# Analysis of surface defects formed in MILD STEEL E250 IS 2062 Material by using magnetic particle testing in various types of welds

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*Abstract* - **MPT is one of the non-destructive testing methods used for defect detection and specifically for cracks and can only be applied on ferromagnetic materials like iron, cobalt, nickel and their alloys. Magnetic Particle Testing is a fast and relatively easy to apply and surface preparation is not that much critical as it is in the case of LPT. MPT uses magnetic fields and small magnetic particles, such as iron filings to detect flaws in the components. This method is used to inspect a variety of products such as castings, forgings, production/manufacturing industries, automobile, aerospace, refineries, structural steel, automotive, petrochemical, power generation industries. In this paper the material of the specimen used is MILD STEEL E250 IS 2062.And for this material by using two different weld procedures i.e. the arc welding & tig welding two types of specimen are prepared and defects formed in these welded joints are detected. The following defects are identified in this paper by the MPT procedure a. Porosity b. undercuts c. Crack d. Porosity e. Incomplete fusion**

*keywords* - **MPT, Porosity,Undercuts,Crack**

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## I. Introduction

### 1.1 A. WELDING DEFECTS

The defects in the weld can be defined as irregularities in the weld metal produced due to incorrect welding parameters or wrong welding procedures or wrong combination of filler metal and parent metal.
Weld defect may be in the form of variations from the intended weld bead shape, size and desired quality. Defects may be on the surface or inside the weld metal. Certain defects such as cracks are never tolerated but other defects may be acceptable within permissible limits. Welding defects may result into the failure of components under service condition, leading to serious accidents and causing the loss of property and sometimes also life.

### CAUSES OF WELDING DEFECTS

According to the American Society Of Mechanical Engineers (ASME), causes of welding defects can be broken down as follows: 41 percent poor process conditions, 32 percent operator error, 12 percent wrong technique, 10 percent incorrect consumables, and 5 percent bad weld grooves.
The two major causes for welding defects are:

- Hydrogen embrittlement.
- Residual stresses.

### Hydrogen embrittlement

During hydrogen embrittlement hydrogen is introduced to the surface of a metal and individual hydrogen atoms diffuse through the metal structure. Because the solubility of hydrogen increases at higher temperatures, raising the temperature can increase the diffusion of hydrogen. When assisted by a concentration gradient where there is significantly more hydrogen outside the metal than inside, hydrogen diffusion can occur even at lower temperatures. Adsorbed hydrogen species recombine to form hydrogen molecules, creating pressure from within the metal. This pressure can increase to levels where the metal has reduced ductility, toughness, and tensile strength, up to the point where it cracks open.

### Residual stresses

Residual stress in welding is mainly the result of thermal expansion, which in basic terms means that materials expand or contract with temperature. Typical engineering materials tend to shrink in size as they cool. As we all know, welding is a highly thermal process where significant heat is applied at the weld joint. The material within the weld joint shrinks as it cools and, as a result, welding residual stress develops as the nearby material pulls back to maintain a bond with the shrinking weld material.

### TYPES OF WELDING DEFECTS

There are various types of surface defects in welded joints which causes failure of joint. Some of the most common types of welding defects are as follows:-

### Incomplete Penetration

Incomplete penetration happens when your filler metal and base metal aren't joined properly, and the result is a gap or a crack of some sort.

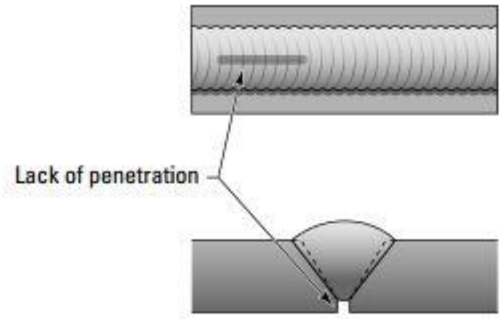



**Fig 1.1 incomplete penetration**

Welds that suffer from incomplete penetration are weak at best, and they'll likely fail if you apply much force to them.

### Incomplete Fusion

Incomplete fusion occurs when individual weld beads don't fuse together, or when the weld beads don't fuse properly to the base metal you're welding.

