AN INVESTIGATION INTO NON DESTRUCTIVE TESTING TECHNIQUES: A SPECIFIC CASE STUDY

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Abstract

This paper investigate applications of ultrasonic phased array technique over magnetic particle inspection, gamma rays radiographic and conventional ultrasonic testing applied during manufacturing of Low Pressure Heater (LPH) at a company X located in India. The existing non destructive testing techniques that are being used for detection of defects are compared with the alternative techniques. Most of the non destructive testing techniques are surely cost effective but time consuming this makes the overall stay time, production time and overall cost indulged in process high. By applying ultrasonic phased array technique the maintenance scheduling and incurred cost of maintenance and also the overall operational cost can be reduced remarkably.

Keywords*: Non destructive testing, maintenance, ultrasonic phased array, radiography.*

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1. INTRODUCTION

Maintenance involves fixing of any sort of electrical or mechanical or both devices that have underwent out of order or in other words it is the group of activities to restore equipment or system in prior working condition accurately. This involves performing routine actions which keep the device in working order that include the combination of all technical and corresponding managerial actions along with administrative and supervision actions. One of the major aspects that deal with the preventive maintenance is non-destructive testing techniques which are a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage. These tests are performed in a manner that does not affect the future use, such as serviceability of the object. Because non destructive testing allows parts and materials to be inspected and measured without damaging them, provides an excellent balance between quality control, cost-effectiveness and reliability [24]. Low pressure heater is a heat exchanger that preheats the feed water prior to its supply to the boiler. The incoming feed water circulates through U-tube with the heating steam passing over the outside of the tubes. Diaphragm plates are used to support the tubes and to direct the steam through the heater. A steam trap ensures that all the heating steam is condensed before it leaves the heater.

2. NON DESTRUCTIVE TESTING TECHNIQUES

Non destructive testing techniques are used since the evolution of mankind and are continuously improvised with time and technology. These techniques are useful in quality control and maintenance. The non destructive techniques that are applied at various manufacturing stages of a ‘low pressure heater’ are discussed as follows.

2.1 Dye Penetrant Testing (DPT)

This technique is regularly uses for surface breaking’s flaw in non-ferromagnetic material. The component is to be examined initially cleaned by using some chemicals usually by vapour to remove all type of contaminants as dirt, dust, foreign material and grease from surface and also from cracks available in surface. Dye is sprayed or painted over the testing area and leaves it there for around 20-25 minutes as dwell time. After dwell the dye is rinsed off and developer is sprayed which suck out the dye penetrated into the cracks. The dye can be seen by naked eyes [17]. Figure 1 shows channel welded to tube plate and dye penetrant testing done on the welded joint.

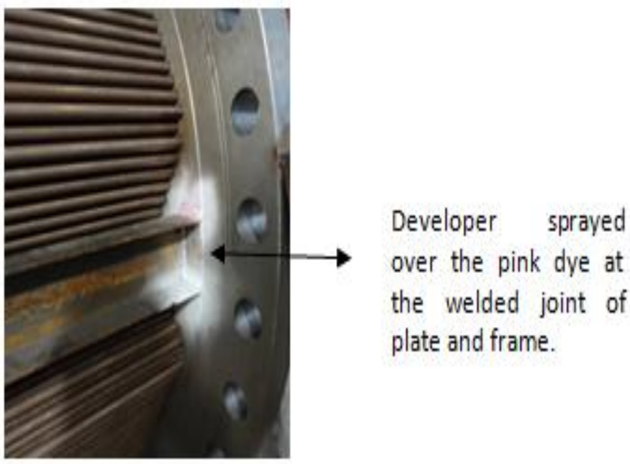

Fig -1: Plate and frame joint.

