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Experimental Analysis of Effect of Different Filler Rods on Mild Steel by Shielded Metal Arc Welding

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***Abstract*—Mild steel which is also known as plain carbon steel, because of its profound industrial applications has been used as the subject for testing the effect of different filler rods via Shielded Metal Arc Welding. The different filler rods used in the present work are Austenitic Stainless Steel, Ferritic Stainless Steel and Mild Steel. Subsequently, the different welded samples have been tested to evaluate and compare significant parameters such as Tensile Strength determined by Universal Testing Machine; Hardness determined by Vickers Hardness Tesing Machine followed by its values conversion into Brinell Hardness Number in order to comply with the standards; Microstructure and Heat Affected Zone determined by Optical Microscope. These comparisons play a crucial role in determining which welded sample is more suitable and viable when it comes to the Mechanical Engineering Field.**

Keywords*—Filler Rods; Shielded Metal Arc Welding, Tensile Strength, Hardness; Microstructure; Heat Affected Zone; Vickers Hardness; Brinell Hardness.

I. INTRODUCTION

Mild Steel AISI 7018, is one of the most common steel forms. It is available at a low price however this metal provides with a wide range of industrial applications. The range of carbon in a mild steel varies from 0.052 to 0.31% approximately. As a reason of this, mild steel depicts traits like malleability and ductility. The tensile strength of mild steel is low. The process of carburizing can be done to increase its surface hardness.

Ferritic Stainless Steel AISI 430, belongs to a group of stainless steels having Chromium content ranging from 12 to 17.8% approximately. The majority of the structure contains ferrite. Such kind of Steels depict good ductility however these don't respond to tempering or hardening processes. Automotive trim and Architectural cladding are some of its type of applications.

Austenitic Stainless Steel AISI 308L, consists of Austenite as its primary phase. These alloys contain Chromium and Nickel. In addition to this, they sometimes may also contain Manganese and Nitrogen. Austenitic Steels cannot be hardened by heat treatment. Type 304 Surgical Stainless Steel is an Austenitic Steel comprising of 18 to 20% chromium and 8 to 10% nickel.

Welding is basically a process in which localized coalescence is produced by heating the material upto suitable temperature with or without the application of filler material. In Shielded Metal Arc Welding, arc is initiated by touching coated electrode with workpiece. Then a gap is maintained between electrode and workpiece. Within this gap, free electrons and holes will be formed in gas. The temperature in the core of the arc ranges between 6000 to 7000 degrees Celsius. Shielded Metal Arc Welding can be performed both using AC and DC source with dropping characteristics.

II. EXPERIMENTAL PROCEDURE

A. Selcting the parent material

Mild Steel was selected as the parent material and six plates were cut out having the dimensions of 75mm X 300mm with thickness of 6mm each as shown in the Fig 1. The plates were cut using a Hydraulic Shearing Machine.

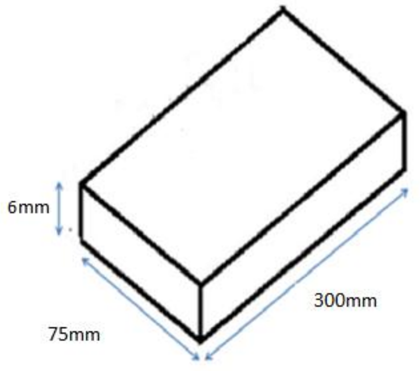

Fig 1 Mild Steel Plate

B. Preparation of samples for welding

The plates were prepared for welding by providing the V-groove between two plates for V-butt joints. V-groove was prepared using the grinder machine. The root gap was maintained 1.5 mm, root face of 1mm and 30°-60° were made on each plate for welding V-groove butt joint. The dimensions were checked by Vernier caliper. The dimensions of the plates are shown in the Fig 2. Therefore such three pairs were subjected for welding using a different consumable or filler rod each time.

