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[Chandra* *et al.*, 6(10): October, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

MICROSTRUCTURAL STUDY OF MAG WELDED JOINT OF AISI 1018 MILD STEEL

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DOI: 10.5281/zenodo.1002630

ABSTRACT

The present investigation aims to study the effect of process parameters of MAG welding (i.e. welding current, arc voltage and welding filler wire) on AISI 1018 mild steel plates considering the microstructure of base metal, heat affected zone and welded zone. CO_2 is used as shielding gas. An optical microscope used for the present investigation. The microstructure of base metal of mild steel represents an equiaxed grains of ferrite (F) as the major phase and smaller grains of fine pearlite (P) as the minor constituent at 50X magnification. Base metal has lower hardness because of fine pearlite. Welding zone microstructure changes with cooling rate. A martensite structure is formed in the weldment due to very fast cooling. So the weldments have higher hardness because the formation of martensite.

KEYWORDS: MAG Welding, AISI 1018 Mild Steel, Microstructure, Base Metal, HAZ, Welded Zone.

I. INTRODUCTION

The word microstructure derives its meaning from the fact that microscopy is required to resolve characteristic features of mild steel internal structures that range in size from those resolvable with the unaided eye to features resolvable only by light and electron microscopy. The unaided eye can resolve 0.1 mm (0.004 in.), and more closely spaced features require microscopy of some sort. The most appropriate unit for many microstructural features of steel, for example, grain or crystal size, is the micron or micrometer (μm), 10–6 m, or 0.001 mm (0.00004 in.), well below features that are resolvable by eye. The light microscope has a resolution on the rder of 0.5 μm and therefore is quite adequate for the characterization of many features of steel microstructures. A microstructure's influence on the mechanical and physical properties of a material is primarily governed by the different defects present or absent of the structure. These defects can take many forms but the primary ones are the pores. Even if those pores play a very important role in the definition of the characteristics of a material, so does its composition.

In MAG welding, as the heat source interacts with the material, the severity of thermal excursions experienced by the material varies from region to region, resulting in three distinct regions in the weldment. These are the fusion zone or welded zone (WZ), the heat-affected zone (HAZ), and the unaffected base metal (BM). The microstructure development in the welded zone and heat affected zone depends on the solidification behavior of the weld pool. The principles of solidification control the size and shape of the grains, segregation, and the distribution of inclusions and porosity. Solidification is also critical to the hot-cracking behavior of metal.

II. LITERATURE REVIEW

Saman Karami et al. [1] have investigated that in lower rotation speed or higher welding speed, probability of welding defect formation is relatively higher owing to the fact that the amount of heat input is not sufficient to provide enough flow-ability. Hence, tunnel or void formation are inevitable. Also indicated that in higher rotation speed or lower welding speed owing to larger amount of heat input, the temperature of the stir zone (SZ) or heat affected zone (HAZ) part would reach to single austenite phase region and consequently during cooling it can transforms to relatively finer ferrite and pearlite.

H. Zhang et al. [2] have observed that the solidification microstructure of the weld metal can be refined, and the quantity of different phases in weld metal can also be changed with wire autorotation, resulting in apparent increase in the tensile strength of the weld metal.

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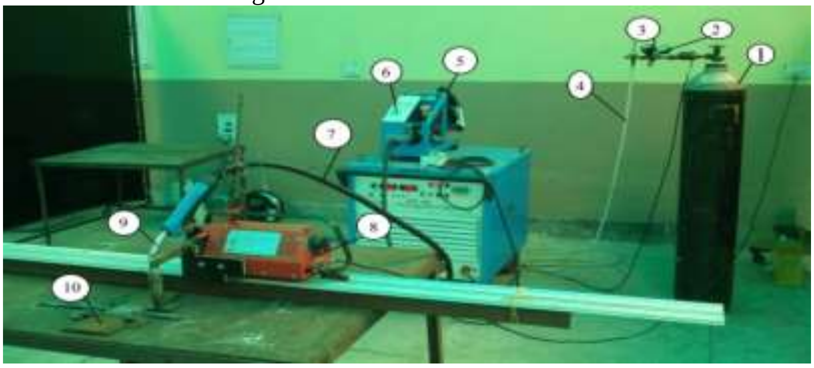
X. Meng et al. [3] have observed that the Similar microstructure distributions for MAG and hybrid arc weld, which consisted of coarse columnar dendrite perpendicularly growing from fusion line to the weld center and the fine acicular dendrite between the columnar dendrites. The microstructures were composed of columnar proeutectoid ferrite side plate and amount of fine acicular ferrite intermingled with a small quantity of fine acicular pearlite between the ferrite side plates. However, the comparison showed that Widmanstatten structure in hybrid arc weld was more obvious, which was typically considered as an undesirable structure that may weaken the dynamic mechanical properties of weld. It was induced that the deposited metal cooling rate of hybrid arc weld was higher, which leaded to more Widmanstatten structure.

