Selection of Suitable Electrode for an Alloy on the basis of Microstructure Analysis of the Weldment

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***Abstract*— This steel was used in the chairs (imported from China) and the problem statement we had, was that the high strength was not obtained from Arc welding. So we determined suitable electrode on the basis of microstructure analysis of the weldments and got the optimum strength.**

Chemical composition of the specimen is determined using ICP-OES and Carbon-Sulphur Determinator. Specimens were prepared as per the AWS standard and subjected to microstructure examination and the results were tabulated. Microstructure analysis is carried out with the help of SEM. Different zones and phases are identified. New microstructural phenomenons are observed and analyzed with the help of ImageJ software.

Keywords—Mild Steel; Electrode; Grains; HAZ; ferrite.

I. INTRODUCTION

Welding is a process of joining materials into one piece. Generally, welding is the preferred joining method and most of the common steels are weldable. Sometimes in certain cases the compositions are such that the optimum strength is not obtained resulting in the failure after a short duration only.

Our sample was low carbon steel (0.10 wt. %C) brittle in nature and 1.45mm thin. We used certain electrodes at different parameters but the required strength was not achieved. Welding mild steels or low carbon steels (carbon content below 0.30%) with mild steel coated electrodes presents no problems as far as tensile strength is concerned since the tensile strength of the weld metal usually exceeds the tensile strength of the base metal. However, chemistry of the base metal is important.

It is also known that the final microstructures and mechanical properties of welded steel depend on some parameters like percentage of carbon and presence of others elements such as sulphur or phosphorous. Certain other properties like yield strength, Ultimate tensile strength, hardness etc. are found as a result of grain analysis using appropriate software and relations. These properties also help in comparison of weld strength of different electrodes.

II. EXPERIMENTAL PROCEDURE

A. Sample preparation for chemical composition analysis

It was known that our specimen is conductive in nature so we used two collective instruments for determining the composition i.e. inductively coupled plasma-optical emissive spectroscopy and Carbon sulphur Determinator. For ICP-OES, mineral acid (H_2SO_4) used for dissolution of samples and it is analyzed. While for C-S determinator, it requires 20-25gms of sample for analysis.

B. Sample prepration for microstructre analsyis.

Basically a great care is taken while preparing sample for microstructure analysis. It includes basic procedures like Mounting, Grinding, Polishing and Etching. As the specimen was composed of weldment it requires special polishing to reveal the structure more clearly.

Nital 2% is used as etchant.

III. RESULTS AND DISCUSSION

A. Chemical composition

The chemical composition of the specimen was ascertained with the help of Inductively Coupled Plasma-OES and Carbon-Sulphur Determinator and the chemical composition is summarized in Table 1.

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TABLE: 1 Chemical composition of specimen.

CONSTITUTENTS	C	S	P	Mn
% BY WEIGHT	0.10	0.048	0.037	0.46

The percentage of carbon gives hardness to the specimen and also accelerates in cementite formation in the specimen (Mild Steel). Manganese gives ductility and accelerates in ferrite formation in the steel.

B. Probable electrode selection

On the basis of the composition i.e. low carbon steel (0.10wt. %C) and thickness of the specimen, the electrode is selected with reference of ASTM chart. From the reference chart of electrode selection it is concluded that electrode of codes as mentioned is suitable:

- E6013 (electrode A)
- E7018 (electrode B)

So, with the help of chemical composition analysis and standard reference chart we confined our search for appropriate electrode selection.

C. Microstructural analysis

Initially we welded our specimen with two different electrodes and prepared the sample for microstructure analysis under SEM. The figure 1 shows the polished specimen, etched by 2% Nital.

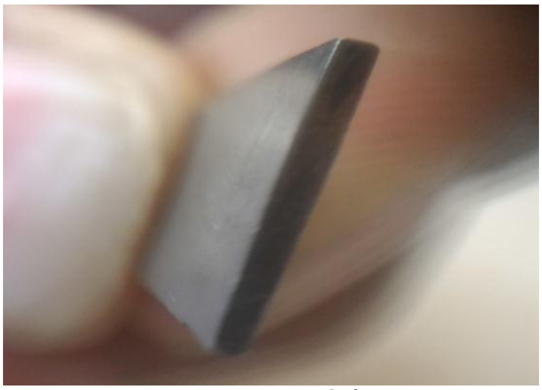

Figure 1: Specimen sample for SEM.

