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EFFECT OF COMPOSITION OF FLUXES ON MECHANICAL PROPERTIES OF MILD STEEL WELDS BY SUBMERGED ARC WELDING

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ABSTRACT: The present work is an attempt to study the effect of flux on the micro-hardness, tensile strength, Impact strength, of mild steel weld made during the submerged arc welding. The effect of different kind of fluxes by keeping the welding parameters like welding current, welding voltage and welding speed constant has been evaluated for the different mild steel weld joints.Submerged Arc Welding (SAW) is used as a heavy metal deposition rate welding process. Saw flux performs the same function as the coating of a manual electrode. It must satisfy certain special condition demanded by the nature of the process. The flux protects the molten pool and the arc against atmospheric oxygen and nitrogen by creating an envelope of molten slag. The process is characterized by the use of granular flux blanket that covers the molten weld pool during operation. Protection through atmospheric contamination of the weld bead and slower cooling rate, achieved by this arrangement can enhance mechanical properties of the weld-ment.

I. INTRODUCTION

WELDING: Welding is a process of permanent join of two materials (usually metals) through localized coalescence resulting from a acceaptable combination of temperature, pressure and metallurgical condition. Depending upon the combination of temperature and pressure from a high temperature with no pressure to a high pressure with low temperature, a wide range of welding process has been developed. The Arc welding in its present form appeared on the industrial scene in 1880's. Arc welding, however, was not accepted for fabrication of critical components till about 1920 by which time coatings for electrodes has been well developed.

SUBMERGED ARC WELDING: Submerged Arc Welding is a fusion welding process in which heat is produced from an arc between the work and a continuously fed filler metal electrode. The molten weld pool was protect from the surrounding atmosphere by thick cover of molten flux and slag forming from the granular flux material pre-placed on the work.

Fig. 1: Submeged Arc Welding Machine

SUBMERGED ARC WELDING PROCESS VARIABLES

Submerged arc welding process variables include the, arc voltage, welding current and welding speed. However, the welding bead dimension is also affect considerably by electrode-to-work angle , inclination of the work piece, joint-edge preparation, electrode sticked out, the kind of current and polarity, electrode diameter, and the type and grain size of the flux. The affect of these process variables are determine through effects on weld bead geometry. Due to high heat input in SAW the weld pool, i.e., the layer of molten metal between the arc and the parent un melted metal is of considerable extent and as this layer is of low thermal conductivity it has , therefore, a marked effect on the depth of penetration. Thus, an increase in depth of this molten metal layer is accompanied by an increase in depth of penetration.

SUBMERGED ARC WELDING EQUIPMENT

Submerged arc welding Equipment depends upon whether the process is of the automatic type of the semi-automatic type. Automatic submerged arc welding it consists of a welding power source, a wire feeder and a control system, an automatic welding head, a flux hopper with flux feeding mechanism, the flux recovery system and the process which usually consists of a travelling carriage and the rail. The power source of automatic submerged arc welding process must be rated for 100% duty cycle as a welding often takes more than 12 times to complete.

Both the AC and the DC power source are used and these sources may be of stable current or stable voltage type. The Submerged arc welding is the high current welding process; an equipment was designed to produce the high deposition rates. For the single arc,the DC power source with SV is the almost invariably employed while the AC power sources was most often used for multi-electrode submerged arc welding. Generally, welding rectifiers are employed as power sources for getting a current range of 50A to 2100A, however most often submerged arc welding is done with a current range of 200 to 1100A. A welding gun for automatic submerged arc welding was attached to the wire feed motor and including the current pick up tips for providing an electrical contact to the wire electrode. A flux hopper was attached to the welding head and it may be magnetically operated through valves so that they can be opened or closed by the control system.

WELDING PARAMETRS AND THEIR EFFECTS

Arc Voltage:

The Arc voltage vary in the direct proportion to the arc length. With the increase in arc length the arc voltage increases and thus more heat is available to melt the metal and the flux. However, an increased arc length means more in spread of the arc column, that leads to the increase in the weld width and the volume of the reinforcement while the depth of penetration decrease. The arc voltage varies with the welding current and the wire diameter, and in SAW it usually ranges between 30 to 50 volts.

