Characterising of Weldmet Defects in Duplex Steel using Non Destructive Testing

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Abstract— Non-destructive testing is a type of testing in which we find out the defects of a specimen without changing any of its properties and without causing any damages. We used two types of NDT methods to find out the defects in duplex stainless steel (200X160 mm) which was butt joined using TIG welding. Mainly two types of defects were found volumetric and linear defects. The defects found in LPT were surface defects are volumetric defect(1mm,1mm) and linear defect(4mm) of lengths. In case of MPT the defects were sub surface and internal defects which were linear defects of lengths (6mm,1.5mm,2mm).

Keywords: NDT methods, Weldmet Defects, Pre-cleaner, Liquid Penetrant Testing

I. Introduction

A general definition of non-destructive testing (NDT) is an examination, test, or evaluation performed on any type of test object without changing or altering that object in any way, in order to determine the absence or presence of conditions or discontinuities that may have an effect on the usefulness or serviceability of that object. Non-destructive tests may also be conducted to measure other test object characteristics, such as size; dimension; configuration; or structure, including alloy content, hardness, grain size, etc. The simplest of all definitions is basically an examination that is performed on an object of any type, size, shape or material to determine the presence or absence of discontinuities, or to evaluate other material characteristics.

Non-destructive examination (NDE), non-destructive inspection (NDI), and non-destructive evaluation (NDE) are also expressions commonly used to describe this technology. Although this technology has been effectively in use for decades, it is still generally unknown by the average person, who takes it for granted that buildings will not collapse, planes will not crash, and products will not fail.

Although NDT cannot guarantee that failures will not occur, it plays a significant role in minimizing the possibilities of failure. Other variables, such as inadequate design and improper application of the object, may contribute to failure even when NDT is appropriately applied.

NDT, as a technology, has seen significant growth and unique innovation over the past 25 years. It is, in fact, considered today to be one of the fastest growing technologies from the standpoint of uniqueness and innovation. Recent equipment improvements and modifications, as well as a more thorough understanding of materials and the use of various products and systems, have all contributed to a technology that is very significant and one that has found widespread use and acceptance throughout many industries.

II. Literature Survey

Shyamji et al. (2017) studied about Non-destructive Testing method by penetrant testing. This investigation focused on those parameters that are not that easy to reconstruct and only briefly discussed the influence on the signal response due to defect position, orientation and size. A number of investigations address the relationships between the defect parameters like roller depth, surface defects also the phenomena of the electrical contacts between the defect surfaces was studied. Defect parameters that are essential to the quality of penetrant testing or defect position in the object, orientation, size, crack surface roughness, closure and tip radius. NDT method depends on material deterioration in a given environment, and often several methods are combined. Liquid penetrant testing was one of the earliest methods used for Non-destructive inspection and has been a main stay of practical NDT for many years. It is the most common NDT method used for the detection of surface breaking cracks in metal components and is used extensively in the aerospace industry during production of aircraft and throughout their service life. Principle of liquid penetrant is that a liquid penetrant is applied on the surface of the specimen. The penetrant is drawn by the surface flaw due to capillary action and this is subsequently revealed by developer, in addition with visual inspection. The aim of study is that introducing inspection and various testing methods to understand its purpose and its importance in industries specially in fabrication industry.

A. Conclusion

The project mainly concentrated on the welding methods and welding defects. While there were many methods to join two metals welding is one of the most convenient and rapid method available. There for the welded region should be flawless. The defect flaws are detected by principle of liquid penetrant and the flaws were made to be within the specified working limits specified by the quality control code.

Alexandra Nana Kwesi Agyenim-Boateng et al. (2015) conducted Dye penetrant inspection technique on turbine rotating component. The role of Non-destructive Evaluation in ensuring pre-service quality and also monitoring in service degradation to avoid premature failure of the components or structure is ever increasing. Critical gas turbine rotating components, such as turbine blades, compressor discs, spacers and cooling fan blades are subjected to cyclic stresses during engine start-up, operation and shut down. The life time of these components are usually established on the basis of probabilistic crack initiation criterion for a known fracture critical location. Therefore, periodic inspections are carried out to detect probable cracks and to prevent sudden failure. The dye penetrant testing basically revealed the cracked, fractured and sound parts of the steam turbine during the inspection period. The various parts of the steam turbine are evaluated were both the compressor and generator rotor, turbine blades, the diffuser, the exhaust hoods, the compressor casings, the generator bearing and retaining ring. Low cycle fatigue occurs as a result of turbine start up and shut down cycles and is predominant in the bores and bolt hole area of compressor and turbine discs that operate under centrifugal stresses.

B. Conclusion

Visual inspection of the different parts of the steam turbines indicated various categories of flaws, these are fractured parts, grinding cracks, heat treat crack and fatigue crack. All these flaws were caused by stresses which were generated by the heat created between the rotatory wheel and adjoining metal.