Initially parent metal is analyzed under SEM model ZEISS EVO 18 and the microstructure is shown in figure 2.

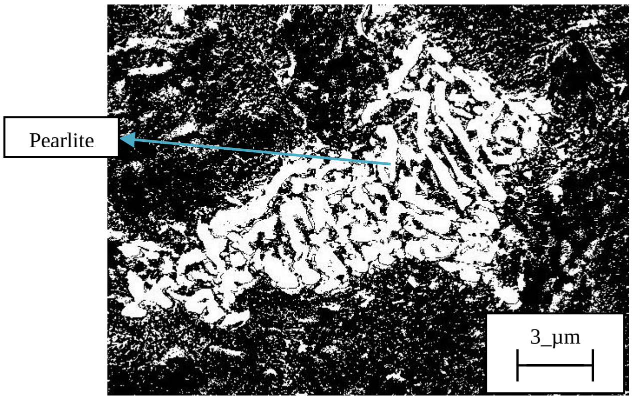

Figure2: Pearlite and cementite grain structure of (0.10 wt. % C) mild steel (parent metal) etched by 2% Nital.

Typical microstructure of sheet (base metal) is composed of ferrite and small regions of pearlite (α-Fe + Fe_3C) at grain boundaries edges and corners.

The specimen is welded by two electrodes under the prescribed conditions and then further analysis by imageJ software gives the result for more suitable electrode for specimen. ImageJ software helps in determining the accurate grain size measurements after setting of appropriate scale and threshold (removing noises)

WELDING BY ELECTRODE A (E6013):

The parameters for successful welding as per American Welding Standards are as following:

I. Current, I =115-120A
II. Voltage, V =25-27V
III. Electrode Diameter =3.2mm

The microstructure image obtained for welded specimen is analyzed and the grain size of the weldment is obtained using the special feature of ImageJ software i.e. Automatic Particle Sizing.

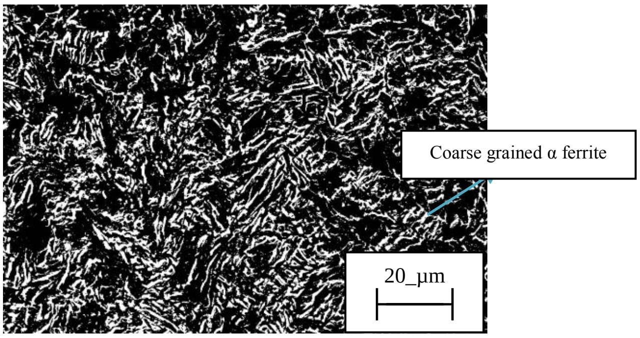

Figure3: Center of weld metal "in the weld fusion zone", 0.10%wt.C Mild steel revealed by 2% nital (2000x)

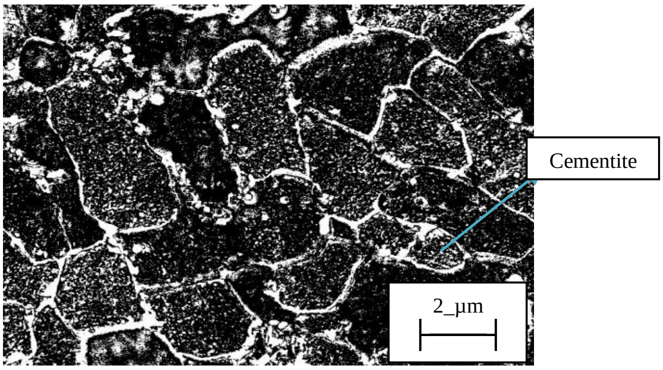

Figure4: Microstructure of HAZ after welding of Mild steel (0.10 wt. % C) by electrode E6013

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From visual inspection it can be seen that the grains at weld pool have needle like structure resembling more recrystallization process occurred their as compared to the grains of Heat-Affected zone.

