Tech Service Products offers all of these devices in its NDT catalog.

The NDT Training & Test Center recommends that the specimen being tested should be well illuminated and has a clean surface. As specifications and tolerances become closer, mechanical and optical aids can help improve the precision of an inspector's vision.

Despite the advance in NDT technology, visual testing will continue to be a technique many industries rely on to ensure that the highest quality examination takes place.

2. Discuss in detail about the Relative merits and limitations, Various physical characteristics of materials and their applications in NDT. (8)

NDT Applications and Limitations

Non-destructive testing (NDT) are non-invasive techniques to determine the integrity of a material, component or structure or quantitatively measure some characteristic of an object. In contrast to destructive testing, NDT is an assessment without doing harm, stress or destroying the test object. The destruction of the test object usually makes destructive testing more costly and it is also inappropriate in many circumstances.

NDT plays a crucial role in ensuring cost effective operation, safety and reliability of plant, with resultant benefit to the community. NDT is used in a wide range of industrial areas and is used at almost any stage in the production or life cycle of many components. The mainstream applications are in aerospace, power generation, automotive, railway, petrochemical and pipeline markets. NDT of welds is one of the most used applications. It is very difficult to weld or mould a solid object that has no risk of breaking in service, so testing at manufacture and during use is often essential.

While originally NDT was applied only for safety reasons it is today widely accepted as cost saving technique in the quality assurance process. Unfortunately NDT is still not used in many areas where human life or ecology is in danger. Some may prefer to pay the lower costs of claims after an accident than applying of NDT. That is a form of unacceptable risk management. Disasters like the railway accident in Eschede Germany in 1998 is only one example, there are many others.

For implementation of NDT it is important to describe what shall be found and what to reject. A completely flawless production is almost never possible. For this reason testing specifications are indispensable. Nowadays there exists a great number of standards and acceptance regulations. They describe the limit between good and bad conditions, but also often which specific NDT method has to be used.

The reliability of an NDT Method is an essential issue. But a comparison of methods is only significant if it is referring to the same task. Each NDT method has its own set of advantages and disadvantages and, therefore, some are better suited than others for a particular application. By use of artificial flaws, the threshold of the sensitivity of a testing system has to be determined. If the sensitivity is to low defective test objects are not always recognized. If the sensitivity is too high parts with smaller flaws are rejected which would have been of no consequence to the serviceability of the component. With statistical methods it is possible to look closer into the field of uncertainly. Methods such as Probability of Detection (POD) or the ROC-method "Relative Operating Characteristics" are examples of the statistical analysis methods. Also the aspect of human errors has to be taken into account when determining the overall reliability.

Personnel Qualification is an important aspect of non-destructive evaluation. NDT techniques rely heavily on human skill and knowledge for the correct assessment and interpretation of test results. Proper and adequate training and certification of NDT personnel is therefore a must to ensure that the capabilities of the techniques are fully exploited. There are a number of published international and regional standards covering the certification of competence of personnel. The EN 473 (Qualification and certification of NDT personnel - General Principles) was developed specifically for the European Union for which the SNT-TC-1A is the American equivalent.

The nine most common NDT Methods are shown in the main index of this encyclopedia. In order of most used, they are: Ultrasonic Testing (UT), Radiographic Testing (RT), Electromagnetic Testing (ET) in which Eddy Current Testing (ECT) is well know and Acoustic Emission (AE or AET). Besides the main NDT methods a lot of other NDT techniques are available, such as Shearography Holography, Microwave and many more and new methods are being constantly researched and developed.

NDT Method	Applications	Limitations
Liquid Penetrant	• used on nonporous materials • can be applied to welds, tubing, brazing, castings, billets, forgings, aluminium parts, turbine blades and disks, gears	• need access to test surface • defects must be surface breaking • decontamination & precleaning of test surface may be needed • vapour hazard • very tight and shallow defects difficult to find • depth of flaw not indicated
Magnetic Particle	• ferromagnetic materials • surface and slightly subsurface flaws can be detected • can be applied to welds, tubing, bars, castings, billets, forgings, extrusions, engine components, shafts and gears	• detection of flaws limited by field strength and direction • needs clean and relatively smooth surface • some holding fixtures required for some magnetizing techniques • test piece may need demagnetization which can be difficult for some shapes and magetizations