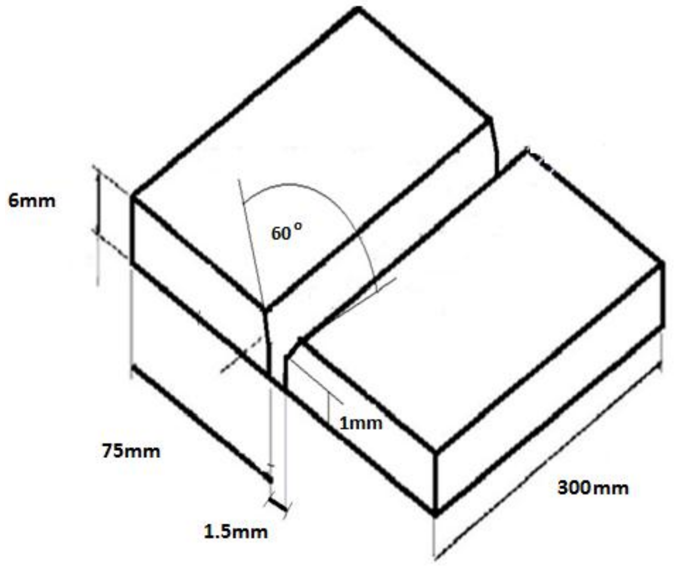

Fig 2 Welding Plates Specifications

C. Welding

Shielded Metal Arc Welding was done. Consumable or the Filler rod used for the first pair was Ferritic Stainless Steel. Mild steel for the second pair and Austenitic Stainless Steel for the third pair. These consumables were used to fabricate the joints. The various welding parameters which were used to fabricate the joints are given in the TABLE I.

TABLE I WELDING PARAMETERS AND ITS CORRESPONDING VALUES

WELDING PARAMETERS	VALUES
Arc Voltage	24V
Welding current	100A
Welding speed	3.31 mm/sec
Efficiency	0.75
Heat flux	1512 J
Heat input	543.8 J/mm
Electrode Diameter	3.15 mm
Electrode material	430, 7018, 308L

D. Samples cut out from the welded plates in order to determine various parameters

After the Shielded Metal Arc Welding process followed by cooling down of the welded samples, three new samples were cut out from each of the three pairs using Power Hacksaw making a total of nine new samples; among which three samples were tested for hardness, three for tensile testing and three for microstructure study.

E. Microstructure

Steps carried out for surface preparation in order to make microstructure clear under optical microscope were

- Sawing
- Grinding on emery paper
- Buffing
- Etching

Once the surface was prepared, the examination of microstructure was done with the help of optical microscope. It was needed to be done as it plays a pivotal role to help understand the properties. Metallography is the study of metals that is done using optical examination. It is done using a conventional light microscope. However useful information can still be gained by examination with the naked eye by examining the surface of metal objects or of polished and etched areas. Structures which are coarse enough to be perceptible by the naked eye are termed as macrostructures. Those which require magnification to become visible are termed as microstructures. The optical microscope used for microstructural observation is shown in the Fig 3.

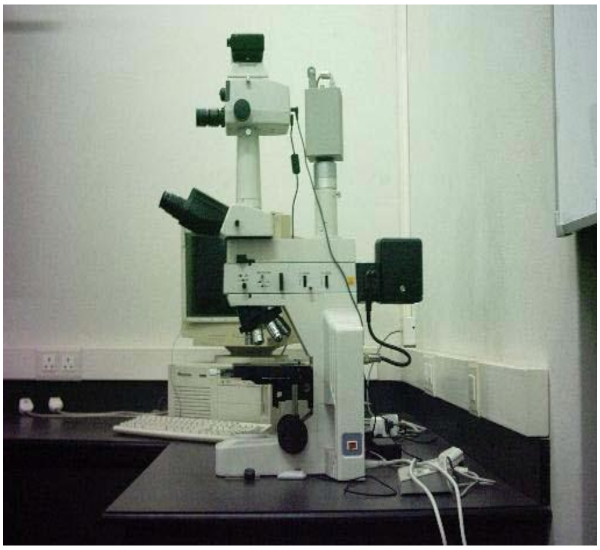

Fig 3 Optical Microscope

The microstructure of parent material i.e. mild steel at 100X magnification can be seen in the Fig 4.