The relation between yield stress and grain size is described mathematically by the Hall-Petch equation

$$\sigma_y = \sigma_0 + \frac{k_y}{\sqrt{d}}$$

where, k_y is the strengthening coefficient (a constant unique to each material),

σ_o is a materials constant for the starting stress for dislocation movement (or the resistance of the lattice to dislocation motion),

d is the grain diameter and,

σ_y is the yield stress.

For Mild Steel σ_o =70MPa and $k_{y=}$ 0.74 MPa $m^{1/2}$.

So, from the cited above two concepts tabulating the computed values of average grain size and yield strength at the various point near the Heat-Affected zones

Table 2(a): Value of diameter and YS for welding by electrode A

Position	Avg. Grain Diameter(μm)	Yield strength (MPa)
At the starting of the HAZ	64.034	162.475
At 120μm from the mushy zone	53.893	170.801
At 210 μm from the mushy zone	37.361	191.066
At 300 um from the mushy zone	16.827	250.396

WELDING BY ELECTRODE B (E7018):

The parameters for successful welding as per American Welding Standards are as following:

I. Current, I =100-110A
II. Voltage, V =22-24V
III. Electrode Diameter =3.2mm

In similar manner the microstructure image of the specimen welded by this electrode is analyzed. Thus the phase of the weld pool, HAZ is being obtained and the Average grain size along with yield strength is computed.

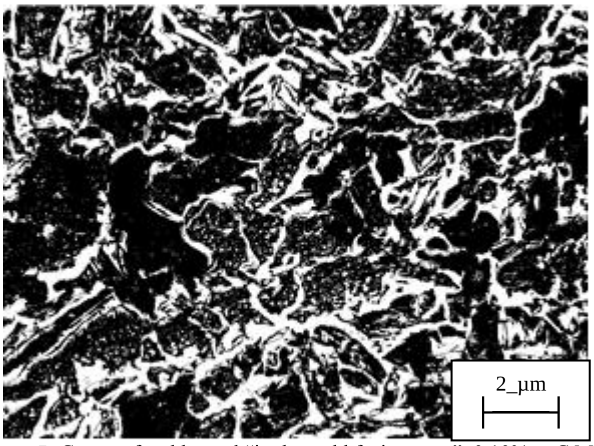


Figure 5: Center of weld metal “in the weld fusion zone”, 0.10%wt.C Mild steel revealed by 2% nital (4000x)

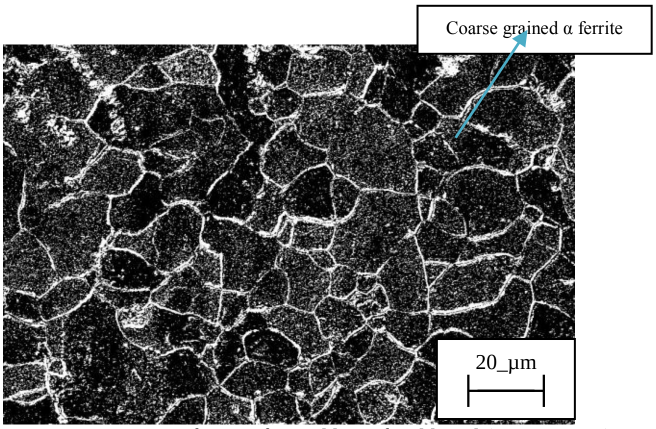


Figure 6: Microstructure of HAZ after welding of Mild steel (0.10 wt. % C) by electrode E7018

It can been seen that in the microstructure of weld pool of specimen welded by electrode E7018 Fig.4 dendrite formation took place because of the freezing of molten metal. Concerning the heat-affected zone (HAZ), Figure 6 illustrates clearly the microstructures of this zone. It contains Widmanstatten ferrite, and some colonies of pearlite. It is known that solid-state phase transformations, such as grain growth, recrystallization, phase transitions, annealing, and tempering, all occur in the HAZ of steel welds.