		• depth of flaw not indicated
Eddy Current	• metals, alloys and electroconductors • sorting materials • surface and slightly subsurface flaws can be detected • used on tubing, wire, bearings, rails, nonmetal coatings, aircraft components, turbine blades and disks, automotive transmission shafts	• requires customized probe • although non-contacting it requires close proximity of probe to part • low penetration (typically 5mm) • false indications due to uncontrolled parametric variables
Ultrasonics	• metals, nonmetals and composites • surface and slightly subsurface flaws can be detected • can be applied to welds, tubing, joints, castings, billets, forgings, shafts, structural components, concrete, pressure vessels, aircraft and engine components • used to determine thickness and mechanical properties • monitoring service wear and deterioration	• usually contacting, either direct or with intervening medium required (e.g. immersion testing) • special probes are required for applications • sensitivity limited by frequency used and some materials cause significant scattering • scattering by test material structure can cause false indications • not easily applied to very thin materials
Radiography Neutron	• metals, nonmetals, composites and mixed materials	• access for placing test piece between source and detectors

	• used on pyrotechnics, resins, plastics, organic material, honeycomb structures, radioactive material, high density materials, and materials containing hydrogen	• size of neutron source housing is very large (reactors) for reasonable source strengths • collimating, filtering or otherwise modifying beam is difficult • radiation hazards • cracks must be oriented parallel to beam for detection • sensitivity decreases with increasing thickness
Radiography X-ray	• metals, nonmetals, composites and mixed materials • used on all shapes and forms; castings, welds, electronic assemblies, aerospace, marine and automotive components	• access to both sides of test piece needed • voltage, focal spot size and exposure time critical • radiation hazards • cracks must be oriented parallel to beam for detection • sensitivity decreases with increasing thickness
Radiography Gamma	• usually used on dense or thick material • used on all shapes and forms; castings, welds, electronic assemblies, aerospace, marine and automotive components • used where thickness or access limits X-ray generators	• radiation hazards • cracks must be oriented parallel to beam for detection • sensitivity decreases with increasing thickness • access to both sides of test piece needed • not as sensitive as X-rays

3. Write briefly about Non Destructive Testing Methods for the detection of manufacturing defects as well as material characterization. (16)

Nondestructive testing or **Non-destructive testing** (**NDT**) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. The terms **Nondestructive examination** (**NDE**), **Nondestructive inspection** (**NDI**), and **Nondestructive evaluation**(**NDE**) are also commonly used to describe this technology. Because NDT does not permanently alter the article being inspected, it is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research. Common NDT methods include ultrasonic, magnetic-particle, liquid penetrant, radiographic, remote visual inspection (RVI), eddy-current testing,[1] and low coherence interferometry NDT is commonly used in forensic engineering, mechanical engineering, petroleum engineering, electrical engineering, civil engineering, systems engineering, aeronautical engineering, medicine, and art.[1] Innovations in the field of nondestructive testing have had a profound impact on medical imaging, including on echocardiography, medical ultrasonography, and digital radiography.

Methods

NDT methods may rely upon use of electromagnetic radiation, sound, and inherent properties of materials to examine samples. This includes some kinds of microscopy to examine external surfaces in detail, although sample preparation techniques for metallography, optical microscopy and electron microscopy are generally destructive as the surfaces must be made smooth through polishing or the sample must be electron transparent in thickness. The inside of a sample can be examined with penetrating radiation, such as X-rays, neutrons or terahertz radiation. Sound waves are utilized in the case of ultrasonic testing. Contrast between a defect and the bulk of the sample may be enhanced for visual examination by the unaided eye by using liquids to penetrate fatigue cracks. One method (liquid penetrant testing) involves using dyes, fluorescent or non-fluorescent, in fluids for non-magnetic materials, usually metals.

Another commonly used NDT method used on ferrous materials involves the application of fine iron particles (either liquid or dry dust) that are applied to a part while it is in an externally magnetized state (magnetic-particle testing). The particles will be attracted to leakage fields within the test object, and form on the objects surface. Magnetic particle testing can reveal surface & some sub-surface defects within the part. Thermoelectric effect (or use of the Seebeck effect) uses thermal properties of an alloy to quickly and easily characterize many alloys. The chemical test, or chemical spot test method, utilizes application of sensitive chemicals that can indicate the presence of individual alloying elements. Electrochemical methods, such as electrochemical fatigue crack sensors, utilize the tendency of metal structural material to oxidize readily in order to detect progressive damage.