Welding Current:

The Welding current increase the pressure exert by the arc increases which was drives out the molten metal from beneath the arc and that was lead to increased depth of the penetration. The width of the weld remains the almost unaffected. As the increased welding current was accompanied by the increase in the wire feed rate, it results in the greater weld reinforcement. The Variation in the current density have nearly the same effect on the weld geometry as the variation in the magnitude of the current. This results in a the weld with the deeper penetration but of somewhat reduced the width. A submerged arc welding was the process which is usually employs wires of 2.5 to 5.5 mm diameter, thus, for the deeper penetration at low currents a wire of diameter 2.5 to 3.00 mm was best suited.

Welding Speed:

With increase in the welding speed, the width of the weld decreases. However, if the increase in a speed is the small the depth of the penetration increased because a layer of the molten metal was reduced which leads to higher heat conduction towards that of the bottom of the plate. With the further increase in welding speed, above 45 m/hour, the heat input was per unit length of the weld decreases considerably and the depth of the penetration is thus reduced. At the speed above 80 m/hour, lack of the fusion may cause that result. It has been established the experimentally that as the first approximation of the welding speed, S, for the well shaped weld should be based on the following relationship.

II. METHODOLOGY

Mild steel is preferred materials for Trucks, construction equipment, off- highway vehicles, mining equipment,. For these applications, sheets or light-gage plates are specified. The Structural forms were specified in the applications such as the offshore oil and the gas rigs, the single-pole power-transmission towers, railroad cars, and in the ship construction. The application of mild steels has been limited by the availability of suitable filler metals. Specially, the weld metal strength have to increases, the acceptability to hydrogen-assisted the cracking increases. To take full advantage of the developments in mild steel base metals, weld flux which minimize the effects of diffusible hydrogen and develop tough microstructures must be developed. The current research proposes to study the effects of welding flux on tensile strength, toughness, micro hardness, microstructure of work piece. The mechanical testing of the weld metal had to be carried out to determine, and co-relate the properties of weld metal with strength, hardness and dilution variations, under the influence of different fluxes.

EXPERIMENTATION

Any change in the parameter of submerged arc welding affect the properties of welding. So, in this experiment by changing the flux (basicity index) and keeping all other parameter constant and find out the result that what is the effect of composition of flux on tensile strength, toughness, micro hardness, microstructure etc. The mild steel plate used as a work material and the dimension 250x125x12.

. The following are the steps which were followed to achieve the objective:

(a) Preparation of flux: For the manufacturing of flux for SAW, various compounds such as CaF2, CaO, MnO, SiO2, Al2O3, TiO2 etc. were used.

(b) Method of preparation of steel plate specimen: To prepare the steel plate specimens, steel plate of dimension 250x125x12 mm was used. After cutting of plates a V joint 60 degree angle was made. Tacking was done on the back side of the plates, to avoid leveling mistake while doing SAW.

(c) After performing SAW operation, the specimens were cut from the welded plate to carry out various tests.

The following are the tests carried out to achieve the objective:

- Micro Hardness
- Tensile Test
- Toughness Test
- Microstructure etc.

Table 3.1 shows the test matrix in which parameters variation is given.

Table : Test Matrix

Welding Flux	Current (A)	Voltage (V)	Travelling speed (m/h)
1	365	40	35
2	365	40	35
3	365	40	35
4	365	40	35
5	365	40	35
6	365	40	35
7	365	40	35

III. METHOD OF PREPARATION OF FLUX

For the manufacturing of flux, 8 different compounds viz., CaF2, CaO, Na2O, MnO, SiO2, Al2O3, TiO2 were used. The compounds were received in powder form and mixed together (manually) with binder (Sodium Silicate) in different weight percentages to prepare the required type of flux. Fluxes are of two types viz., acidic and basic. To prepare the basic flux basicity index was calculated shown below.

B.I=CaF2+CaO+Na2O+0.5(MnO+FeO)/SiO2+0.5(Al2O3+TiO2+ZrO2)

The following table 3.2 to 3.5 shows the weight of constituents in grams to prepare the flux of required chemical compositions.

