SUB : WELDING TECHNOLOGY

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PREPARED BY:K.ARUNKUMAR

UNIT V NON DESTRUCTIVE TESTING & EVALUATION 10 hrs.

Principles of Non-Destructive Testing (NDT) -Significance of NDT in pressure vessel manufacture - Crack detection methods -Liquid penetrant testing -Magnetic particle testing -Radiographic methods -Ultrasonic testing -Eddy current testing

Categories of Non-destructive Testing

The different types of non-destructive testing used to inspect welding are shown below:

- **Radiographic Inspection (Graphs)**
- **Magnetic Particle Inspection(MPI)**
- **Ultrasonic Testing (UT)**
- **Dye Penetration (Dye Pen)**

Description and Application of Non Destructive Testing Methods

Radiographic Inspection (Graphs)

This is carried out where the welded components require a very critical inspection technique due to their application.

Shielding from x-ray and gamma-ray radiation is a strict requirement; this can be of a portable means or the components can be brought to a specialised building to be x-rayed. In my old offshore construction yard, radiography was carried out during the dead hours between shifts, when a visible and audio alarm would howl continuously to warn against entrance to the assembly buildings.

Anyway, the relative components are exposed to the radioactive source from which a radiograph is produced. This will show any irregularities in the welding when checked by an experienced radiograph interpret

Radiography is used in a very wide range of aplications including medicine,engineering, forensics, security, etc. In NDT, radiography is one of the mostimportant and widely used methods. Radiographic testing (RT) offers anumber of advantages over other NDT methods, however, one of its majordisadvantages is the health risk associated with the radiation.

In general, RT is method of inspecting materials for hidden flaws byusing the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials. The intensity of the radiation that penetrates and passes through the material is either captured by a radiation sensitive film (*Film Radiography*) or by a planer array of radiation sensitive sensors (*Real-timeRadiography*). Film radiography is the oldest approach, yet it is still

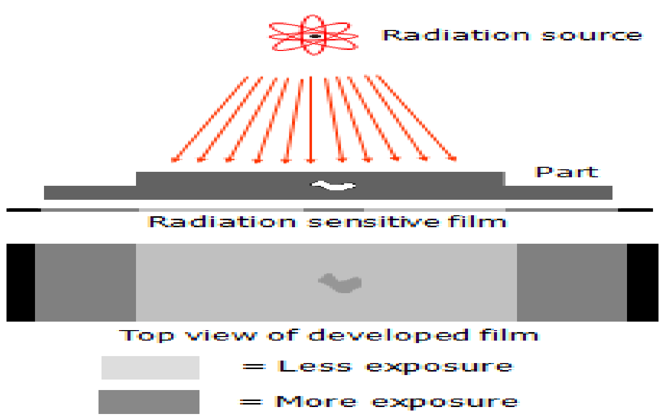
the most widely used in NDT.

Basic Principles

In radiographic testing, the part to be inspected is placedbetween the radiation source and a piece of radiation sensitive film. The radiation source can either be an Xray machine or a radioactive source (Ir-192, Co-60, or inrare cases Cs-137). The part will stop some of the

radiation where thicker and more dense areas will stopmore of the radiation. The radiation that passes through the part will expose the film and forms a shadowgraphof the part. The film darkness (density) will vary with the amount of radiation reaching the film through the test

object where darker areas indicate more exposure(higher radiation intensity) and lighter areas indicate less exposure (lower radiation intensity).This variation in the image darkness can be used to determine thickness or composition of material and would also reveal the presence of any flaws or discontinuities inside the material.



Advantages

- Both surface and internal discontinuities can be detected.
- Significant variations in composition can be detected.
- It has a very few material limitations.
- Can be used for inspecting hidden areas (*direct access to surface is not required*)
- Very minimal or no part preparation is required.
- Permanent test record is obtained.

- Good portability especially for gamma-ray sources.