2.2 Radiography Testing (RT)

In this technique material is placed between the source of radiation and the film for testing internal crack of it. The voids or other internal defects are shown by darkened areas on which maximum radiation reaches on cleaned background after exposure. Figure 2 shows the placement of source inside the isotope box and the arrangement to take it out to exposure [17]. It is suitable only for thin section up to 50 mm and for thicker sections the time required for the exposure is more which is possibly hazardous for personnel. This technique is unable to detect the depth of defect from top surface although it gives a correct view of the flaw whether a crack or slag is present inside the material. The equipments and accessories for viewing and reading film are necessary so to replace that by electronic devices to get real time imaging is an expensive affair and hence the automation of process is costly.

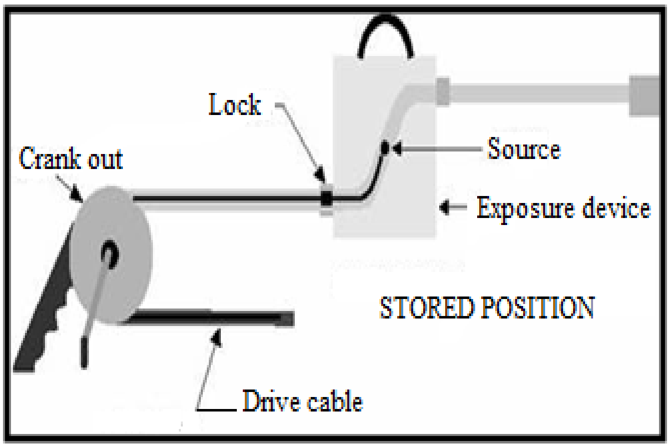

Fig -2: Schematic layout of Radiographic testing. [17]

Fig -3: Exposure device [17]

2.3 Magnetic Particle Inspection (MPI)

Magnetic-particle inspection is based on the fact that when a ferromagnetic material is magnetized, discontinuities that lie in a direction generally transverse to the direction of the magnetic field cause a leakage field to form above the surface. The presence of the leakage field, and therefore the presence of the discontinuity, is detected by finely divided ferromagnetic particles applied over the surface. These particles have size from 20 to 30 micron of oxide. These particles provide mobility for particles on surface of parent material assisting crack on the surface of parent material. Some of the particles are gathered and held by the leakage field. The magnetically held particles form an outline of the discontinuity and generally indicate its location, size, shape, and extent. Magnetic particles are applied over a surface either as dry particles, or as wet particles in a liquid carrier such as water or oil. The magnetic-particle method is a sensitive means to locate small, shallow surface cracks. The figure 4 represents the magnetic flux lines and the completion of circuit by the magnetic particles that are spread over the surface. [20]

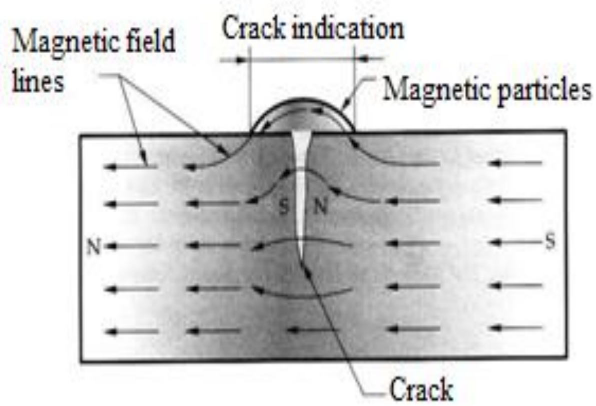

Fig -4: Flow of magnetic flux lines over the surface.

2.4 Ultrasonic Flaw Detection (UT)

Ultrasonic testing is technique which uses ultra sound of frequency range between 0.5 to 15 MHz to conduct testing of component. An ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by a couplant such as water, oil or glycerin. There are two methods of receiving the ultrasound waveform namely attenuation and reflection. In attenuation mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium. Irregularities or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence. In reflection or pulse-echo mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an irregularity within the object. The diagnostic machine displays these results in the form of a signal with amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection.