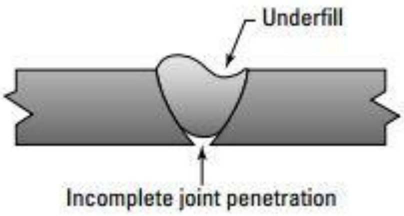



**Fig 1.2 incomplete fusion**

The most common type of incomplete fusion is called overlap and usually occurs at the toe (on the very top or very bottom of the side) of a weld. One of the top causes is an incorrect weld angle.

### Undercutting

Undercutting is an extremely common welding defect. It happens when your base metal is burned away at one of the toes of a weld.

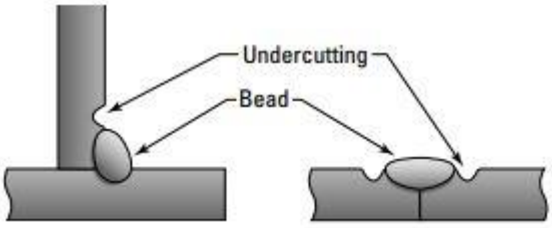



**Fig 1.3 undercut**

When you weld more than one pass on a joint, undercutting can occur between the passes because the molten weld is already hot and takes less heat to fill, yet you're using the same heat as if it were cold.

### Slag Inclusions

Slagis the waste material created when you're welding, and bits of this solid material can become incorporated (accidentally) into your weld.

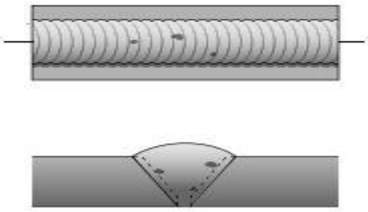


**Fig 1.4 Slag inclusions**

### Porosity

Porosity (tiny holes in the weld) can be a serious problem in your welds (especially stick or mig welds). Molten puddle releases gases like hydrogen and carbon dioxide as the puddle cools; if the little pockets of gas don't reach the surface before the metal solidifies, they become incorporated in the weld, and nothing can weaken a weld joint quite like gas pockets.

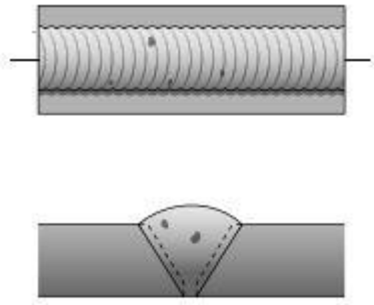


**Fig 1.5 porosity**

### Cracks

Cracks can occur just about everywhere in a weld: in the weld metal, the plate next to the weld metal or in any other piece affected by the intense heat of welding.

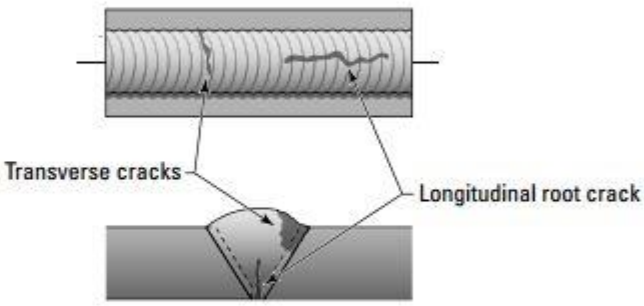



**Fig 1.6 cracks**

The three major types of welding cracks are:-

- Hot cracks
- Cold cracks
- Crater cracks

### Overlap

*When the weld face extends beyond the weld toe, then this defect occurs. In this condition the weld metal rolls and forms an angle less than 90 degrees.*

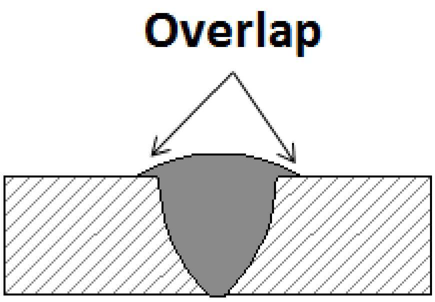



**Fig 1.7 overlapping**

## IDENTIFICATION OF DEFECTS USING MPT

Magnetic particle testing (MPT) is one of the oldest NDT methods. Defects in welded joints which cannot be detected by visual inspection can be detected by using Magnetic Particle Testing. Magnetic particle testing is a cheap and simple method of non-destructively detecting cracks which reach the surface in ferromagnetic materials. Over the years it has proven itself to be not only reliable, but cost effective, when it is applied properly with qualified personnel.

