Identification of Defects in EN-O8 Mild Steel by Magnetic Particle Inspection

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Abstract-This paper describes the defects of welded EN-08 mild steel specimen. Magnetic particle inspection (MPI) uses the magnetic field in the specimen and where the magnetic particles are grouped together on the specimen surface, that region is detected as flaw area and the specimen is demagnetized for cleaning. EN-08 mid steel material is mostly used in mechanical engineering applications because of its stress handling capacity, physical strength and good surface finish. This testing method is often used for detecting the surface in ferrous machinery components (cranes, steel structures and etc.,) and surface defects. In this project, the identification of defects are determined by MPI since this test is mainly used for identifying the surface and sub-surface imperfections clearly.

Keywords: Magnetic Particle Inspection, Surface Defects, Sub-Surface Defects, Magnetic Field, EN-08 Mild Steel.

1. Introduction

Non-destructive testing (NDT) is an extensive variety of analyzing techniques and it is also used to examine the performance and properties of materials without causing any damage to the material [1], [8]. NDT is used to examine, inspect and evaluate under the proper test procedure such that the material or product will be used further again for useful work. NDT plays a vital role in our daily life and is important to ensure the safety and security of a product or component. Some of the applications of NDT are power stations, motor vehicles, aircraft, refineries, trains, etc.

There are different types of NDT methods used for testing different work samples in different aspects. Some of the NDT methods are visual inspection, Ultrasonic inspection test, X-ray radiography, Liquid Penetrant Examination and magnetic particle inspection. Here Magnetic particle inspection (MPI) is conducted to detect the defects or flaws of an EN-08 mild steel specimen

2. Literature Review

Ranganayakulu et al (2015) said that in case of TIG welded specimen, the test was conducted on EN-08 mild steel specimen by magnetic particle inspection, liquid penetration test and radiography test to detect the defects like cluster porosity, slag inclusion. It was concluded that radiography test gives more accurate results than magnetic particle inspection and liquid penetration test [1].

MohitBector et al (2014) said that in case of comparison of different NDT methods, it was concluded that liquid penetration test consumes less time when compared to magnetic particle inspection and ultrasonic test. Magnetic particle test is more hazardous compared to other tests [2].

Jiteshkumarsingh et al (2015) said that NDT is very useful method for checking the quality of the component since it does not damage the component while inspecting. The accuracy of detecting the defects is also very good [3].

Ranganayakulu et al (2017) said that the selection of NDT method depends on various parameters of the work piece and the type of crack detection [4].

Korning et al (1994) experimented and said that it is not only important to find a defect but equally it is important to repair the found defect. The micro structure of the defect should not vary after conducting the test [5].

Umeshsingh et al (2012) said that Magnetic particle crack detection helps in finding defects on ferrous materials like mild steel, cast iron, etc. Magnetic particle crack detection should be conducted on each and every component manufactured in the industry before supplying in to the market so as to avoid failures [6].

Gorkunov et al. (2011) said that the magnetic particle testing allows us to find structural changes as well as crack detection of the component (high carbon pearlitic steel) which was subjected to fatigue loading. In most of the cases, if the life of a fatigue crack exceeds more than 80% the dimensions of the crack will not exceed more than 1mm [7].

3. Ndt Methods And Their Outline

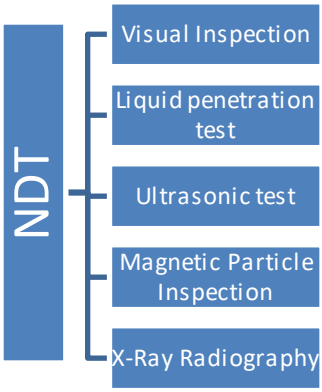

Fig. 1 NDT Classification

Some of the NDT methods are visual inspection, liquid penetration test, magnetic particle inspection, ultrasonic test, and etc., as shown in fig. 1

Visual inspection test is basically conducted by human eye in earlier days but now a days the inspection takes place by sensor analyzing method, where the sensor analyses the surface of material [9].In visual inspection, when detecting the industrial part (or) material, Three factors should be considered they are 1.camera angle/camera pose on detecting material, 2.light direction, 3. Normal vector of a part. The detection of flaw on material will takes place by rotating the material and taking the poses of material through camera in a sequence way. By the variation of pixels in image sequence, defect can be known [10]. RVI (Remote visual inspection) used at risky areas instead of using general visual inspection.

Liquid penetration test is used for detection of cracks, porosity, and surface discontinuities in ferrous and non-ferrous materials. In this test, penetrant is used to find out the cracks, surface discontinuities in the solid materials. The penetrant will remain where the surface discontinuities takes place due to capillary action. Now developer is applied on the material and is kept under the ultraviolet rays or white light for inspection. The operating condition of material would be in between 4°c to 52°c [11].

Ultrasonic testing uses the High frequency sound waves to detect the internal flaws and cracks, etc., The frequency of sound waves ranges between 0.5 to 15MHZ. The sound waves are sent to the material/ specimen by using the probe and the waves will reflect back to the transducer. If any defect is identified in the material, ultrasonic waves will get back and the defect is identified in monitor. Ultrasonic testing plays a major role in detection of defects in aero plane, rails, train wheels, automobiles, carbon fiber Reinforced plastic, Glass fiber Reinforced plastic. Now a days the ultrasonic testing comes as a wireless sensor networks [12].