Analyzing and documenting a non-destructive failure mode can also be accomplished using a high-speed camera recording continuously (movie-loop) until the failure is detected. Detecting the failure can be accomplished using a sound detector or stress gauge which produces a signal to trigger the high-speed camera. These high-speed cameras have advanced recording modes to capture some non-destructive failures.[5] After the failure the high-speed camera will stop recording. The capture images can be played back inslow motion showing precisely what happen before, during and after the non-destructive event, image by image.

4. Discuss in detail about NDT vs Mechanical Testing? (6)

Mechanical & Non-Destructive Testing Fundamental Manufacturing Processes Study Guide, DV06PUB6 - 1 - Training Objective After watching the program and reviewing this printed material, the viewer will gain an understanding and become familiar with the various methods, equipment, and applications of mechanical and non-destructive materials testing. • Mechanical testing methods are clearly shown • Non-destructive testing methods are shown in detail

• Advantages and limitations of the various tests are detailed Materials Testing Prior to manufacturing, many material, design, and production decisions are made to ensure product reliability and proper performance. To validate these decisions, a variety of testing methods are employed. The methods are grouped into two major categories: • Mechanical Testing • Non-Destructive Testing (NDT) Mechanical testing, which is also known as destructive testing, is accomplished by forcing a part to fail by the application of various load factors. In contrast, non-destructive testing does not affect the part's future usefulness and leaves the part and its component materials in tact.

Mechanical Testing Mechanical testing specifications have been developed by the American Society for Testing and Materials (ASTM) and many of these specifications have been adopted by the American National Standards Institute (ANSI). Typically mechanical testing involves such attributes as hardness, strength, and impact toughness. Additionally, materials can be subjected to various types of loads such as tension or compression. Mechanical testing can occur at room temperatures or in either high or low temperature extremes. Hardness – The resistance to indentation and to scratching or abrasion. The two most common hardness tests are the Brinell test and the Rockwell test. In the Brinell hardness test, a known load is applied for a given period of time to a specimen surface using a hardened steel or tungsten-carbide ball, causing a permanent indentation. Standard ball diameter is 10 millimeters, or approximately four-tenths of an inch. The diameter of the resulting permanent indentation is then measured and converted to a Brinell hardness number.

The Rockwell hardness test involves the use of an indentor for penetrating the surface of a material first by applying a minor, or initial load, and then applying a major, or final load under specific conditions. The difference between the minor and major penetration depths is then noted as a hardness value directly from a dial or digital readout. The harder the material the higher the number.

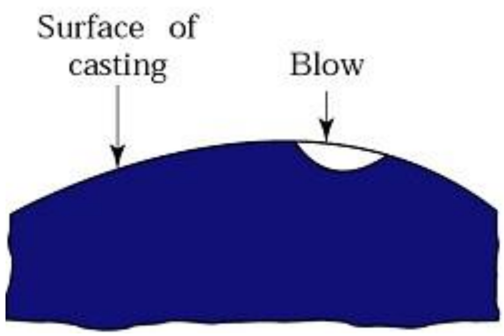
5. Discuss in detail about types of defects and it causes? (16)

Surface defects:

Due to design and quality of sand molds and general cause is poor ramming.

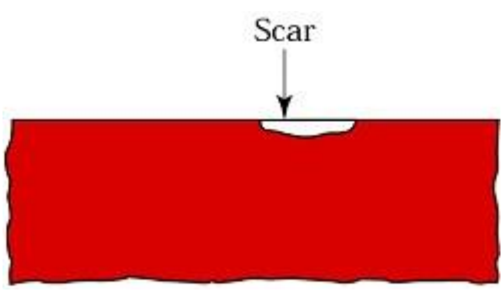
Blow:

Blow is relatively large cavity produced by gases which displace molten metal form.



