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Non Destructive Testing of Castings in Foundries

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Abstract
Non destructive testing is a technique to test the engineering components without destroying it. It is often called as NDT and can be used to ensure the quality of components manufactured by different processes. Today, NDT finds wider applications in the areas of condition monitoring, residual life assessment and energy auditing. It is used to test the engineering parts to identify and locate the surface cracks, internal flaws without interfering the integrity of the material or its suitability for service. These methods can be applied for individual inspection or may be used for absolute 100% checking of components in a manufacturing quality control system. This review paper discusses different types of non destructive methods, it advantages and applications specifically in foundries.

Keywords: *Non Destructive Testing (NDT), radiography, ultrasonic flaw detection, eddy current testing, magnetic particle inspection, foundry, castings, flaws, voids, defects*

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INTRODUCTION

Non Destructive Testing (NDT) is the application of non destructive techniques to identify the integrity of a material or an engineering component or structure or to quantify the characteristics of a manufactured object.

It is a quality control method. NDT techniques are used for the following

1. Surface flaw detection, locating and quantification.
2. Detection of leakage and identifying the location.
3. Measurement of geometrical dimensions.
4. Component structure and characterization of microstructures.
5. Determination of physical, chemical and mechanical properties.
6. Measurement of Stresses.
7. Sorting of different materials and estimation of chemical composition of the constituents present in a material system.

NDE is called as Non destructive evaluation. Its applications are almost in all the stages in the manufacturing cycle, consecutive process steps.

Few important NDE applications are mentioned below

1. To guide and assist in engineering component development.
2. To sort out the incoming raw materials.
3. To monitor, improve, and control the production processes.
4. To verify heat treating operations.
5. To verify the assembled parts.
6. To inspect all types of service damages

COMMON NDT METHODS APPLIED IN FOUNDRIES

Visual Inspection of Castings

This is the most basic inspection method. Different types of tools like fiberscope, borescopes, magnifying glasses and mirrors are used to identify the casting defects.

Dye Penetrant Testing of Castings

This method is frequently used for the detection of surface breaking flaws in non-ferromagnetic materials. The subject to be examined is chemically cleaned, usually by vapor phase, to remove all traces of foreign material, grease, dirt, etc. from the surface, and also from within the cracks. Then, the liquid dye penetrant is applied that remains in contact with the test surface for fifteen minutes. Due to capillary action, the penetrant imbibes into the crack. The remaining penetrant on the component surface is then taken away. After this, a thin coating of powdered chalk is applied. Like a blotting paper, the chalk powder draws the dye from the crack in the component. This is well visualized and magnified to find out the width. This operation is a mechanical process or considered as a chemical process. It requires sophisticated tanks, spraying and drying equipments[1,2]. The dye penetrant testing method is shown below in Figure 1.