Disadvantages

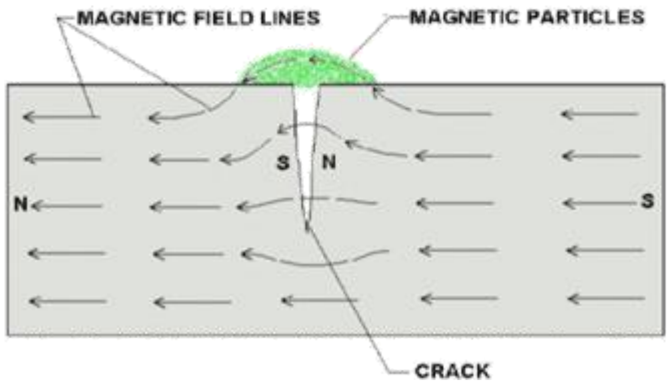
- Hazardous to operators and other nearby personnel.
- High degree of skill and experience is required for exposure and interpretation.
- The equipment is relatively expensive (*especially for x-ray sources*).
- The process is generally slow.
- Highly directional (*sensitive to flaw orientation*).
- Depth of discontinuity is not indicated.
- It requires a two-sided access to the component.

Magnetic Particle Inspection (MPI)

The welded area is coated with a magnetic flux containing iron ferrous particles. An electric yoke magnet is placed across the flux producing a visible magnetic field. Any surface cracks or weld irregularities will become evident by the accumulation of the flux due to the forming of a new magnetic pole each side of the crack. This is a very inexpensive and quick method of weld inspection, however it is only used to check fillet welds for surface imperfections, and of course can only be used on ferrous metals.

This method can detect surface and internal irregularities in ferrous and non-ferrous metal welding.

The first step in a magnetic particle inspection is to magnetize the component that is to be inspected. If any defects on or near the surface are present, the defects will create a leakage field. After the component has been magnetized, iron particles, either in a dry or wet suspended form, are applied to the surface of the magnetized part. The particles will be attracted and cluster at the flux leakage fields, thus forming a visible indication that the inspector can detect



It operates by transmitting high frequency pulsing sound waves through the weld, the results being transmitted to a monitor as a trace. If the pulse comes in contact with an irregularity in the weld, the waves are sent back to the transmitter and show up on the monitor screen. The defect can be placed very accurately, but it requires an experienced operator to interpret the tracings on the monitor.

In theory, magnetic particle inspection (MPI) is a relatively simple concept. It can be considered as a combination of two nondestructive testing methods: magnetic flux leakage testing and visual testing. Consider the case of a bar magnet. It has a magnetic field in and around the magnet. Any place that a magnetic line of force exits or enters the magnet is called a pole. A pole where a magnetic line of force exits the magnet is called a north pole and a pole where a line of force enters the magnet is called a south pole. When a bar magnet is broken in the center of its length, two complete bar magnets with magnetic poles on each end of each piece will result. If the magnet is just cracked but not broken completely in two, a north and south pole will form at each edge of the crack. The magnetic field exits the north pole and reenters at the south pole. The magnetic field spreads out when it encounters the small air gap created by the crack because the air cannot support as much magnetic field per unit volume as the magnet can. When the field spreads out, it appears to leak out of the material and, thus is called a flux leakage field. If iron particles are sprinkled on a cracked magnet, the particles will be attracted to and cluster not only at the poles at the ends of the magnet, but also at the poles at the edges of the crack. This cluster of particles is much easier to see than the actual crack and this is the basis for magnetic particle inspection.

Advantages

1. High sensitivity (small discontinuities can be detected).

2. Indications are produced directly on the surface of the part and constitute a visual
3. representation of the flaw. Minimal surface preparation (no need for paint removal)
4. Portable (materials are available in aerosol spray cans)
5. Low cost (materials and associated equipment are relatively inexpensive)

Disadvantages

1. Only surface and near surface defects can be detected.
2. Only applicable to ferromagnetic materials
3. .• Relatively small area can be inspected at a time.
4. Only materials with a relatively nonporous surface can be inspected.
5. The inspector must have direct access to the surface being inspected.