4. Material Used

EN-08 mild steel is a very famous material used in most of the manufacturing industries. The grade EN-08 is a very popular grade which is readily machinable in any condition. This material is most suitable for gears, shafts, axles etc.

The composition of the material used for testing is tabulated in table 1.

Table 1- composition of material

Carbon	Mg	Si	P	S	Fe
0.35-0.45%	0.70-0.90%	0.10-0.35	0.05	0.05	Rest

5. Magnetic Particle Inspection

MPI tests the surface of Ferro-magnetic materials and its structures. It uses the magnetic field to find the defects of materials. Magnetic particles are sprinkled on the specimen surface where the magnetic particles are grouped together, that region is identified as defected area.

Magnetic forces are greater at the poles and repels each other where the place is called defect identified region. North to south magnetic lines flows internally whereas south to north magnetic lines flows externally. There are two modes of magnetic fields. They are longitudinal and circular magnetic fields. The direction of magnetic lines is identified by using the instrument called pie gauge and the amount of magnetic field passed in the specimen is measured by using shims. There are two types of methods for application of magnetic particles on the specimen they are dry method and wet method. In wet method, water and kerosene (liquid medium) is applied on the specimen prior the sprinkling of Ferro-magnetic materials whereas in dry method only Ferro-magnetic particles are sprinkled on the specimen directly. In wet method, two types of coatings are employed, where there the particles are colored and coated on the specimen and those indications can be viewed under the white light whereas when the specimen is coated using the fluorescent particles then the defects will be viewed under the ultraviolet light

Magnetization of materials are classified on the basis of direct magnetization and indirect magnetization as shown in fig. 2.

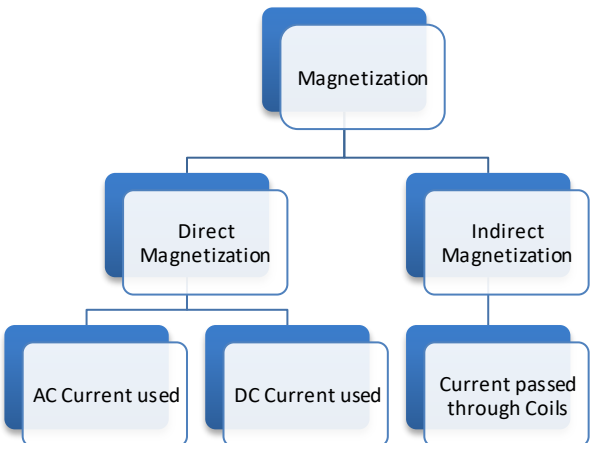

Fig. 2 Magnetization Methods

In direct magnetization, AC and DC currents are passed through the components so that the magnetic fields are generated in certain directions. AC current is used to identify the surface defects with high sensitive frequency waves and DC current is used to identify in-depth defects up to 6mm. In indirect magnetization, the current is passed through coils to the component / specimen.

There are three methods of demagnetization they are 1. Heat the specimen to above Curie temperature. 2. Use mechanical vibrations on the specimen 3. Subjecting the specimen to field continuously reversing its direction and at the same time gradually decreasing its strength to zero.

A. Steps involved in MPI:

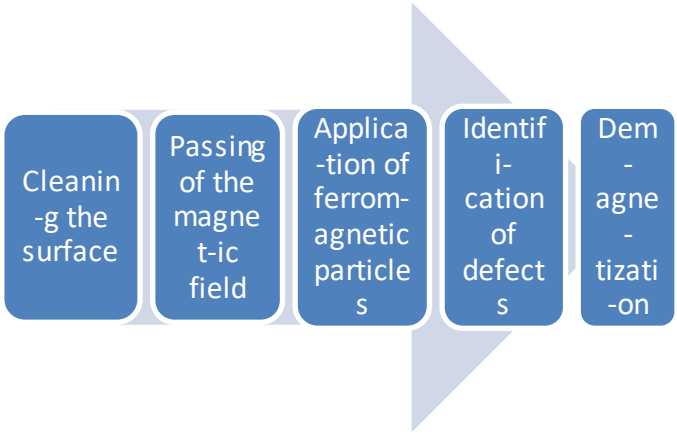

Fig. 3 Steps involved in MPI

The steps involved in MPI are shown in fig. 3. They are

1. Cleaning the surface
2. Passing of the magnetic field
3. Application of ferromagnetic particles
4. Identification of defects.
5. Demagnetization.

MPI can identify surface and sub-surface defects within short time even if the defects are very small. It can even identify defects for irregular objects (Crankshaft, connecting rods) with low cost. The main disadvantage of MPI is that it can only identify defects for ferromagnetic materials and the paint thickness of the material should not exceed than 0.005mm.

B. Weld Defects:

There are many processes in welding for joining two metals. Some of the welding processes are tungsten inert gas welding, metal arc welding, submerged arc welding, etc., [13]. Here, defects of arc welding process are considered for examination. Some of the defects in welding are discussed below as shown in fig. 4.