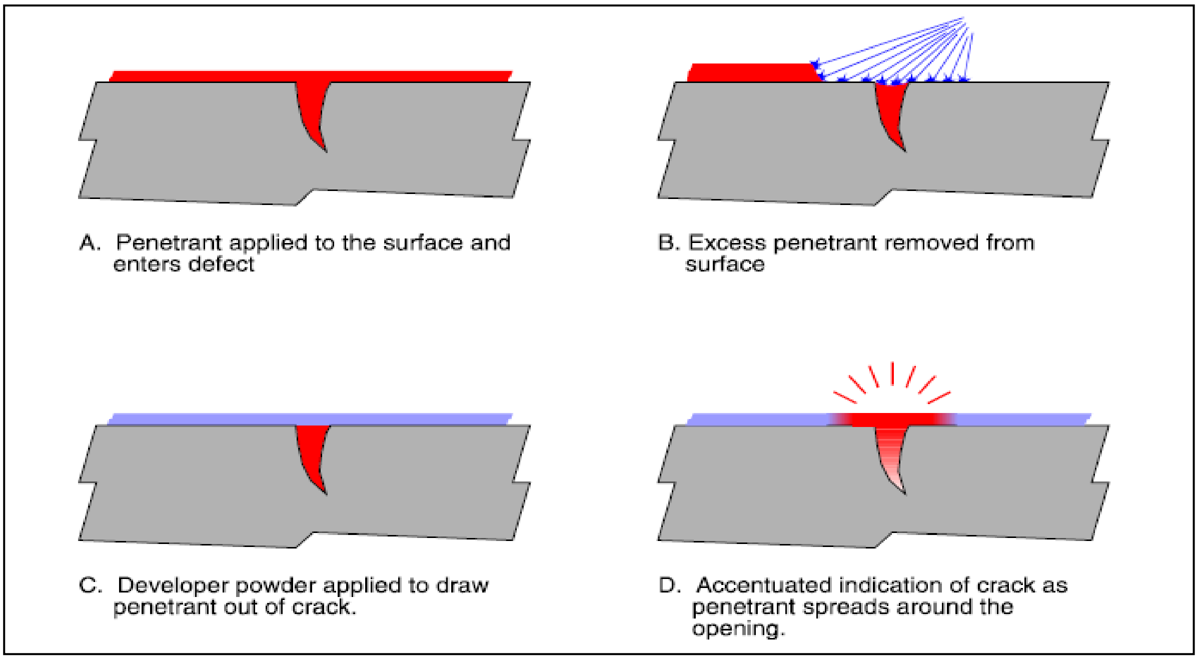


Fig. 1: *Dye Penetrant Testing.*

Advantages of Dye Penetrant Testing

1. Operational procedure is simple.
2. Easier to identify the surface cracks in non-ferrous metals.
3. Automated inspection is possible by this technique.

Disadvantages of Dye Penetrant Testing

1. Lower sensitivity.
2. More consumables are required.
3. Only suitable to identify and quantify surface defects.

Magnetic Particle Inspection Method to Study Casting Defects

This technique is used to detect surface and discontinuities in magnetic materials. The working principle in this method is to generate magnetic flux in the component to be examined, with the flux lines running along the surface at right angles to the defective regions[3,4]. The generated flux lines approach a discontinuity and they will stray out at the mouth of the crack. The crack edge becomes magnetic attractive north and south poles. It has the power to attract finely divided particles of magnetic material such as iron fillings. These particles are made of an iron oxide in the size ranging from 20–30 microns. These are suspended in a liquid which provides mobility for the particles on the surface of the test piece and also assisting their migration to the crack edges. The particles can be red or black oxide, and often coated with a substance, which fluoresces under ultra violet illumination. There are various methods available to generate magnetic flux in the test piece. The easiest and simplest one is applying a permanent magnet to the surface. This method cannot be controlled accurately because of indifferent surface contact and deterioration in magnetic field strength. Recently developed devices, generate the magnetic field electrically either directly or indirectly. An illustration of the magnetic particle inspection method is shown below in Figure 2.

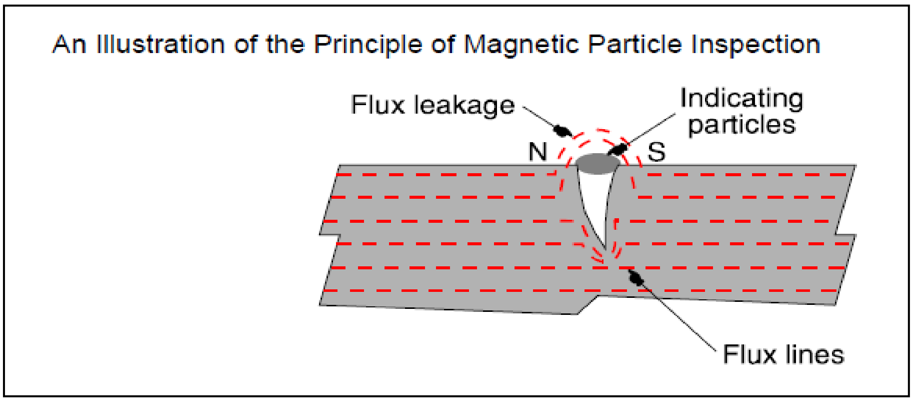


Fig. 2: *Illustration of the Principle of Magnetic Particle Inspection Technique.*

Detection of longitudinal defects in hollow shafts is a typical application by this method. The current used to generate the magnetic flux in any of these methods can be alternating current, half wave rectified direct current or full wave rectified direct current. Magnetic flux, because of the skin effect, preferentially follows the contours of the surface. It does not penetrate deeply into the component material. An illustration of the actual magnetic particle inspection method is shown below in Figure 3.