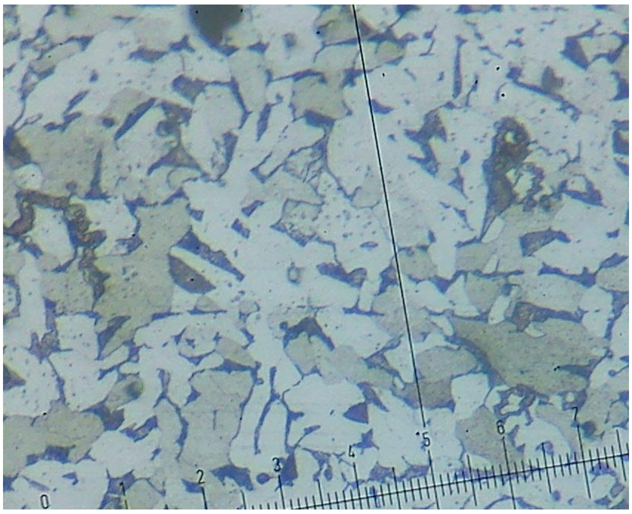

Fig 4 Microstructure of mild steel at 100X

The microstructure for the welded sample and Heat Affected Zone using Ferritic Steel AISI430 filler rod at 100X magnification can be seen in Fig 5 and Fig 6 respectively. The etching agent used was Vilella's Reagent (HCl-5 ml, Picric acid- 1gm, Methanol- 100ml).

Fig 5 Weld at 100X

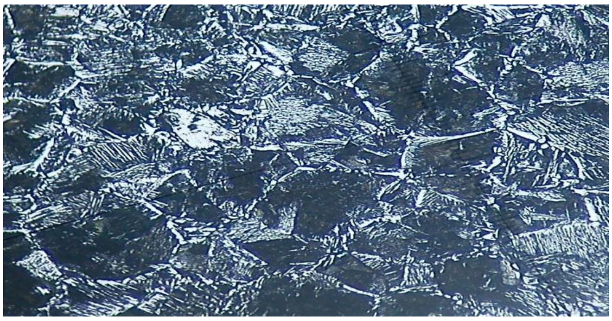

Fig 6 Heat Affected Zone at 100X

The microstructure for the welded sample and Heat Affected Zone using Mild Steel AISI7018 filler rod at 100X magnification can be seen in Fig 7 and Fig 8 respectively. The etching agent used was Nital (2% Nital-98ml Methanol +2ml Nitric Acid).

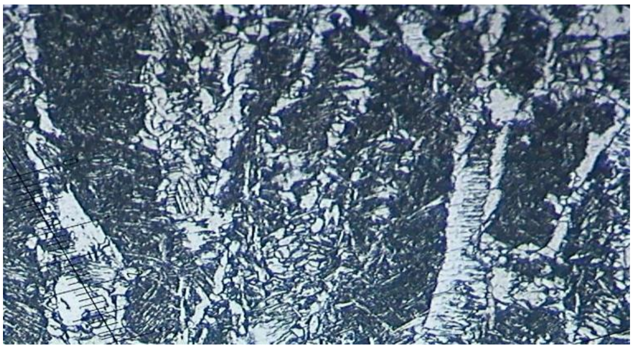

Fig 7 Weld at 100X

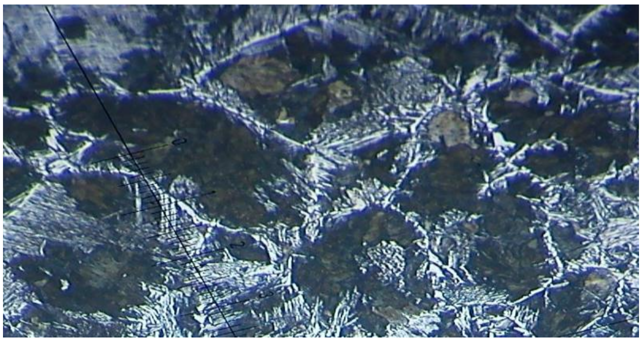

Fig 8 Heat Affected Zone at 100X

The microstructure for the welded sample and Heat Affected Zone using Austenitic Steel AISI308L filler rod at 100X magnification can be seen in Fig 9 and Fig 10 respectively. The etching agent used was Vilella's Reagent (HCl-5 ml, Picric acid- 1gm, Methanol- 100ml).