The average grain is computed by Automatic Particle Sizing technique in ImageJ software and yield strength via Hall-Petch equation. The values of the same for electrode B (E7018) is tabulated below in the table:

Table 2(b): Value of diameter and YS for welding by electrode B

Position	Avg. Grain Diameter(μm)	Yield strength (MPa)
At the starting of the HAZ	79.193	152.841
At 120μm from the mushy zone	72.618	156.837
At 210 μm from the mushy zone	54.202	171.513
At 300 um from the mushy zone	31.892	201.036

D. COMPARATIVE ANALYSIS

Table 3: Graph showing the variation of Yield strength with respect to grain size for two electrodes in MATLAB.

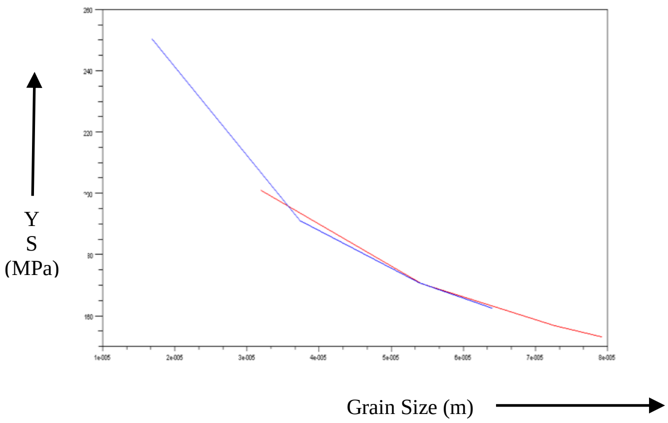
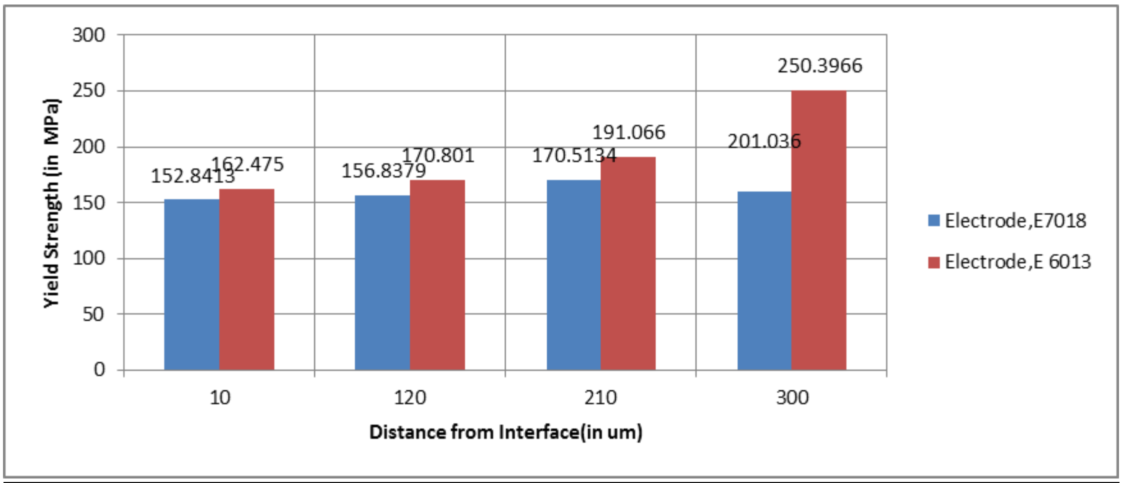


Table 4: Comparison of Yield Strength at different points of different electrodes.



The difference in the Yield Strength for at a particular point is mainly due to the Grain Boundary Strengthening.

From the Table 4, it can be seen that specimen welded by electrode (E7018) has average grain diameter 79.1937µm and yield strength 152.841MPa, whereas specimen welded by electrode a (E6013) has average grain diameter 64.034µm and yield strength 162.475MPa which requires greater force to traverse grain boundaries and travel from grain to grain.

IV. CONCLUSION

In the presented work, various parameters are employed to find out the electrode through which necessary strength and durability can be achieved in welding.

From the above calculation and the data shown in Table 4, it can be deduced that the value of Yield strength has a higher value for all calculated distances from the Interface of weldment using Electrode A (E6013).

So Electrode E6013 is found best suitable for welding of this low carbon mild steel.

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