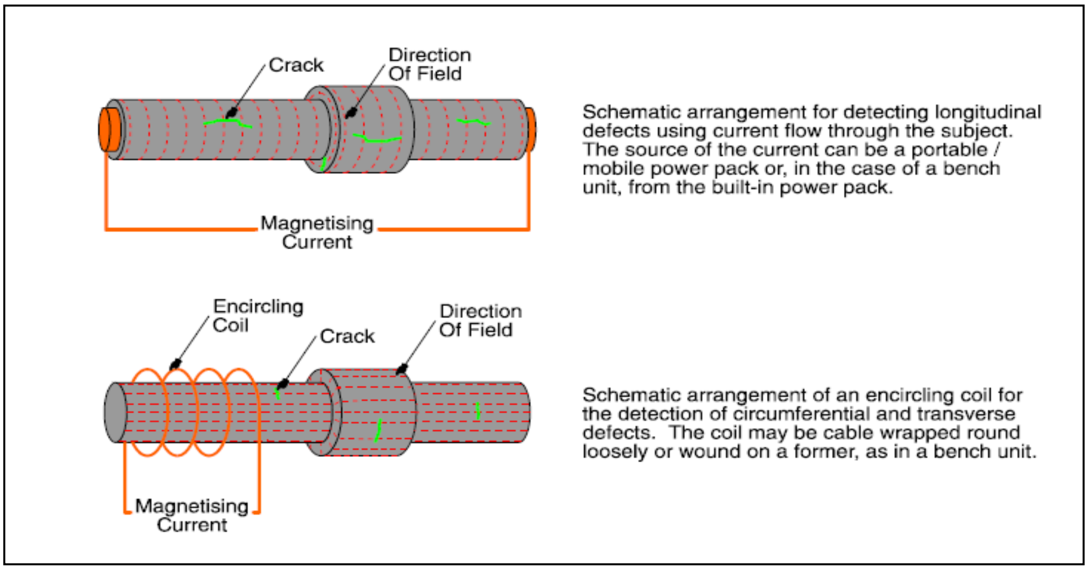


Fig. 3: *Magnetic Particle Inspection Technique.*

Advantages of Magnetic Particle Crack Detection

1. Simplicity of operation and application.
2. Quantitative.
3. Can be automated, apart from viewing.

Disadvantages of Magnetic Particle Crack Detection

1. Restricted to ferromagnetic materials.
2. Restricted to surface or near surface flaws.
3. Not fail safe in that lack of indication could mean no defects or process not carried out properly.

Radiography on Castings

Radiography is best suitable to detect the internal defects in ferrous and nonferrous metals and alloys. X-rays and Gamma rays penetrate inside the materials, which is differentially absorbed by them through which it passes. The greater the thickness, the greater will be the absorption. Similarly, the denser the material, the greater will be the absorption[3,4,5].

An illustration of the radiography of castings is shown below in Figure 4.