Fig 9 Weld at 100X

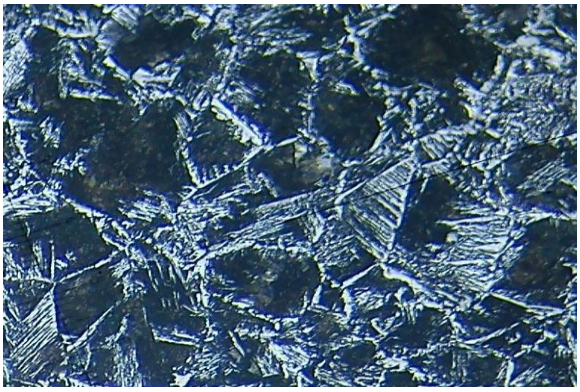

Fig 10 Heat Affected Zone at 100X

From the three microstructures of the weld zone, we observe that it consists of ferrite structure and pearlite in dendritic form. It has inter dendritic casting structure in the weld metal zone. The grain structure of the welded region is observed coarser than grain structure of the parent metal.

From the three microstructures of heat affected zone, we observe that it contains the coarser grain ferrite structure. In this zone, it is seen that the smaller grains are coagulated to form new grains, hence grain growth is there.

F. Hardness Test

Vickers Micro hardness testing Machine was employed for measuring the hardness of the weld with 0.5 kg load. The Micro Vickers was used to find out the hardness at different points from weld zone on both side of the weld. Four test samples (one sample from each welded plate by SMAW, one of parent sample) were prepared for the test.

- Welded plates were cut along with the heat affected zone by grinder cutter. After that cut portion was grinded by a grinder.
- As the surface started shining, grinder was stopped.
- Samples were set close to the indentor.
- Load was applied automatically.
- Diagonals of square based pyramid were measured by a special microscope.
- From measured diagonal, area of indentation was calculated automatically.
- Vickers Hardness Number(VHN) was calculated and the values were converted into Brinell Hardness Number(BHN) in order to comply with the standards set by the institution where the apparatus was setup.

The hardness of the weld metal region was observed to be greater than the heat affected zone region (HAZ) and the base metal region which can be seen in TABLE II.

TABLE II VALUES FOR HARDNESS

SAMPLE	AT WELD (BHN)	AT HEAT AFFECTED ZONE(BHN)
FERRITIC STAINLESS STEEL	390	190
MILD STEEL	171	156
AUSTENITIC STAINLESS STEEL	170	162

G. Tensile Test

The strength and the ductility of materials were determined from the tensile test. Samples for testing were taken parallel to the rolling direction of the plate and 90^0 to the rolling direction. These type of tests are called longitudinal and transverse tensile strength respectively. The ultimate tensile strength is calculated by dividing the load (max) by original area and it is the maximum stress in the stress-strain curve.

The ductility of the materials is evaluated by percentage elongation (% E) and percentage reduction in the area (% RA). A standard gauge length (GL) was marked on the samples before application of the load and after testing increase in gauge length was measured. The %E is the ratio of increase in GL by the original GL (dl/L).

The results of the tensile testing are given in TABLE III.

TABLE III VALUES FOR TENSILE STRENGTH

SAMPLE	TENSILE STRENGTH (N/mm^2)	% ELONGATION
FERRITIC STAINLESS STEEL	431.452	38.46%
MILD STEEL	463.934	34.61%
AUSTENITIC STAINLESS STEEL	403.226	24.61%

III. CONCLUSION

Tensile Strength for the welded samples was found out to be maximum for the sample welded using Mild Steel 7018 filler rod.

Microstructures of the weld zone were observed and it was concluded that that ferrite structure and pearlite are present in dendritic form. Interdendritic casting structure is present in the weld metal zone and the grain structure of the welded region is observed coarser than grain structure of the parent metal whereas from Microstructures of heat affected zone, it was observed that coarser grain ferrite structure is present. Also it was concluded that the smaller grains are coagulated to form new grains, hence grain growth is present.

Hardness for the welded samples was found out to be maximum for the sample welded using Ferritic Stainless Steel 430 filler rod.

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