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NON DESTRUCTIVE TESTING OF WELDED METALS TO ENHANCE THE QUALITY OF MATERIALS

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Abstract- Welding is a common joining process used extensively in automobile industries, aircraft machine frames structural work ship building and various other fields. The physical properties of these welds are influenced by several factors. In order to produce satisfactory weldments which fulfill the requirement of quality the integrity of quality control is important. To understand the various defects, their causes and remedies can help to ensure higher quality and longer lasting welds. This report contains essential information of surface irregularities and weld discontinuities. Non destructive testing (NDT) is a mechanism which helps in finding out of defects of any item like welds before major harms happen to the item without affecting its usefulness. This thesis discusses the non destructive testing of weld structures. There are more than fourteen methods of NDT in metals, in this thesis the most important ones-Visual, Ultrasonic, X-ray and penetrant testing are discussed in detail. The experimental results are discussed and comparisons are made based on cost, accuracy, safety, time consumption, etc. Based on these comparisons conclusions and recommendations are made.

***Index Terms*— Weldments, Penetrant, destructive, consumption, accuracy, etc.**

I. INTRODUCTION

The term NDT is often considered to be concerned only with the detection and location of flaws. Actually, the methods and techniques used in NDT measure physical properties or non-uniformity in physical properties of materials as well as variations or non uniformities in physical properties may or may not affect the usefulness of a material, depending upon the particular application under consideration. These methods and techniques can be used to determine what variations or non-uniformities in properties can be tolerated in the anticipated service. As our technology advances further, there will be a demand and need for new performance from engineering materials.

II. PURPOSE OF NON DESTRUCTIVE TESTING

The primary purpose of a non-destructive inspection is to determine the existing state or quality of a material, with a view to acceptance or rejection. By use of NDT methods and techniques it has been possible to decrease the factor of ignorance about material without decreasing the factor of safety in the finished product. The use of non-destructive testing has been and is being more fully recognized by management as a means of meeting consumer demands for better products, reduced cost, and increased production. While performing NDT it is also important to consider how the material is produced, what manufacturing processes are used to form the finished product and what discontinuities are typically initiated by the process operations. Discontinuity is categorized by the stage of manufacturing or use in which it initiates.

Discontinuity is categorized in four stages

I. Inherent discontinuities.
II. Primary processing discontinuities.
III. Secondary processing discontinuities.
IV. Service induced discontinuities.

Common NDT Methods

I. Ultrasonic Testing.
II. Magnetic Particle Testing.
III. Liquid Penetrant Testing.
IV. Radiography Testing.
V. Eddy Current Testing.

III. METHODOLOGY

A. Ultrasonic Testing (UT)

In ultrasonic testing high frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws. Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound. The reflected wave signal is transformed into electrical signal by the transducer and is displayed on a screen. The reflected signal strength is displayed versus the time from signal generation to when an echo was received. Signal travel time can be directly related to the distance that the signal travelled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained. If any dislocation is found in welds, it's located easily by using ultrasonic testing.

1. Types of Sound waves are used for finding the dislocation in welds

In solids, molecules can support vibrations in other directions so the numbers of different types (modes) of sound waves are possible. On the basis of particle displacement in the medium ultrasonic waves are classified as longitudinal waves, transverse waves, surface waves and lamb waves. Velocity remains the same in the given medium but differs when the method of vibration changes.

There are four types of sound waves are used for finding the dislocation in welds:-

- Longitudinal - Parallel to wave direction
- Transverse - Perpendicular to wave direction
- Surface (Rayleigh) - Elliptical orbit symmetrical mode
- Plate Wave (Lamb) - Component perpendicular to surface (extensional wave)

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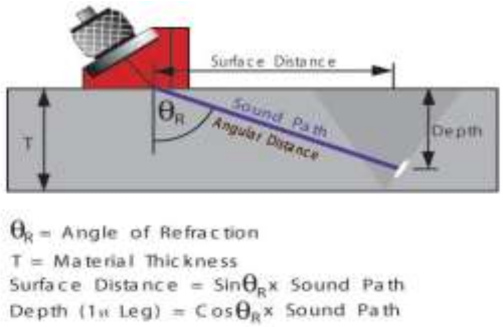

Fig-1 Ultra Sonic Testing

2. *Main uses of Ultrasonic Testing*

Ultrasonic testing is sued to locate surface and subsurface defects in many materials including metals, weld metals, plastics, and wood. Ultrasonic inspection is also used to measure the thickness of materials and otherwise characterize properties of material based on sound velocity and attenuation measurements.