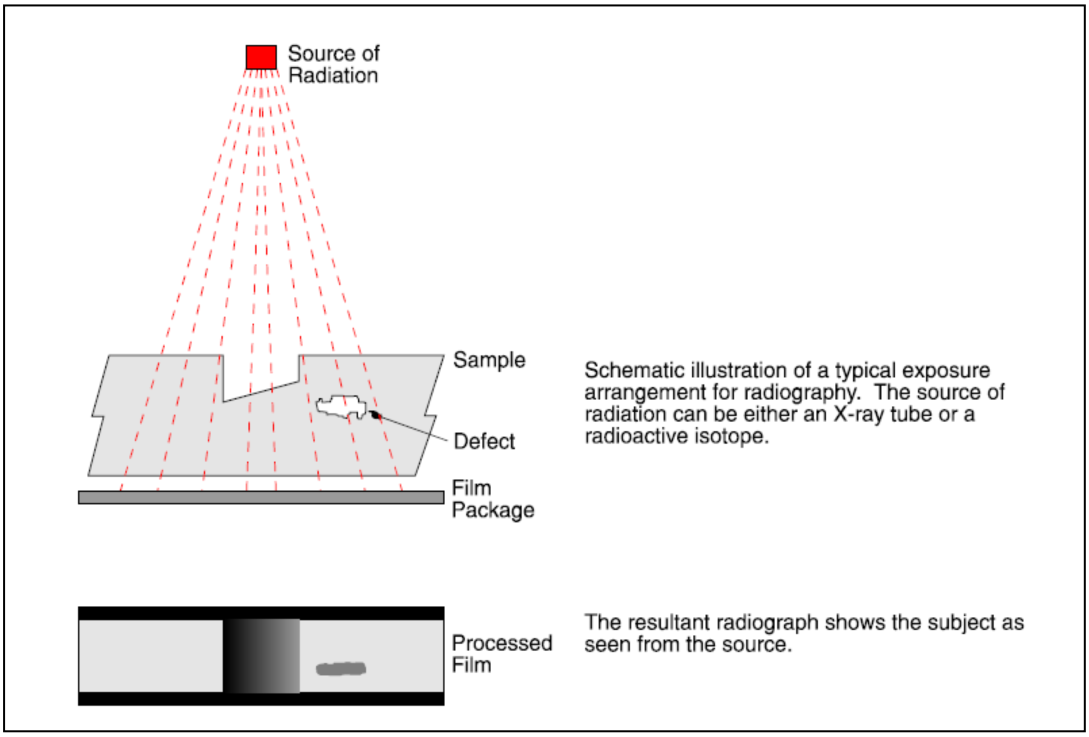


Fig. 4: *Radiography on Castings.*

Radioscopy is the best way for controlling the quality of cast pieces produced in die casting through computer-aided analysis of captured images. NDT method is applied to identify discontinuities, which may be located within the piece.

An example of such discontinuities in a wheel is shown in Figure 4 in the above X-ray image.

Advantages of Radiography

1. Pictorial information can be presented.
2. Permanent record is possible which may be viewed at any time and place.
3. Thin sections can be tested.
4. Sensitivity may be declared on each radiographic film.
5. This method is suitable for any material or an alloy.

Disadvantages of Radiography

1. Health hazard is possible.
2. It is a must to direct the X-Ray beam accurately for two dimensional defects.

3. Radiographic film processing and viewing facilities are necessary.
4. Automation is impossible, unless the system incorporates fluoroscopy with an image intensifier.
5. It is not suitable for surface defects and no indication of depth of a defect below the surface can be identified.

Eddy Current Testing of Castings

Eddy current techniques are applied to detect the surface and subsurface flaws, conductivity measurement and coating thickness measurement in a variety of materials. This method is very sensitive to the material conductivity, permeability and dimensions of a component. Eddy currents can be generated in any conducting material that is subjected to an alternating magnetic field range from 10 Hz to 10 MHz. The alternating magnetic field is normally generated by passing an alternating current through a conducting coil[1,3]. The coil can have different shapes and range between 10 and 500 turns of wire. The magnitude of the eddy currents produced in the component is dependent on material conductivity, permeability and the set up geometry. Any change in the testing material or material geometry can be identified and detected by the coil excitation as a change in the coil impedance. The coil consists by a ferrite rod with several turns of wire wound at one end. It is closely positioned to the component surface. When a crack occurs in the component surface the eddy currents must travel farther around the crack and finally detected by the impedance change. As shown in Figure 5, coils can be used in pairs, called as a driven pair. This set up can be used with the coils connected differentially. By this way, 'lift off' signals can be enhanced, shown in Figure 6. Coils can also be applied and used in a transformer type configuration, where one coil winding is a primary and one or two coil windings are used for the secondary's, shown below in Figure 7.