Ultrasonic Testing (UT)

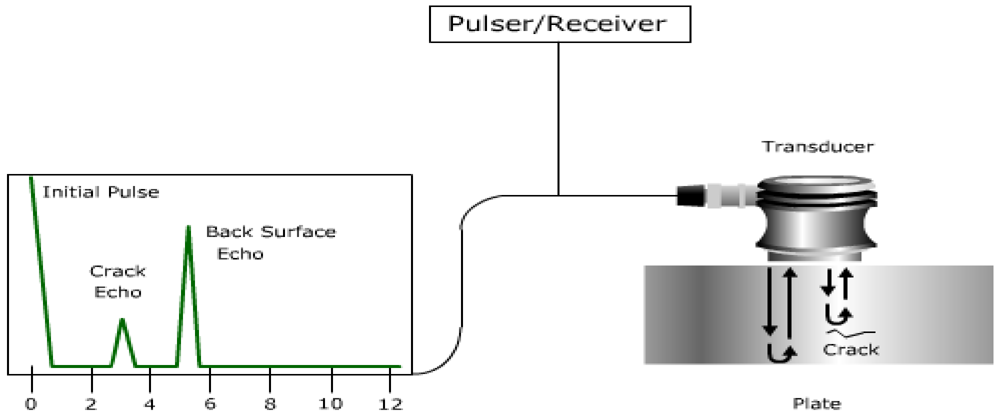
This method can detect surface and internal irregularities in ferrous and non-ferrous metal welding.

It operates by transmitting high frequency pulsing sound waves through the weld, the results being transmitted to a monitor as a trace. If the pulse comes in contact with an irregularity in the weld, the waves are sent back to the transmitter and show up on the monitor screen. The defect can be placed very accurately, but it requires an experienced operator to interpret the tracings on the monitor.

Basic Principles

A typical pulse-echo UT inspectionsystem consists of several functional units, such as the pulser/receiver,transducer, and a display device. A pulser/receiver is an electronic device that can produce high voltage electrical pulses. Driven by thepulser, the transducer generates high frequency ultrasonic energy.The sound energy is introduced and propagates through the materials in the form of waves. When there is a discontinuity (*such as a crack*) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen. Knowing the velocity of the waves, travel time can be directly related to the distance that the signal traveled.

From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.



Advantages

- It is sensitive to both surface and subsurface discontinuities.
- The depth of penetration for flaw detection or measurement is superior to other NDT methods.
- Only single-sided access is needed when the pulse-echo technique is used.
- It is highly accurate in determining reflector position and estimating size and shape.
- Minimal part preparation isrequired.
- It provides instantaneous results.
- Detailed images can be produced with automated systems.
- It is nonhazardous to operators or nearby personnel and does not affect the material being tested.
- It has other uses, such as thickness measurement, in addition to flaw detection.
- Its equipment can be highly portable or highly automated.

Disadvantages

Surface must be accessible to transmit ultrasound.

- Skill and training is more extensive than with some other methods.
- It normally requires a coupling medium to promote the transfer of sound energy into the test specimen.
- Materials that are rough, irregular in shape, very small, exceptionally thin or not

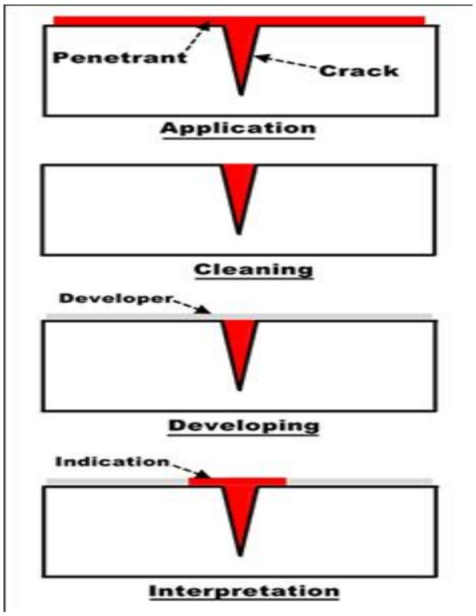
homogeneous are difficult to inspect.

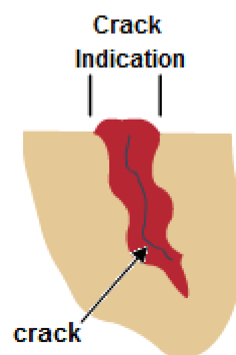
- Cast iron and other coarse grained materials are difficult to inspect due to low sound transmission and high signal noise.
- Linear defects oriented parallel to the sound beam may go undetected.
- Reference standards are required for both equipment calibration and the characterization of flaws.