Umesh Singh et al. (2012) conducted analysis studies on surface and sub surface imperfections through magnetic particle crack detection for non-linear dynamic model of some mining components. Different mine gear components are evaluated through magnetic particle detection techniques and results are analyzed in terms of their suitability acceptance or rejection norms of the mining industry in India. Magnetic particle crack detection (MPCD) technique is most widely used technique because it reduces cost of inspection and enhance the quality of the component. It not only detects the defects on surface but also detect the defects which are in some depth. It is concluded that MPCD must be used in industry prior use of component so that failure of equipment is reduced. Defects plays a crucial role in influencing the various material properties and exhibit complex structure on varying length scales from the electronic structure of the defect core to elastic field of continuum. There are many methods of generating magnetic flux in the test piece few are, the first common method is the permanent magnet to the surface but this method cannot be controlled accurately because of indifferent surface contacts and deterioration in magnetic strength. The second method is the direct method high amperage current is passed through the test piece and magnetic flux is generated perpendicular to the current flow. The effect is to pass magnetic flux along the prat to reveal transverse and circumferential defects. The author conclude that visual technique is useful to find out the condition of sample and helpful to get ready for future NDT technique MPCD Can detect transverse as well as longitudinal cracks which can be identified and quantified.

C. Conclusion

Magnetic particle crack detection detected transverse and as well as longitudinal cracks which were indentified and quantified. Some components like distribution plate, c-coupling were accepted due to no harmful character of surface imperfection. Other components like shackle, swivel, and safety hook outer plate were rejected to harmful character of surface imperfection. Magnetic particle crack detection should be conducted on manufactured equipment prior to use so that failure of component in stipulated time could be prevented.

Ranganayakulu et al. (2015) studied about TIG welded EN-08 steel specimen by the use of Non-Destructive Evaluation. The work describes the correlation of different NDT methods for identifying intensity of flaw, accuracy of orientation and position of flaw in same specimen is carried out. Liquid penetration process is relatively simple, low capital cost the arrangement of discontinuities is not a limitation but it has its own limitations as it can inspect depth up to 2 mm. The defects need to open to the surface. This testing produce offer low reliability and moderate sensitivity and requiring considerably high degree of operator skill. Mild steel is most widely used material in manufacturing. EN-08 is usually supplied untreated material which can also be supplied in the normalized or finally heat treated, quenched and tempered which is adequate for a wide range of applications. As the test specimen is mild steel magnetic particle inspection is also possible, fluorescent magnetic particle are chosen for better sensitivity of inspection. According to the studies surface defects are discontinuous that are detected through liquid penetrant test and magnetic particle inspection.

D. Conclusion

Surface defects are discontinuities that were detected through liquid penetrant test. The flaws open to the surface were fixed. Cluster porosity were detected by magnetic particle testing. Two internal discontinuities were detected through ultrasonic testing. Overall ultrasonic and radiography testing showed high sensitivity then other methods.

III. METHODOLOGY

A. Process Involved In Methodology

1) Liquid Penetrant Testing

Liquid Penetrant testing (LPT) is one of the most widely used nondestructive testing methods for the detection of surface discontinuities in nonporous solid materials. It is almost certainly the most commonly used surface NDT method today because it can be applied to virtually any magnetic or nonmagnetic material. LPT provides industry with a wide range of sensitivities and techniques that make it especially adaptable to a broad range of sizes and shapes. It is extremely useful for examinations that are conducted in remote field locations, since it is extremely portable. The method is also very appropriate in a production type environment where many smaller parts can be processed in a relatively short period of time.

B. Equipment used in Liquid Penetrant Test

1) Precleaners

Precleaning is an essential first step in the penetrant process. The surface must be thoroughly cleaned to assure that all contaminants and other materials that may prohibit or restrict the entry of the penetrant into surface openings are removed. Thorough cleaning is essential if the examination results are to be reliable.

Fig. 1: Pre-cleaner

2) Penetrant

Penetrant Equipment systems range from simple portable kits to large, complex in-line test systems. he kits contain pressurized cans of the penetrant, cleaner/remover, solvent, and developer and, in some cases, brushes, swabs, and cloths. A larger fluorescent penetrant kit will include a black light. These kits are used when examinations are to be conducted in remote areas, in the field, or for a small area of a test surface. In contrast to these portable penetrant kits, there are a number of diverse stationary-type systems. These range from a manually operated penetrant line with a number of tanks, to very expensive automated lines, in which most steps in the process are performed automatically.

Fig. 2: Penetrant Applied

3) Emulsifiers/Removers

The purpose of the emulsifiers used in penetrant testing is to emulsify or break down the excess surface penetrant material. In order for these emulsifiers to be effective, they should also possess certain characteristics, including: The reaction of the emulsifier with any entrapped penetrant in a discontinuity should be minimal in order to assure that maximum sensitivity is achieved. The emulsifier must be compatible with the penetrant. The emulsifier must readily mix with and emulsify this excess surface penetrant. The emulsifier mixed with the surface penetrant should be readily removable from the surface with a water spray.