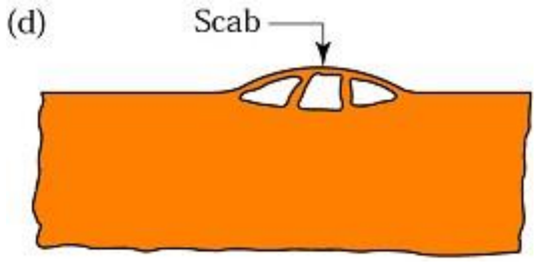
Scar:

Due to improper permeability or venting.A scare is a shallow blow. It generally occurs on flat surf; whereas a blow occurs on a convex casting surface. A blister is a shallow blow like a scar with thin layer of metal covering it,



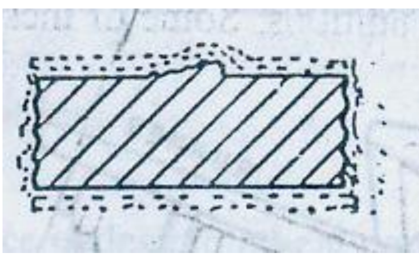
Scab:

This defect occurs when a portion of the face of a mould lifts or breaks down and the recess thus made is filled by metal. When the metal is poured into the cavity, gas may be disengaged with such violence as to break up the sand which is then washed away and the resulting cavity filled with metal. The reasons can be: - to fine sand, low permeability of sand, high moisture content of sand and uneven moulds ramming.



Drop:

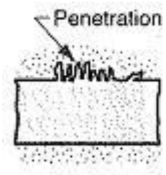
Drop or crush in a mould is an irregularly shaped projection on the cope surface of a casting. This defect is caused by the break-away of a part of mould sand as a result of weak packing of the mould, low strength of the molding sand, malfunctioning of molding equipment, strong jolts and strikes at the flask when assembling the mould.
The loose sand that falls into the cavity will also cause a dirty casting surface, either on the top or bottom surface of the casting, depending upon the relative densities of the sand and the liquid.



Penetration:

It is a strong crust of fused sand on the surface of a casting which results from insufficient refractoriness of molding materials, a large content of impurities, inadequate mould packing and poor quality of mould washes.

When the molten metal is poured into the mould cavity, at those places when the sand packing is inadequate, some metal will flow between the sand particles for a distance into the mould wall and get solidified. When the casting is removed, this lump of metal remains attached to the casting. Of course, it can be removed afterwards by chipping or grinding.

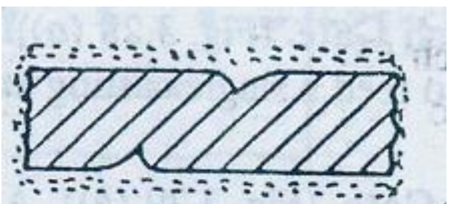


Buckle:

A buckle is a long, fairly shallow, broad, vee depression that occurs in the surface of flat castings. It extends in a fairly straight line across the entire flat surface.

It results due to the sand expansion caused by the heat of the metal, when the sand has insufficient hot deformation. It also results from poor casting design providing too large a flat surface in the mold cavity.

Buckling is prevented by mixing cereal or wood flour to sand.



Internal defects:

Blow holes:

Blow holes, gas holes or gas cavities are well rounded cavities having a clean and smooth surface. They appear either on the casting surface or in the body of a casting.

These defects occur when an excessive evolved gas is not able to flow through the mould. So, it collects into a bubble at the high points of a mould cavity ad prevents the liquid metal from filling that space.

This will result in open blows. Closed, cavities or gas holes are formed when the evolved gases or the dissolved gases in the molten metal are not able to leave the m ass of the molten metal as it solidifies and get trapped within the casting.

These defects are caused by :

i) excessive moisture content (in the case of green sand moulds) or organic content of the sand, moisture on chills, chaplets or metal inserts,

ii) inadequate gas permeability of the molding sand (due to fine grain size of sand, high clay content, hard ramming),

iii) poor venting of mould, insufficient drying of mould and cores, cores not properly vented, high gas content of the molten metal,

iv) low pouring temperature and incorrect feeding of the casting etc.

Pin holes:

Pin holes are small gas holes either at the surface or just below the surface. When these are present, they occur in large numbers and are fairly uniformly dispersed over the surface.