Advantages of Ultrasonic Testing

- 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 high accuracy in determining reflector position and estimating size and shape.
- Minimal part preparation required.
- Detailed images can be produced with automated systems.
- Surface must be accessible to transmit ultrasound.
- Skill and training is more extensive than with some other methods.
- Materials that are rough, irregular in shape, very small, exceptionally thin or not homogeneous are difficult to inspect.
- Linear defects oriented parallel to the sound beam may go undetected.
- Reference standards are required for both equipment calibration, and characterization of flaws.

B. *Magnetic Particle Inspection (MPI)*

MPI uses magnetic fields and small magnetic particles, such as iron filings to detect flaws in components. The only requirement from an inspect ability standpoint is that the component being inspected must be made of a ferromagnetic material such as iron, nickel, cobalt, or some of their alloys. Ferromagnetic materials are materials that can be magnetized to a level that will allow the inspection to be affective. The method is used to inspect a variety of product forms such as castings, forgings, and weldments. Many different industries use magnetic particle inspection for determining a component's fitness-for-use.

1. *Basic Principles of MPI*

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 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.

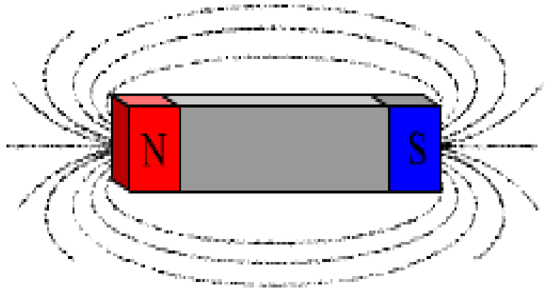

Fig-2 Principles of MPI

Testing Procedure of MPI

- Cleaning.
- Demagnetization.
- Contrast dyes (e.g. white paint for dark particles).
- Magnetizing the object.
- Addition of magnetic particles.
- Illumination during inspection (e.g. UV lamp).
- Interpretation.
- Demagnetization - prevent accumulation of iron particles or influence to sensitive instruments.
- Magnetizing the object- There are a variety of methods that can be used to establish a magnetic field in a component for evaluation using magnetic particle inspection. It is common to classify the magnetizing methods as either direct or indirect.
- Direct magnetization: current is passed directly through the component.

2. *Clamping the component between two electrical contacts in a special piece of equipment-*

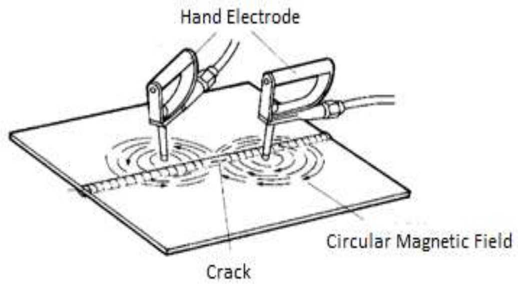

Fig-3 Magnetization using hand held electrodes

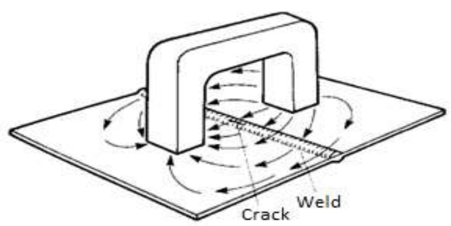

Fig-4 Magnetization using a permanent magnet

Demagnetization

- After conducting a magnetic particle inspection, it is usually necessary to demagnetize the component. Remnant magnetic fields can:
- Affect machining by causing cuttings to cling to a component.
- Interfere with electronic equipment such as a compass.
- Can create a condition known as "ark blow" in the welding process. Arc blow may causes the weld arc to wonder or filler metal to be repelled from the weld.
- Cause abrasive particle to cling to bearing or faying surfaces and increase wear.