4) Application of Developer

After excess penetrant has been removed, a white developer is applied to the sample. Several developer types are available, including: non-aqueous wet developer, dry powder, water-suspendable, and water-soluble. Choice of developer is governed by penetrant compatibility (one can't use water-soluble or -suspendable developer with water-washable penetrant), and by inspection conditions. When using non-aqueous wet developer (NAWD) or dry powder, the sample must be dried prior to application, while soluble and suspendable developers are applied with the part still wet from the previous step. NAWD is commercially available in aerosol spray cans, and may employ acetone, isopropyl alcohol, or a propellant that is a combination of the two. Developer should form a semi-transparent, even coating on the surface.

The developer draws penetrant from defects out onto the surface to form a visible indication, commonly known as bleed-out. Any areas that bleed out can indicate the location, orientation and possible types of defects on the surface. Interpreting the results and characterizing defects from the indications found may require some training and/or experience.

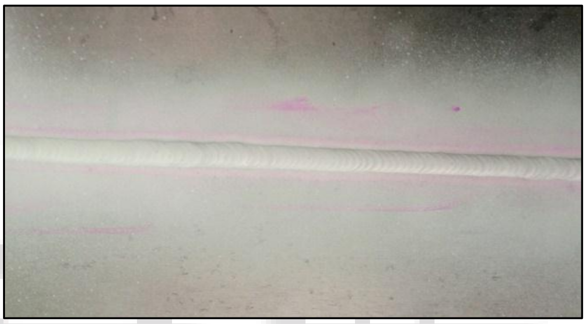

Fig. 3: Application of developer

5) Inspection

The inspector will use visible light with adequate intensity (100 foot-candles or 1100 lux is typical) for visible dye penetrant. Ultraviolet (UV-A) radiation of adequate intensity (1,000 micro-watts per centimeter squared is common), along with low ambient light levels (less than 2 foot-candles) for fluorescent penetrant examinations. Inspection of the test surface should take place after 10- to 30-minute development time, and is dependent on the penetrant and developer used. This time delay allows the blotting action to occur. The inspector may observe the sample for indication formation when using visible dye. It is also good practice to observe indications as they form because the characteristics of the bleed out are a significant part of interpretation characterization of flaws

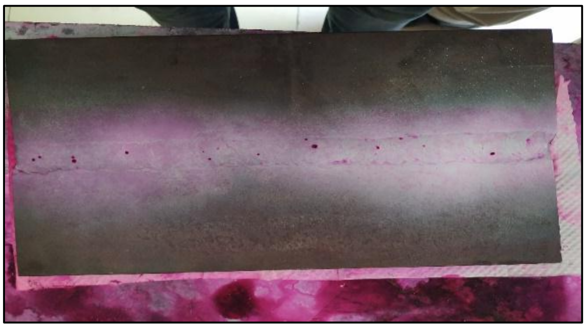

Fig. 4: Inspection

6) *Post Cleaning*

The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.

IV. MAGNETIC PARTICLE TESTING PROCEDURE

A. *Pre-Cleaning*

Oil, paint, rust and other foreign materials on the surface to be inspected not only prevent attraction of magnetic particles to the flux leakage, but also lead to form a false indication. Therefore duplex stainless steel cleaned chemically or mechanically before magnetization process.

Fig. 6: pre-cleaning

B. *Magnetization*

The workpiece is magnetized as direction of magnetic flux is orthogonal to direction of a flaw.

Following method is applied for proper magnetization.

1) Axial current method: To pass electric current longitudinal direction of the workpiece.
2) Cross current method: To pass electric current cross direction of axis of the workpiece.
3) Prod method: To pass electric current between two prods contacted inspection area of the workpiece.
4) Through conductor method: To pass electrical current through the hole of the workpiece.
5) Coil method: Put the workpiece in a magnetizing coil.
6) Yoke method: Put the workpiece between magnetic poles.
7) Through flux method: To pass magnetic flux through the hole of the workpiece.

C. *Applying magnetic particle*

1) *Types of Magnetic Particle*

Easy magnetization and migration to flux leakage and discriminative flaw indication are required for performance of magnetic particle.

There are two types of magnetic particle, one is non-fluorescent particle (white, red, black) for observation under visible light, and the other is fluorescent magnetic particle for observation under UV light. Dry method, magnetic particle is applied to the surface as it stands, and wet method, magnetic particle is dispersed in oil or water, are applied.

2) *Applying Timing of Magnetic Particle*

There are two methods. Magnetic particle is applied during magnetization of the workpiece, or applied after ceasing magnetization. In later case residual magnetism is utilized for forming flaw indication.

D. *Observation*

UV light is used for observation of the workpiece under dark environment in case of using fluorescent magnetic particle for inspection.

Fig. 7: Defects under Observation

1) *Post-cleaning*

Demagnetization, removing residual magnetic particle and rust proofing of the workpiece are done if required.

V. RESULTS AND DISCUSSIONS

Surface defects on the welded region of the duplex stainless steel consisting of volumetric and linear defects were found using liquid penetrating test. While the sub surface defects consisting of only linear defects were found using magnetic particle testing. The defects founded out were both under the specified working limit. Therefore the material was suitable for the further manufacturing process.

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