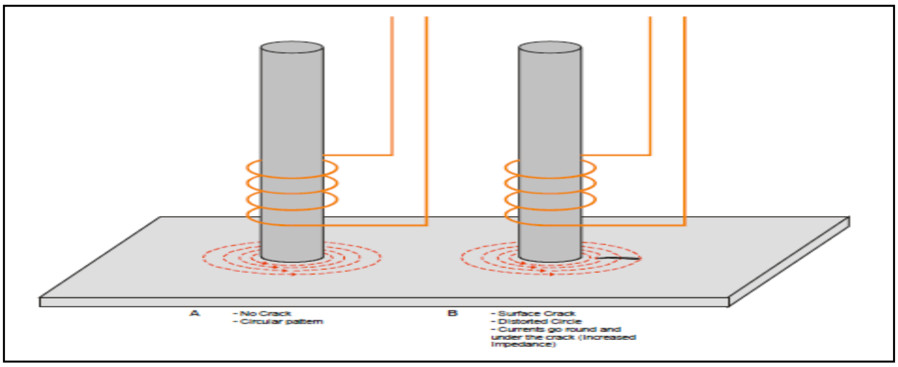


Fig. 5: *Coil with Single Winding.*

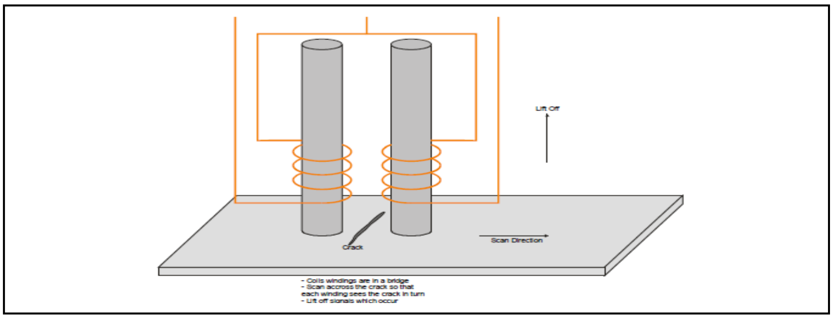


Fig. 6: *Coil with 2 Windings.*

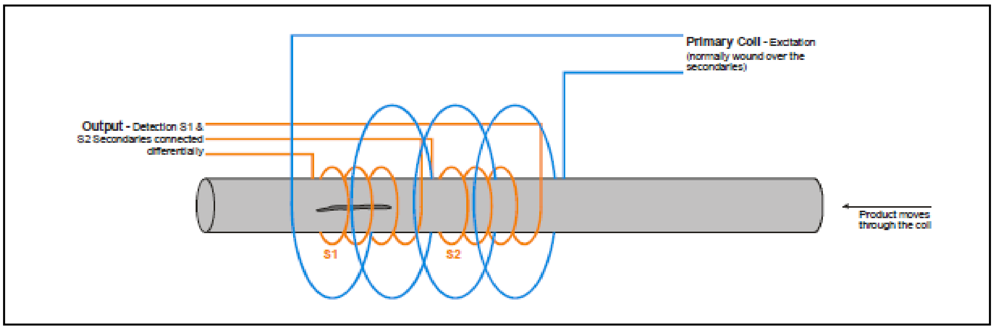


Fig. 7: *Transformer Type Coil with 3 Windings.*

The identified eddy current signals contain amplitude and phase details. This can be displayed on CRT displays. Signals can be displayed as the absolute signal, and only a signal change is displayed. The best results are obtained where only one product variable changes, for example, the presence of a crack in the material. Normally, changes in the eddy current signals are caused by differences in chemical composition, material hardness, surface texture, shape, material conductivity, permeability and geometry.

In few cases, the effects of the crack can be hidden by changes in other parameters and unnecessary rejection can occur. However, the coils can be selected for configuration, size and test frequency in order to enhance detection of cracks, conductivity, metal loss etc. as required. The depth to which the eddy currents can penetrate a material can be changed by adjusting the test frequency. The higher the frequency, the lower is the penetration. However, the lower the frequency, the lower is the sensitivity to small defects. Larger coils are less sensitive to roughness of surface and vice versa. The latest electronic units are able to operate a wide range of coil configurations in absolute or differential modes and at a wide range of frequencies. For surface testing for cracks in single or complex shaped components, coils with a single ferrite cored winding are normally used. The probe is placed on the component and 'balanced' by use of the electronic unit controls. As the probe is scanned across the surface of the component the cracks can be detected which is shown in Figure 5, where surfaces are to be scanned automatically the single coil windings are suitable only if the lift off distance is accurately maintained which is shown in Figure 6. Tubes, bar and wire can be inspected using an encircling coil and these usually have a coil configuration with one primary and two secondary's connected differentially which is shown in Figure 7. An illustration of the Eddy current testing for a tube is shown below in Figure 8 with the aid of eddy current testing equipment. Figure 9 shows the eddy current testing of a flat conductive plate casting.