R. Kumar et al. [9] have investigated that the structures of microstructure of weld metal of mild steel represents a fine grains of ferrite and pearlite. No formation of martensite takes place. So according to the results they can conclude that the weldments have lower hardness because both pearlite are soft constituents and there is no sign of formation of martensite.

III. EXPERIMENTATION

In the present work, mild steel AISI 1018 has been used as base metal for the purpose of MAG welding. The thickness of base metal is taken as 3 mm. From a sheet of mild steel the work piece of desired dimension i.e. 125 mm in length, 75 mm width have been shared with the help of shearing machine. The edges of the specimens have been finished using surface grinding machine to remove rust from the surface. The pure CO_2 shielding gas is supplied in a regulated manner at a constant flow rate of 12 lit./cm^3 at a constant pressure. The tubular electrode (mild steel - ER70S-6) with 1.2 mm diameter wire containing flux inside it is fed through the welding gun by a roller drive system (automatic wire feeder). During the welding process, for measuring the welding speed welding torch is attached with arm of a motorized portable gas cutting machine (PUG M/C). Thus the welding speed is fixed at 0.5 cm/sec during the welding with this machine. The experiment is carried out at 140 amps current and 26 volts voltage.



[(1) Cylinder containing pure CO_2 gas, (2) Pressure indicator, (3) Gas flow rate indicator, (4) Gas supply pipe, (5) Electrode reel, (6) Automatic wire feeder, (7) Current, wire and gas supply pipe, (8) Motorized machine, (9) Welding torch, (10) Work piece]

Figure 1: Experimental Setup

IV. SAMPLE PREPARATION AND OPTICAL MICROSCOPE

A. Sample Preparation

In order to identify the HAZ and the weld zone a small section specimens has been cut out from the welded plates. The direction of cut is perpendicular to the direction of welding. A rectangular section has also been cut out from the base plate, in order to compare the post welding changes. After cutting, the surface of the specimens which is to be studied under the microscope is polished with the help of a hand held polisher and polishing wheels of different grades to give it a mirror like finish. Figure 2 shows the equipment used for polishing the specimens for studying under microscope. After polishing, the specimens are etched by the etching machine.

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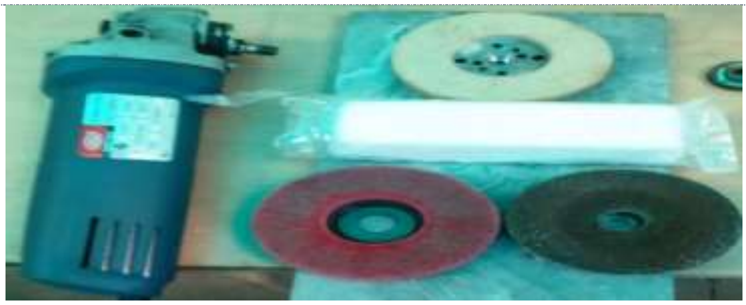

Figure 2: Tools Used for Preparing Specimens for Microstructure Study

B. Optical Microscope

Once the polishing and etching of the specimens are finished, they are studied under optical microscope for analyzing the microstructure. Figure 3 shows the optical microscope used for the present investigation. Table 1 shows the specification of the optical microscope used in the present investigation.