Dye Penetration (Dye Pen)

It is one of the oldest and simplists NDT methods where its earliest versions (*using kerosene and oil mixture*) dates back to the 19th century. This method is used to reveal surface discontinuities by bleedout of a colored or fluorescent dye from the flaw. The technique is based on the ability of a liquid to be drawn into a "clean" surface discontinuity by capillary action. After a period of time called the "dwell time", excess surface penetrant is removed and a developer applied. This acts as a blotter that draws the penetrant from the discontinuity to reveal its presence. The advantage that a liquid penetrant inspection offers over an unaided visual inspection is that it makes defects easier to see for the inspector where that is done in two ways: It produces a flaw indication that is much larger and easier for the eye to detect than the flaw itself. Many flaws are so small or narrow that they are undetectable by the unaided eye (*a person with a perfect vision can not resolve features smaller than 0.08 mm*). It improves the detectability of a flaw due to the high level of contrast between the indication and the background which helps to make the indication more easily seen (*such as a red indication on a white background for visable penetrant or a penetrant that glows under ultraviolate light for flourecent penetrant*). Liquid penetrant testing is one of the most widely used NDT methods. Its popularity can be attributed to two main factors: its relative ease of use and its flexibility. It can be used to inspect almost any material provided that its surface is not extremely rough or porous. Materials that are commonly inspected using this method include; metals, glass, many ceramic materials, rubber and plastics. However, liquid penetrant testing can only be used to inspect for flaws that break the surface of the sample (*such as surface cracks, porosity, laps, seams, lack of fusion, etc.*). This system operates on a capillary action principle where a fluid in the form of a florescent or nonflorescent dye is applied to a weld surface.

Once the fluid has been given time to penetrate the surface, (between 15 and 30 minutes) the excess is wiped away and a developing fluid applied. The developer draws fluid out from any flaws and when viewed under a UV or white light, imperfections in the weld become visible.





Steps of Liquid Penetrant Testing

The exact procedure for liquid penetrant testing can vary from case to case depending on several factors such as the penetrant system being used, the size and material of the component being inspected, the type of discontinuities being expected in the component and the condition and environment under which the inspection is performed. However, the general steps can be summarized as follows:

1. *Surface Preparation*: One of the most critical steps of a liquid penetrant testing is the surface preparation. The surface must be free of oil, grease, water, or other contaminants that may prevent penetrant from entering flaws. The sample may also require etching if mechanical operations such as machining, sanding, or grit blasting have been performed. These and other mechanical operations can smear metal over the flaw opening and prevent the penetrant from entering.

2. *Penetrant Application*: Once the surface has been thoroughly cleaned and dried, the penetrant material is applied by spraying, brushing, or immersing the part in a penetrant bath.

3. *Penetrant Dwell*: The penetrant is left on the surface for a sufficient time to allow as much penetrant as possible to be drawn from or to seep into a defect. Penetrant dwell time is the total time that the penetrant is in contact with the part surface. Dwell times are usually recommended by the penetrant producers or required by the specification being followed. The times vary depending onthe application, penetrant materials used, the material, the form of the material being inspected, and the type of discontinuity being inspected for. Minimum dwell times typically range from five to 60 minutes. Generally, there is no harm in using a longer penetrant dwell time as long as the penetrant is not allowed to dry. The ideal dwell time is often determined by experimentation and may be very specific to a particular application.

4. *Excess Penetrant Removal*: This is the most delicate part of the inspection procedure because the excess penetrant must be removed from the surface of the sample while removing as little penetrant as possible from defects. Introduction to Non-Destructive Testing Techniques Liquid Penetrant Testing Page 3 of 20 Depending on the penetrant system used, this step may involve cleaning with a solvent, direct rinsing with water, or first treating the part with an emulsifier and then rinsing with water. 5. *Developer Application*: A thin layer of developer is then applied to the sample to draw penetrant trapped in flaws back to the surface where it will be visible. Developers come in a variety of forms that may be applied by dusting (*dry powders*), dipping, or spraying (*wet developers*).

6. *Indication Development*: The developer is allowed to stand on the part surface for a period of time sufficient to permit the extraction of the trapped penetrant out of any surface flaws. This development time is usually a minimum of 10 minutes. Significantly longer times may be necessary for tight cracks.

7. *Inspection*: Inspection is then performed under appropriate lighting to detect indications from any flaws which may be present.

8. *Clean Surface*: The final step in the process is to thoroughly clean the part surface to remove the developer from the parts that were found to be acceptable.

Advantages

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

Rapid inspection of large areas and volumes.

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

Disadvantages

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