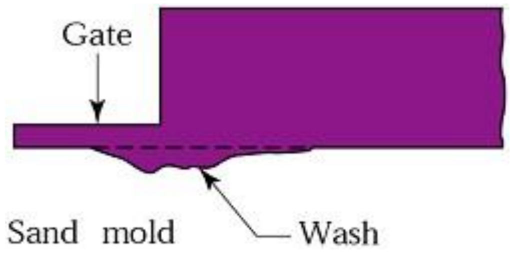
This defect occurs due to gas dissolved in the alloy and the alloy not properly degassed.

Visible defects:

Wash:

A cut or wash is a low; projection on the drag face of a casting that extends along the surface, decreasing in height as it extends from one side of the casting to the other end.

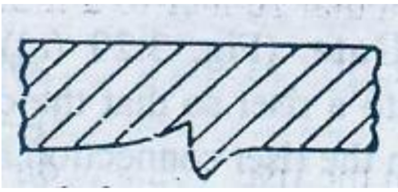
It usually occurs with bottom gating castings in which the molding sand has insufficient hot strength, and when too much metal is made to flow through one gate into the mold cavity,



Rat tail:

A rat tail is a long, shallow, angular depression in the surface of a flat rating and resembles a buckle, except that, it is not shaped like a broad vee.

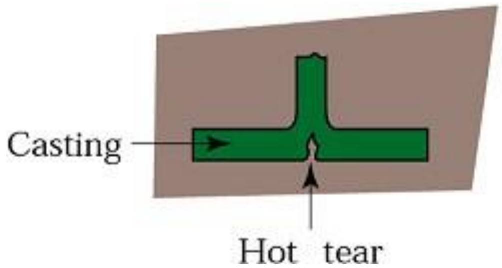
The reasons for this defect are the same for buckle.



Hot tear:

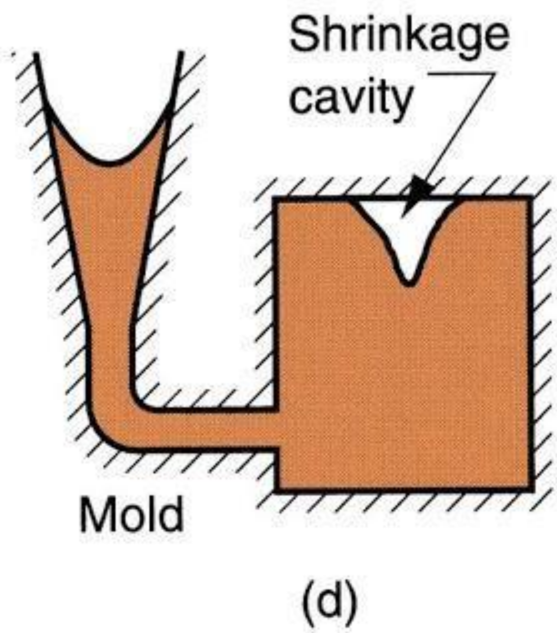
Hot tears are hot cracks which appear in the form of irregular crevices with a dark oxidizedfracture surface. They arise when the solidifying met does not have sufficient strength to resist tensile forces produced during solidification.

They are chiefly from an excessively high temperature of casting metal, increased metal contraction incorrect design of the gating system and casting on the whole (causing portions of the casting to be restrained from shrinking freely during cooling which in turn causes excessive high intern resistance stresses), poor deformability of the cores, and non-uniform cooling whichgives rise t internal stresses. This defect can be avoided by improving the design of the casting and by having a mould of low hot strength and large hot deformation.



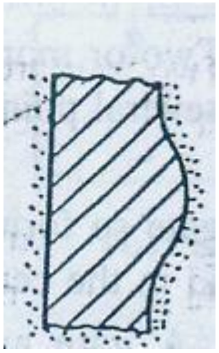
Shrinkage:

A shrinkage cavity is a depression or an internal void in a casting that results from the volume contraction that occurs during solidification.



Swell:

A swell is a slight, smooth bulge usually found on vertical faces of castings, resulting from liquid metal pressure. It may be due to low strength of mould because of too high a water content or when the mould is not rammed sufficiently.



Shift:

Mold shift refers to a defect caused by a sidewise displacement of the mold cope relative to the drag, the result of which is a step in the cast product at the parting line. Core shift is similar to mold shift, but it is the core that is displaced, and (he dis-placement is usually vertical. Core shift and mold shift are caused by buoyancy of the molten metal