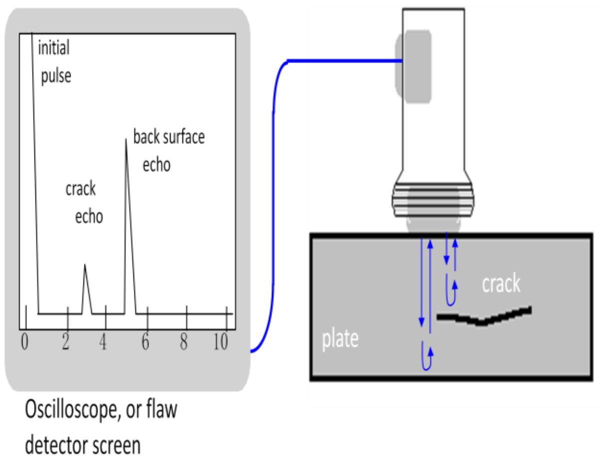

Fig -5: Assembly of UT showing detector screen, probe and the defective work piece [17]

2.5 Ultrasonic Phased Array Testing

Radiographic Testing and Ultrasonic Testing are among the most used techniques for the inspection of circumferential and longitudinal weld joints of shell. The shell of nuclear reactor is a crucial part and critical to observe and maintain. It is difficult to do radiographic testing on the shell once it is fixed and very easy to perform ultrasonic phased array testing to get accurate and reliable result. [24]

Seunghan Yang et al (2009) describe the conventional broad beam ultrasonic inspection technique usually has inadequate resolution for flaw sizing and tendency for false calls. But the phased array technique by improved detection capability and resolution could increase coverage of the examination areas with less scanning required.

C. Colla et al (2002) discuss ultrasonic crack detection and sizing is an essential tool in determining the asset integrity of pressure vessels and piping. Conventional ultrasonic testing shear wave techniques have proved to be time consuming, requiring high skill levels and frequently resulting in unreliable and inconsistent data. Phased array ultrasonic testing technology can provide novel solutions to these problems with reliable results, imaging of the cracks showing direction or propagation and reduced inspection times.

Dong Hu et al (2012) substantiate the belief that for a circumferential shell the non destructive testing used conventionally is radiographic testing but in spite of that Ultrasonic phased array has excellent abilities of electronic steering, deflection and focusing. As the rapid development of electronic and computer technology, it has been widely employed in industry non destructive testing, the nuclear industry and chemical industries. Ultrasonic phased array technology has the advantages of convertible beam direction and focus, the results is easy imaging and the detection has better accessibility and applicability. Therefore, it can solve the problems and difficulties of non destructive testing inspection in over-lapped pack structure and coarse grain materials testing. The technology can improve the accuracy of ultrasonic testing and the reliability of test results.

Paritosh Nanekar et al (2013) simulated and computed the focal law phased array examination over the conventional ultrasonic test and radiography test for the circumferentially welded joints in shell of reactor pressure vessel and the weld joints in reactor pressure vessel of boiling water reactors. These are required to be examined periodically for assurance of structural integrity. So the only technique to examine such joints was radiography which in very difficult to implement in ongoing service. Ultrasonic phased array examination technique has been developed by author for inspection of the top flange to shell circumferential weld joint. Ultrasonic phased array technique has been developed for in-service inspection of circumferential weld joint between the top flange and reactor pressure vessel shell. As compared to conventional ultrasonic test, the phased array approach offers several benefits. The most important fact is that it ensures 100% volume coverage for detection of defects in the weld joint. The use of focused sound beam helps in achieving good resolution and sensitivity. The focal laws for phased array examination were computed based on detailed simulation studies.