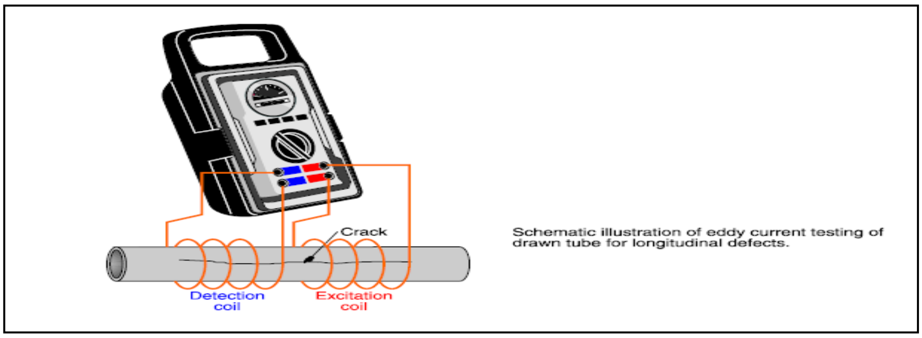


Fig. 8: *Illustration of Eddy Current Testing of a Tube.*

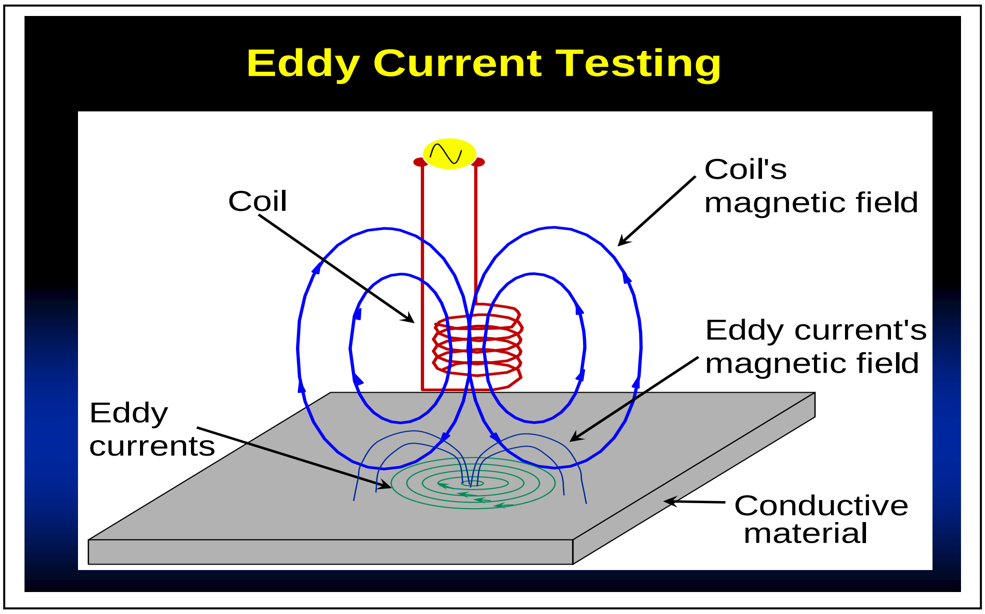


Fig. 9: *Illustration of Eddy Current Testing of a Plate Casting.*

Advantages of Eddy Current Testing

1. Preferable for the determination of a wide range of conditions of conducting materials, such as defect identification, chemical composition, material hardness, conductivity, and permeability in a wide variety of engineering metals and alloys.
2. Material Information can be provided in simple terms by go or no go.
3. Electronic units can be applied to attain much component information.
4. Compact and portable units are available.
5. No consumables are required, except sensing probes.
6. Flexibility in probes selection and choosing test frequencies to suit different industrial applications.
7. Complete automation is always possible.