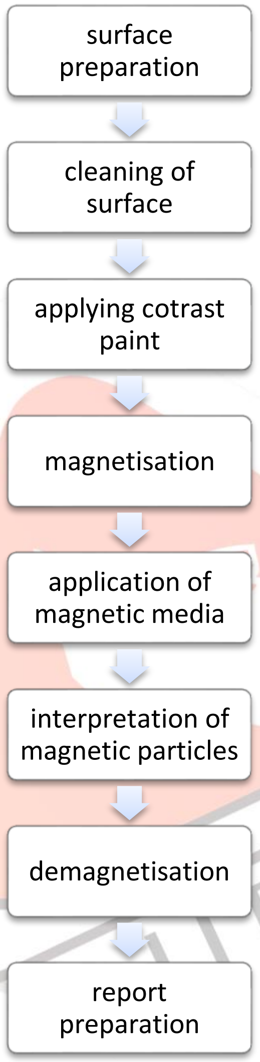
MPT can be able to detect the defects up to the depth of 6mm and also because the magnetic particle testing method excels all other NDT methods for finding very shallow surface cracks in ferromagnetic materials it is the more likely suitable for finding the defects in welding joints.

MPT uses electrical currents to create magnetic field on the surface of the welded joints. The cracks present on the surface of the joint leads the leakage of the magnetic flux and then fine magnetic particles are suspended on to the surface of the weld joint. The magnetic particles will form a cluster where the defect is present due to leakage of magnetic flux.

## 2. Objective of the work

The objective of this study is to detect the surface and sub-surface imperfections in welded joints by applying magnetic particles crack detection (MPCD) test without interfering in any way with the integrity of the welding. This study also ascertains the identification and quantification of surface imperfections followed by assessment of its suitability on basis of acceptance and rejection norms.

### 2.1 Flow process chart of detection of the welding defects by using MPT




**Flow process chart of welding defect detection**

## 3. Specimen used for testing

Two types of specimen are used which are welded by arc welding & tig welding procedures are used here .

**Material of the specimen**

MILD STEEL E250 IS 2062

- Carbon-0.22%
- Manganese-1.5%
- Sulphur-0.045%
- Phosphorous-0.045%
- Silicon-0.4%

**Mechanical properties of the material**

Yield strength – 250Mpa
Tensile strength – 410Mpa
Young's modulus – 22*10$_{5}$Mpa