Figure 3: Leica DM 2700 M

Table 1: Specifications of Leica DM 2700 M

For indoor use only	
Supply Voltage	100 – 240 V AC
Frequency	50/60 Hz
Power Input	Max. 80 VA
LED	Max. 15 W
Fuse	T 1.6 A 250 V AC
Ambient Temperature	15 – 35 ^{0}C
Relative Humidity	Max. 80% up to 30 ^{0}C (non – condensing)
Overvoltage Category	II
Pollution Degree	2

V. MICROSTRUCTURE

Figure 4 shows the microstructure of base metal of mild steel represents an equiaxed grains of ferrite (F) as the major phase and smaller grains of fine pearlite (P) as the minor constituent at 50X magnification. Base metal has lower hardness because of fine pearlite.

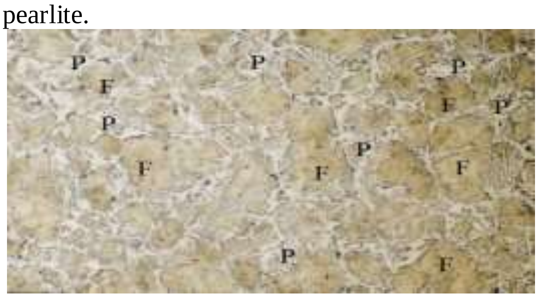

Figure 4: Microstructure of base metal at 50X magnification

The heat effected zone (HAZ) of MAG joints were composed of coarse grain zone near the weld zone, fine grain zone and incomplete recrystallization zone adjacent to the base metal. The coarse grain zone which was a typical weakness of joint as a result of its poor plasticity and impact toughness had obvious Widmanstatten structure containing parallel acicular ferrite at grain boundary and the pearlite between the ferrites. The fine grain zone was mainly equiaxial ferrite and intermingled pearlite. The incomplete recrystallization zone had the same structure with fine grain zone, but immingled with coarse ferrite.

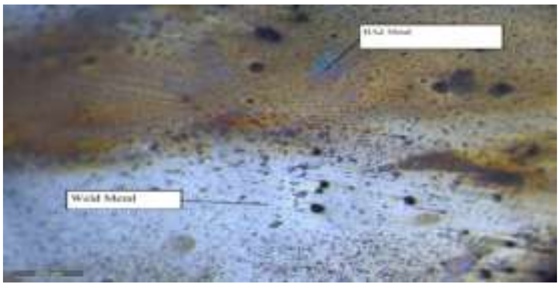

Figure 5: Microstructure of Weld Metal and HAZ Metal at 20X magnification

Welding zone microstructure changes with cooling rate. A martensite structure is formed in the weldment due to very fast cooling. So the weldments have higher hardness because the formation of Martensite.

The MAG arc generated lager heating area, which resulted in longer high-temperature period but lower peak temperature under the equivalent heat input. Grain growth under isothermal conditions can be described by

$$D_f^{\,n} - D_o^{\,n} = A\,[\,\exp(-Q/RT)\,]\,(t_1 - t_2) \qquad (1)$$

Where D_f = the grain sizes after holding at temperature T for time t_1,
D_o= the grain sizes after holding at temperature T for time t_2,
n= a growth exponent,
Q= the activation energy,
R= the gas constant,
and A= a material constant.

The grain growth in welding process can be calculated by integrating Eq.(1) over a welding thermal cycle. However, welding is a highly non-equilibrium process considering high heating and cooling rate, which makes T a more dominant factor compared with t. As a consequence, the width of coarse grain zone and its degree of grain coarsening were much less in hybrid arc welding.

VI. CONCLUSION

In this study, the effect of welding current, welding voltage and filler wire on microstructure development of AISI 1018 mild steel processed by metal active gas (MAG) welding is considered to investigate. The main results obtained from this study are as follow.

i. Macroscopic analysis demonstrated that the heat effected zone (HAZ) of MAG joints were composed of coarse grain zone near the weld zone, fine grain zone and incomplete recrystallization zone adjacent to the base metal. The coarse grain zone which was a typical weakness of joint as a result of its poor plasticity and impact toughness.

ii. Microstructural analysis also indicated that welding zone microstructure changes with cooling rate. A martensite structure is formed in the weldment due to very fast cooling. So the weldments have higher hardness because the formation of martensite.

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ISSN: 2277-9655
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CITE AN ARTICLE

Chandra , P. C. (2017). MICROSTRUCTURAL STUDY OF MAG WELDED JOINT OF AISI 1018 MILD STEEL. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 6*(10), 53-57.