Disadvantages of Eddy Current Testing

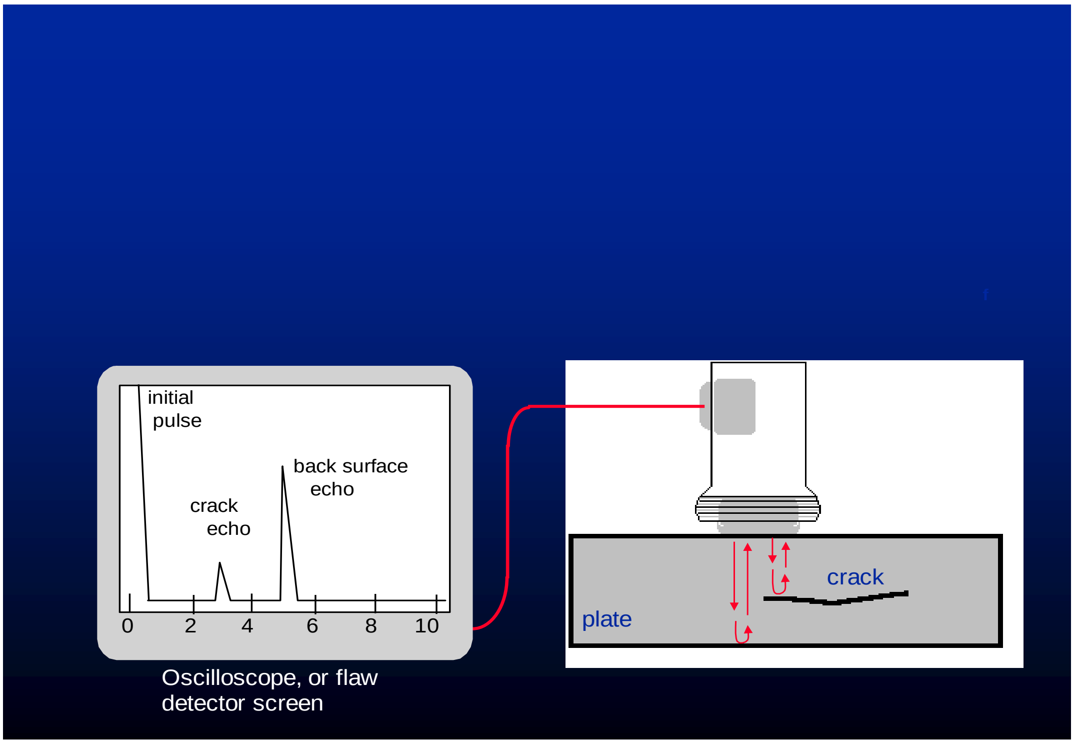
The range of parameters and variables which affect the eddy current responses means that the signal from a desired material characteristic, for example, a minor crack, can be masked by an unwanted variable, for example, change in the value of hardness. Appropriate and careful selection of probes will be needed in some industrial applications. These tests are restricted to surface breaking conditions and subsurface flaws.

Ultrasonic Flaw detection in castings

Ultrasonic flaw detection is used to detect the internal, surface and sub surface defects in conducting materials. The working principle is similar to echo sounding technique. Ultrasonic pulses are generated by a piezo electric crystal, which vibrates for a shortest period of time at a frequency depends on the thickness of the crystal. The frequency is normally in the range of one million to six million times per second, ranges from 1–6 MHz Sound waves at this frequency range have the capability to travel a considerable distance in materials such as metals and alloys with little attenuation coefficient[3,5]. The velocity at which these waves propagate is related to the Young’s Modulus for the material and is characteristic of that material. For example, the velocity in steel is 5900 meters per second, and in water 1400 meters per second. Ultrasonic energy is considerably attenuated in air, and a beam propagated through a solid will, on reaching an interface between that material and air reflect a considerable amount of energy in the direction equal to the angle of incidence. For contact testing the oscillating crystal is incorporated in a hand held probe, which is applied to the surface of the material to be tested.

A couplant is used to transfer the energy in between the air gap between the Peizo crystal and the component. Couplants are liquids. Commonly used couplants are water, oil and grease, which are applied on the surface. Piezo electric materials convert electrical pulses to mechanical vibrations and oscillations. Mechanical oscillations are further converted into electrical signals in the form of pulses by transduction principle. The piezo crystal can detect the pulses which are returned. It takes a finite time to travel through the component and gets reflected back to the probe. It is possible to identify and locate a defect between the component surface and the back wall. Besides, it is also possible to measure its distance below the surface of the component. The ultrasonic testing device should be properly calibrated before its use. Ultrasonic inspector must be able to identify and locate the origin of each peak in the display clearly. Ultrasonic pulses form a sharp beam. It helps to calculate the plan position of a flaw. The echo peak height is approximately proportional to the surface area of the reflector. The beam gets reflected at a material/air interface but also at any contact point junction where there is a change in velocity. A good example is at the steel/slag interface in a welded joint.

In ultrasonic testing process, probes are placed on all the faces of a component. It helps to locate the three-dimensional defect and measures its depth from the component surface, and also to determine its size. Two-dimensional defects can also be identified if the incident beam strikes on the defect as near to right angles to the plane. To attain this, few sensing probes are introduced[1,5]. By applying this technique, longitudinal defects in the hollow tubes are detected. Figure 10 shows the ultrasonic flaw testing of a casting sample component.