Comparison of ultrasonic phased array technique with other techniques that have been used during the manufacturing of ‘low pressure heater’ is tabulated in table 1 on the basis of requirement for the suitable and desired results during manufacturing and in service. [10]

Table -1: Comparison of non destructive testing techniques

	Testing Techniques				
Important considerations	**Ultrasonic testing**	**Radiography**	**Ultrasonic phased array**	**Magnetic particle inspection**	**Dye penetrant test**
Capital cost	Medium to high	High	Low to medium	Medium	Low
Consumable cost	Very low	High	Very low	Medium	Medium
Time of results	Immediate	Delayed	Immediate	Short delay	Short delay
Effect of geometry	Important	Important	Important	Not too important	Not too important
Access problems	Important	Important	Important	Important	Important
Type of defect	Internal	Most	Most	External	Surface breaking
Relative sensitivity	High	Medium	High	Low	Low

Formal record	Expensive	Standard	Expensive	Unusual	Unusual
Operator skill	High	High	High	Low	Low
Operator training	Important	Important	Important	Important	Important
Training needs	High	High	High	Low	Low
Portability of equipment	High	Low	High	High to medium	High
Dependent on material composition	Very	Quite	Very	Only magnetic	Little
Ability to automate	Good	Fair	Good	Fair	Fair

3. CASE STUDY OBJECTIVES

The 'low pressure heater' works under high pressure hence it is of prime importance to ensure that all the joints and fastening assembly are up to the mark of standard norms. To meet the standards it is crucial to observe and analyze quality measure of component to reduce the occurrence of defects in service. The objectives that must be fulfilled in the manufacturing of 'low pressure heater' to get a high level of maintainability and reliability are as follows:-

- To Investigate a technique that can effectively replace the conventional NDT techniques
- To reduce capital and consumable cost
- Technique must provide immediate and real time results.

4. INVESTIGATIVE METHODOLOGY

As the dye penetration test and magnetic particle testing is having low to moderate cost and it is irreplaceable. However for moderate to high capital cost techniques like ultrasonic testing and radiography, it can be substituted by a single ultrasonic phased array testing technique.[9]

4.1 Comparison between Conventional Ultrasonic Test and Ultrasonic Phased Array Test

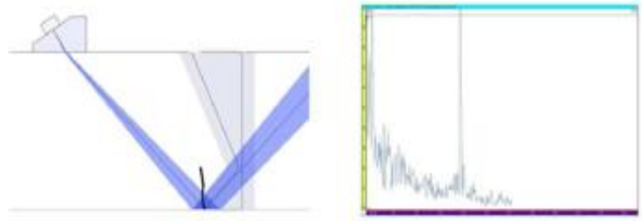

Fig -6: Conventional ultrasonic test with its representation.[8]

Conventional ultrasonic testing gives images in 2D graphical form also it does not cover the complete defect at once. This makes the technique time consuming and tedious. Further, back-scattering tip signals are absent with conventional ultrasonic testing. Cracks get confused with weld joints on parent material create further complications in efforts to verify separation or crack interaction. If separation could not be confirmed results into overly conservative values with erroneous data for crack growth rates and hasty repairs.

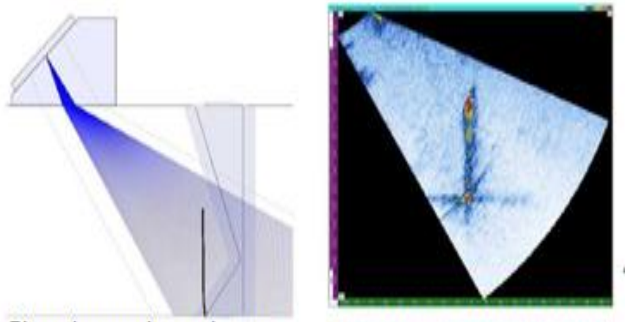

Fig -7: The ultrasonic phased array with full coverage of defect along with its sectional view. [8]

Ultrasonic phased array testing technique images illustrate the crack face, providing the ability to distinguish and characterize welding discontinuities from cracks. Strong backscatter tip-diffraction signals also become apparent. Phased array imaging shows crack propagation angle, ID connections, depth and orientation. This has subsequently reduced the inspection time to approx 50% to that previously found with conventional ultrasonic testing.