Magnetic particles-

- Pulverized iron oxide (Fe_3O_4) or carbonyl iron powder can be used.
- Colored or even fluorescent magnetic powder can be used to increase visibility.
- Powder can either be used dry or suspended in liquid.

Advantages of MPI

- Fast, simple and inexpensive.
- Direct, visible indication on surface.
- Unaffected by possible deposits, e.g. oil, grease or other metals chips, in the cracks.
- Can be used on painted objects.
- Surface preparation not required.
- Only good for ferromagnetic materials.
- Sub-surface defects will not always be indicated.
- Relative direction between the magnetic field and the defect line is important.
- Objects must be demagnetized before and after the examination.

Examples of visible dry magnetic particle indications-

Fig-5 Indication of crack in weldments

3. *Liquid Penetrant Inspection (LPI)*

Liquid Penetrant inspection is one of the most widely used nondestructive evaluation (NDE) methods. Its popularity can be attributed to two main factors, which are its relative ease of use and its flexibility. LPI can be used to inspect almost any material provided that its surface is not extremely rough or porous. Materials that are commonly inspected using LPI include metals (aluminum, copper, steel, titanium, etc.), glass, many ceramic materials, rubber, and plastics.

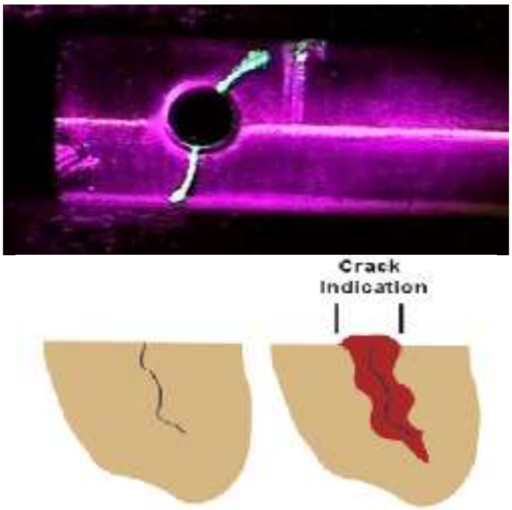

Fig-6 Liquid Penetrant Inspection of a Material

Basic processing steps of LPI

I. Surface Preparation: One of the most critical steps of a liquid Penetrant inspection 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 the surface of the sample, thus closing the defects.

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

III. 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. The times vary depending on the application, Penetrant materials used, the material, the form of the material being inspected, and the type of defect being inspected. Generally, there is no harm in using a longer Penetrant dwell time as long as the Penetrant is not allowed to dry.

IV. 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. Depending on the Penetrant system used, this step may involve cleaning with a solvent, direct rinsing with water, or first treated with an emulsifier and then rinsing with water.

V. 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 powdered), dipping, or spraying (wet developers).

VI. 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 and significantly longer times may be necessary for tight cracks.

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

VIII. 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.

The following Penetrant are used for LPI-

Dye Penetrant

- The liquids are colored so that they provide good contrast against the developer.
- Usually red liquid against white developer.
- Observation performed in ordinary daylight or good indoor illumination.

Fluorescent Penetrant

- Liquid contain additives to give fluorescence under UV.
- Object should be shielded from visible light during inspection.
- Fluorescent indications are easy to see in the dark

Advantages of LPI

- The method has high sensitive to small surface discontinuities.
- The method has few material limitations, i.e. metallic and non-metallic, magnetic and nonmagnetic, and

conductive and nonconductive materials may be inspected.

- Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.
- Parts with complex geometric shapes are routinely inspected.
- Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
- Aerosol spray cans make Penetrant materials very portable.
- Penetrant materials and associated equipment are relatively inexpensive.

4. *Radiography*

Radiography involves the use of penetrating gamma- or X-radiation to examine materials and product's defects and internal features. An X-ray machine or radioactive isotope is used as a source of radiation. Radiation is directed through a part and onto film or other media. The resulting shadowgraph shows the internal features and soundness of the part. Material thickness and density changes are indicated as lighter or darker areas on the film. The darker areas in the radiograph below represent internal voids in the component.

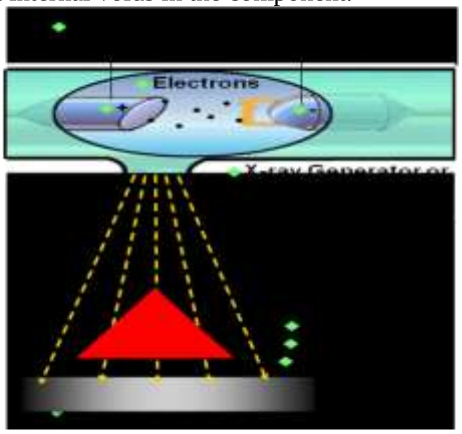

Fig-7 Radiography

Radiation sources

- X-rays or gamma radiation is used in radiography.
- X-rays are electromagnetic radiation with very short wavelength ($\approx 10^{-8}$ -10^{-12} m).
- The energy of the x-ray can be calculated with the equation $E = h\nu = hc/\lambda$ e.g. the x-ray photon with wavelength 1Å has energy 12.5 keV.

5. *Radio Isotope (Gamma) Sources*

- Emitted gamma radiation is one of the three types of natural radioactivity. It is the most energetic form of electromagnetic radiation, with a very short wavelength of less than one-tenth of a nano-meter. Gamma rays are essentially very energetic x-rays emitted by excited nuclei. They often accompany alpha or beta particles, because a nucleus emitting those particles may be left in an excited (higher-energy) state.
- Men made sources are produced by introducing an extra neutron to atoms of the source material. As the material rids itself of the neutron, energy is released in the form of gamma rays. Two of the more common industrial Gamma-ray sources are Iridium-192 and Colbalt-60. These isotopes emit radiation in two or three discreet wavelengths.
- Advantages of gamma ray sources include portability and the ability to penetrate thick materials in a relativity short time.
- Disadvantages include shielding requirements and safety considerations.

Film Radiography

- The part is placed between the radiation source and a piece of film. The part will stop some of the radiation. Thicker and denser area will stop more of the radiation.
- The film darkness (density) will vary with the amount of radiation reaching the film through the test object. Defects, such as voids, cracks, inclusions, etc., can be detected.

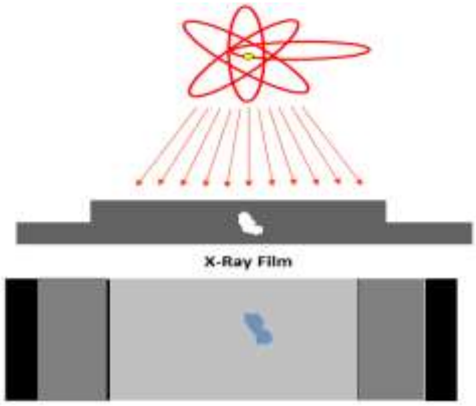

Fig-8 Top View of Development Film

Application of Radiography

- Can be used in any situation when one wishes to view the interior of an object.
- To check for internal faults and construction defects, e.g. faulty welding.
- To 'see' through what is inside an object.
- To perform measurements of size, e.g. thickness measurements of pipes.

Non Destructive Testing Methods and Applications

Where- M.T = Magnetic Particle Testing
U.T = Ultrasonic Testing
R.T= Radiography Testing
P.T= Liquid Penetrant Testing
E.T=Eddy Current Testing

IV. RESULT AND DISCUSSION

Now it is found that non destructive testing (NDT) is mechanism which helps in finding out of defects of welded materials before major harms happen to the item without affecting its usefulness.