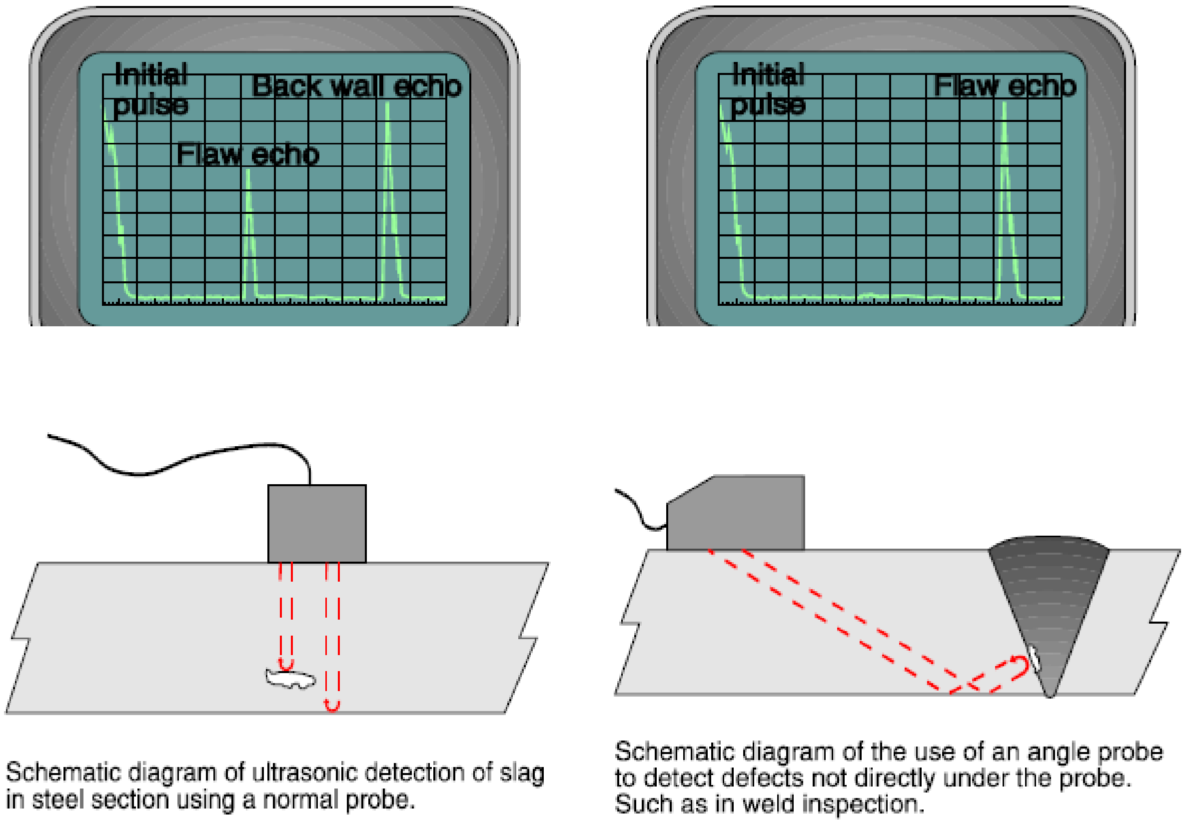


Fig. 10: *Illustration of Ultrasonic Flaw Inspection of Casting.*

Advantages of Ultrasonic Flaw Detection

1. Thickness and lengths up to 30 ft can be tested.
2. Position, size and type of defect can be determined.
3. Instant test results.
4. Portable.
5. Extremely sensitive if required.
6. Capable of being fully automated.
7. Access to only one side necessary.
8. No consumables.

Disadvantages of Ultrasonic Flaw Detection

1. Difficult to maintain permanent record.
2. Ultrasonic inspector can decide whether the component is defective or not during the progress.
3. Flaw detections require an appropriate interpretation to conform the defects observed.
4. Operators must have higher degree of skills to obtain the complete information from the ultrasonic inspection test.
5. Components with very thin sections cannot be tested by ultrasonic inspection method.

CONCLUSIONS

Non Destructive Testing (NDT) is the use of noninvasive techniques to determine the integrity and defects in castings. A certain degree of skill is required to apply the techniques properly in order to obtain the maximum amount of information concerning the cast product, with consequent feed back to the production facility. Non-destructive Testing is not just a method for rejecting castings. It uses a variety of principles and there is no single method around which a black box may be built to satisfy all requirements in all circumstances.

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