4.2 Comparison between Radiography Testing and Ultrasonic Phased Array Test

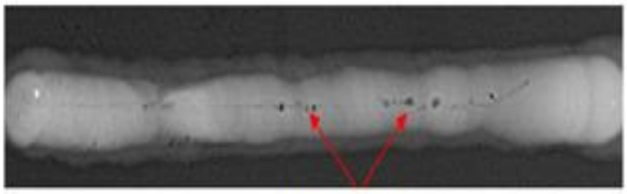

Fig -8: Radiography image showing slag in the weld joint.[21]

The dark spots shown in figure 8 are air bubbles or impurities present in the welding material. This slags are not propogative like cracks but if present there it will cause damage during working of the component.

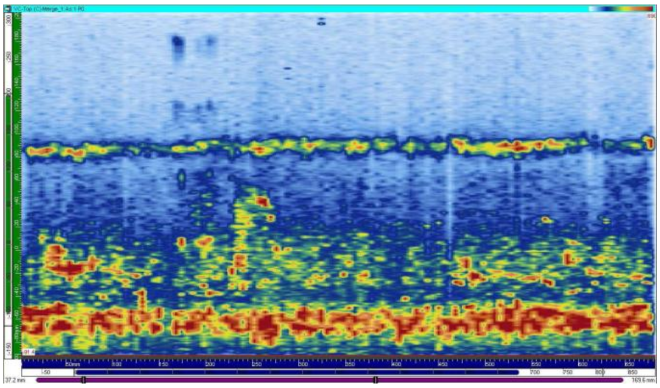

Fig -9: Representation of longitudinal weld joint using ultrasonic phased array test. [8]

A belt of welded area is shown in the figure 9 where the red color shows the irregularities present in the weld and also the improper fusion of the weld to parent material. It is a real time scan view.

5. COMPARATIVE FINDINGS

The techniques used to detect surface and subsurface defects are dye penetrant test and magnetic particle test respectively. As the initial and consumables cost are low these methods are economic and sufficient to get accurate results hence it does not required to replace.

The capital cost incurred in ultrasonic testing is high but the consumable cost is low and when it is compared to ultrasonic phased array testing the overall cost of phased array technology is low. The conventional ultrasonic test usually have inadequate resolution, flaw sizing and the result interpretations are in 2D. It also have a tendency for false calls as weld to parent material joints get confused with cracks. The single beam ultrasonic testing does not cover the complete area of inspection so different angle probes are required and it takes time to examine. In ultrasonic phased array testing the interpretations are in 2D and 3D form which is much easier to understand also it gives accurate flaw sizing. The broad beam phased array ensures the complete coverage of the inspection area with less scanning which is time saving for maintenance practice and during servicing.

In radiography testing the apparatus and setup are tedious also the time consumed in radiation shooting, film processing and analysis is on an average of 3 hours whereas ultrasonic phased array testing gives the real time images of the test. As radiographic test has huge immovable setup and performing test is hazardous, it is required to test in a properly protected area in spite of this the ultrasonic phased array testing is portable and sensitive to defects. Radiography test cannot show the depth of the irregularities found in the weld area and the ultrasonic phased array testing explains the dimension, depth and orientation of defect more accurately. Ultrasonic phased array testing has vast, accurate, time saving, cost efficient and real time results.

6. CONCLUSION

This paper presents an investigation using literature of the ultrasonic phased array testing technique over radiography and conventional ultrasonic testing. Ultrasonic phased array testing showed significant reductions in scanning times and crack imaging also it is proved to be accurate for complex geometries, indicating the direction of propagation via imaging. Phased array inspection time found at least 50% quicker than conventional ultrasonic testing techniques, resulting in less down time for vessels passing and cost savings to the owner. Data is stored for trending, reporting, auditing and comparison purposes. The Focal laws can be changed during inspection for each situation, thus optimizing tip signals and accuracy of depth measurements. Data can be projected onto 2D and 3D sketches for interpretation. Imaging shows the crack face, tip and direction of propagation; all valuable information for the reliability engineer.

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