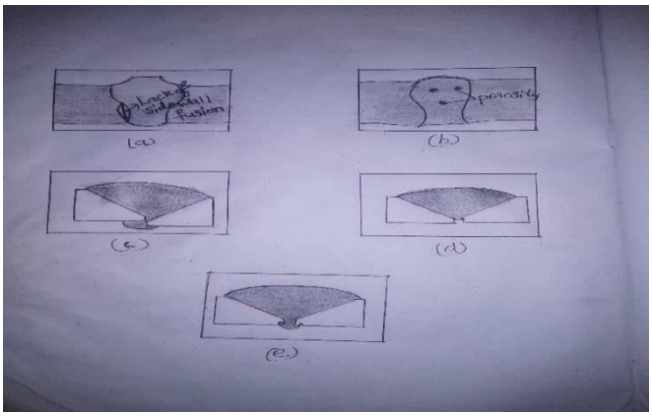

Fig. 4 Weld Defects

Cracking defect occurs due to incorrect implementation of welding technique and inappropriate filler material. Defects occur in hot and cold stages of welding. In order to overcome this defect, manganese is used and also the base metal has to be preheated and post heated as well.

Lack of fusion is a defect that occurs in weld due to the supply of incorrect power (current) and also due to inappropriate welding.

Porosity is a defect which occurs due to improper cleaning of the specimen by which the flux reacts and converts in to slag. This defect also occurs due to the lack of gas supply to the weld.

Root undercut occurs when the weld metal is not filled in the melted parent metal.

Misalignment occurs when the two joining metals are not fit properly while welding.

6.Experimental Procedure

Magnetic particle inspection gives the result on the principle of magnetic flux leakage. Magnetic particle inspection is used to test / inspect only ferromagnetic particles. In this, EN-08 mild steel material is inspected for cracks and surface defects. The material is joined using TIG welding which is single V butt welded. The experimental procedure includes the following steps:

A. Pre cleaning the material:

The specimen is initially rubbed with emery paper to remove all the rust and corrosion on the specimen and then the specimen is cleaned with universal cleaner (MR 3002 water based cleaner) to clear the dust particles and contaminants present on it as shown in Fig. 5. Here developer is applied on the test piece for clear vision of defects since the color of mild steel here is black.

Fig 5. Specimen after Pre Cleaning.

B. Magnetizing the material:

The material is magnetized longitudinally by using the instrument called Yoke. An electromagnetic yoke is very common equipment that is used to establish a magnetic field, which can be used in AC and DC modes with the help of a switch on it. DC mode produces a smooth a magnetic field whereas AC mode produces vibrations on it. Here direct method with direct current (DC) is employed for magnetizing since the material thickness is >2 mm. The magnetic yoke should be placed perpendicular to the weld region as shown in fig.6.

Fig. 6 Magnetizing the Material

C. Sprinkling of magnetic particles:

Dry powdered magnetic particles are fine particles that are milled from iron and iron oxide. Here dry powdered magnetic particles are used on the specimen since they attract magnetic flux leakage. The magnetic particles are sprinkled with the help of sprinkler as shown in fig. 7.

Fig.7 Sprinkler.

D. Blowing off excess magnetic particles:

Remove the excess powder on the surface of the test piece with few gentle air puffs as shown in fig.8. The air should be blowed in such a way that the air should be strong enough to remove the excess powder particles but not to remove the particles held by magnetic flux leakage

Fig.8 BlowingOff Particles.

Inspection:

Now the specimen is inspected for defects after removing the yoke from the top of the specimen. In this test, defects / flaws are found on the welded region as shown in fig.9. The defects are linear in side A due to improper welding and also defects are linear in side B due to misalignment. The part is rejected as they have exceeded the limit.

Fig.9 Defects on Specimen.

F. Post cleaning:

The magnetic particles on the specimen are cleared and the specimen is again cleaned with universal cleaner.

7. Result and Discussion

EN-08 mild steel specimen is being tested by using magnetic particle inspection and found defects on the welded region. The defects were linear on one side due to improper welding and on the other side the defects were linear due to misalignment. Therefore the test piece is rejected. The parts should be re-welded with proper alignment and with sufficient amount of flux and current supply. For quick and low cost inspection, MPI is the best NDT method for detecting surface and subsurface discontinuities.

8. Conclusion

Now in the present generation, products are manufactured by using modern technology in which the defects may be in less number and output may be with high quality. The main advantage of non-destructive testing when compared to destructive testing is that the work piece after testing is useful for productive work. Here magnetic particle inspection is conducted on EN-08 mild steel specimen for detecting surface and sub-surface defects.

- Magnetic particle inspection is used to detect defects up to 6mm from the surface level.
- It is clearly noted that magnetic particle gives better results for detecting surface defects than sub-surface defects.
- It is concluded that the specimen is rejected due to linear discontinuities on the surface.
- The sample should be re-welded with proper alignment and with sufficient amount of flux, current supply and adequate cooling rate to rectify the defects found on the sample.

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