**Welding procedures**

1. **Arc welding**

   Dimensions:-168mm X 145mm X 7mm

**Fig 3.1 Arc welded specimen**

**2. TIG welding**

Dimensions:-168mm X 145mm X 7mm

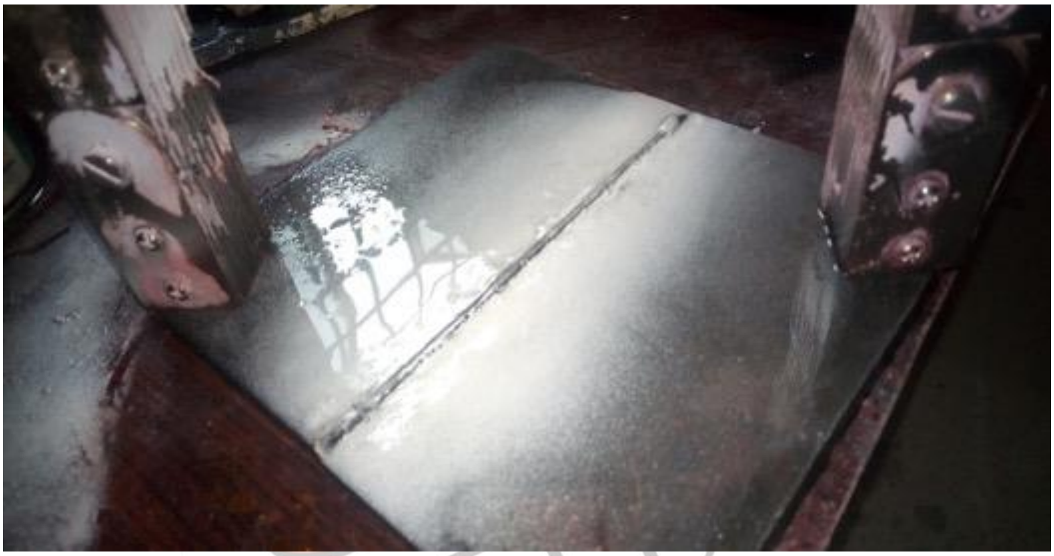


**Fig 3.2 TIG welded specimen**

## 4. RESULTS

### 4.1 Test results

**Specimen made by arc welding**

| | |
|---|---|
| MAGNETIC PARTICLE TESTING REPORT | |
| CLIENT :M.Rajesh | DRAWING NO. :01 |
| CONTRACT NO. :14 | PROCEDURE NO. : ASME/SECTION V / ARTICLE 7 |
| SPECIMEN SIZE | 168mm X 145mm X 7mm |
| JOINT TYPE & CONFIGURATION | Butt joint |
| EQUIPMENT USED | Electromagnetic yoke |
| TYPE OF MAGNETIZATION USED | AC&DC |
| TYPE OF MAGNETIZATION MEDIA USED | Dry and wet magnetic particles |
| CONTRAST PAINT USED | MR72 white contrast paint |
| NUMBER OF DIRECTIONS MAGNETIZED | Two direction |
| VISIBLE LIGHT INTENSITY | 1000lux |
| **DEFECT LOCATION SKETCHES** | |

| SUMMARY OF DEFECTS LOCATION | | | |
|---|---|---|---|
| DISTANCE FROM '0' | TYPE | LENGTH | LOCATION |
| 20 | Porosity | 25 | Surface |
| 56 | undercuts | 18 | surface |
| ALLOWABLE TOLERANCE | | ±5MM | ±10MM |
| REMARKS: ALL DIMENSIONS ARE IN MM | | | |

**4.2 Specimen made by TIG welding**

| MAGNETIC PARTICLE TESTING REPORT | |
|---|---|
| CLIENT : M.Rajesh | DRAWING NO. :02 |
| CONTRACT NO. :14 | PROCEDURE NO. : ASME/SECTION V / ARTICLE 7 |
| SPECIMEN SIZE | 168mm X 145mm X 7mm |
| JOINT TYPE & CONFIGURATION | Butt joint |
| EQUIPMENT USED | Electromagnetic yoke |
| TYPE OF MAGNETIZATION USED | AC&DC |
| TYPE OF MAGNETIZATION MEDIA USED | Dry and wet magnetic particles |
| CONTRAST PAINT USED | MR72 white contrast paint |
| NUMBER OF DIRECTIONS MAGNETIZED | Two direction |
| VISIBLE LIGHT INTENSITY | 1000lux |
| **DEFECT LOCATION SKETCHES** | |

| SUMMARY OF DEFECTS LOCATION | | | |
|---|---|---|---|
| DISTANCE FROM '0' | TYPE | LENGTH | LOCATION |
| 10mm | Incomplete fusion | 65 | internal |
| 115mm | Crack | 10 | Surface |
| 75mm | Porosity | 20 | Surface |
| ALLOWABLE TOLERANCE | | ±5MM | ±10MM |
| REMARKS: ALL DIMENSIONS ARE IN MM | | | |

**CONCLUSIONS**

For the specimens made of Arc welding & Tig welding when the MPT is performed the following discussions are drawn

The MPT method for the specimen made of arc welding has detected the porosity defect of length 25 mm on the surface Of the weld And the another defect identified as undercut of length 18mm on surface Of the weld.

The MPT method for the specimen made of tig welding has detected the porosity defect of length 20 mm on the surface Of the weld .And the another defect identified is crack of length 10mm on surface Of the weld .The defect that is identified is due to incomplete fusion of length 65mm and this defect is on the internal of weld

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