In a survey of local companies for their experience on NDT it is found that most manufactured products are not checked for defects using NDT. Consequently some products will fail during operation. To avoid these failures they are manufacturing products which are over design, which increases cost of products. Reasons for not using NDT are due to lack of awareness of NDT, lack of testing machineries and lack of skilled personnel. There is appropriate type of testing method for each type of NDT, but due to a limited type of NDT machines, some companies implement their available testing method which may not be appropriate to the part to be tested, which leads to un-accurate result.

V. CONCLUSION

- Quality assurance and quality control complement each other. With a higher level of quality assurance the extent of testing may be reduced.
- These defects weaken the structural fatigue strength that in critical structural are not tolerated. In this way, effective and reliable non destructive techniques are required for the detection of these flaws.
- The geometry, location and micro structural nature of the weld defects, which typical of fusion welding of mild steel, lead to very difficulties in identification when using the common NDT techniques.
- NDT techniques provide a great deal of information about maintenance and support of metal structures at relatively low cost. In case, extra information is needed about the quality of a structure or if the damaged areas are not visible, NDT becomes a useful tool for the field of engineers.
- A number of reliable NDT techniques exist for measuring material properties and strength of metal and welds. Some other NDT methods have been used to detect and measure the delaminating, voids and thickness.

VI. FUTURE SCOPE

- Non-destructive testing (NDT) is a non invasive technique for determining the integrity of a material, component or structure. Because it allows inspection without interfering with a product's final use, NDT provides an excellent balance between quality control and cost-effectiveness.
- The main goal of NDT is to predict or assess the performance and service life of a component or a system at various stages of manufacturing and service cycles.
- NDT is used for quality control of the facilities and products, and for fitness or purpose assessment (so-called plant life assessment) to evaluate remaining operation life of plant components (processing lines, pipes and vessels).
- NDT inspection of industrial equipment and engineering structures is important in power generation plants, petroleum and chemical processing industries, and transportation sector.
- State-of the-art methodology is applied to assess the current condition, fitness-for-service, and remaining life of equipment. NDT inspection provides basic data helping to develop strategic plans for extending plant life.

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Materials	Flaw Type					
	Surface Cracks & Flaws	Sub-Surface Cracks & Flaws	Internal Flaws & Discontinuities	Lack of bond of lock of Fusion	Non-Metallic Inclusions Slag, porosity	Lamina-tions, Thickness Measurement
Ferrous components & finished	M.T.	U.T. E.T.	R.T. U.T.	U.T.	M.T. U.T.	U.T.
Non-ferrous components finished	P.T.	U.T. E.T.	R.T. U.T.		U.T. E.T.	U.T.
Aircraft ferrous components	R.T. M.T. E.T.	M.T. U.T.	R.T. U.T.	U.T.	M.T. U.T.	U.T
Aircraft non-ferrous components	R.T. P.T. E.T.	R.T. U.T.	R.T. U.T	U.T.	P.T	U.T
Ferrous forgings & stampings	M.T.	M.T. U.T	R.T U.T		R.T. U.T.	U.T
Ferrous raw materials & rolled products	M.T.	M.T. U.T.	U.T.		M.T. U.T.	U.T
Ferrous tube & pipe	M.T. E.T.	M.T. U.T.	U.T.	U.T.	M.T. U.T.	U.T
Ferrous welds	M.T. U.T. P.T	U.T.	R.T. U.T	R.T. U.T.	R.T. U.T.	U.T.
Steel castings	M.T.	M.T. U.T.	R.T. U.T		R.T. U.T.	U.T.
Iron castings	M.T.	U.T. E.T.	U.T.		R.T. U.T	U.T.
Non-ferrous components & materials	P.T. E.T.		R.T. U.T.	U.T.	P.T. U.T.	U.T.