Table : Chemical composition of Flux 1:

S. No	Flux Constituent	Weight of constituent (gm)
1	CaO	14
2	CaF_2	19

3	MnO	4
4	TiO_2	9
5	Al_2O_3	9
6	FeO	14
7	SiO_2	4
8	Sodium Silicate	18

Table 3.3: Chemical composition of Flux 2:

S. No	Flux Constituent	Weight of constituent (gm)
1	CaO	9
2	CaF_2	16
3	MnO	4
4	TiO_2	9
5	Al_2O_3	14
6	FeO	19
7	SiO_2	4
8	Sodium Silicate	19

Table 3.4: Chemical composition of Flux 3:

S. No	Flux Constituent	Weight of constituent (gm)
1	CaO	12
2	CaF_2	13
3	MnO	4
4	TiO_2	14
5	Al_2O_3	19
6	FeO	11
7	SiO_2	4
8	Sodium Silicate	18

Table 3.5: Chemical composition of Flux 4:

S. No	Flux Constituent	Weight of constituent (gm)
1	CaO	17
2	CaF_2	11
3	MnO	4
4	TiO_2	09
5	Al_2O_3	11
6	FeO	19
7	SiO_2	4
8	Sodium Silicate	18

The solution of sodium silicate (20% weight of flux) binder was added to the dry mixed powder (fig.4.1) and it was mixed for 10 min. Sodium silicate was added for better arc stability. The mixture flux were dried in air for 24 h and then baked in the pit furnace at approximate 700°C for nearly 3 h. After cooling, this flux were crushed and sieved to get required size. After sieving, fluxes were kept in air-tight bags so as to keep it free from moisture. By using this method we make 8 different kind of flux.

Fig. : Compounds mix with Binder

Fig. : Flux after mixing

IV. RESULT AND DISCUSSION

IMPACT TOUGHNESS TEST

Specimens after impact toughness test carried out at room temperature .

Table : For Impact Toughness Values

Basicity Index	Charpy Test (joule)	Average (joule)
Base metal	72+64+86/3	74
1.86	67.56+74.08+74.36/3	72.24
1.45	44.45+36.55+25.40/3	35.4
1.02	24.65+34.45+12.25/3	23.7
2.10	46.32+74.25+73.26/3	64.61

Discussion of Impact Toughness

Impact toughness tests for each specimen and average impact toughness values of base material & weld metals at room temperature are shown in table 5.1. Charpy impact toughness increases with the increase in basicity index. There are several factors affecting the impact toughness of the welds including hardness level, microstructure, percentage of martensite-austenite constituent etc. In all the specimens average value of impact toughness is lower than that of base metal values except flux 4. This is due to the reduced amount of oxygen in the weld metal because of CaF2 which acts as a deoxidizer results in increased impact toughness

MICROHARDNESS TEST

Micro hardness values at welded region for different types of fluxes are discussed. Micro hardness test was performed at a constant load of 310 gm. For each specimen two readings were taken and the average of these two readings was calculated.

Table : Micro hardness values at welded region

S. No	Flux	Basicity Index	Indentation Load(gm)	Hardness value (HV)	Hardness value (HV)	Average Hardness(HV)
Base Metal			315	220 HV	188 HV	204
1	1	1.86	315	230 HV	225HV	227.5
2	2	1.45	315	290 HV	285 HV	287.5
3	3	1.02	315	275HV	268 HV	271.5
4	4	2.10	315	235HV	220 HV	227.5

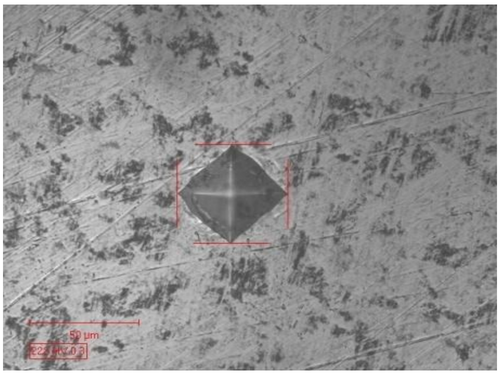

Fig. : Micro hardness of Base metal

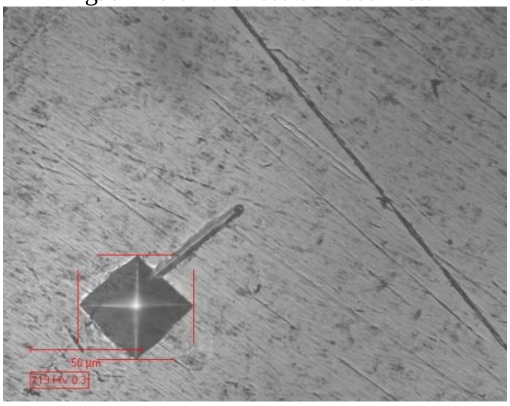

Fig. : Micro hardness of flux 1

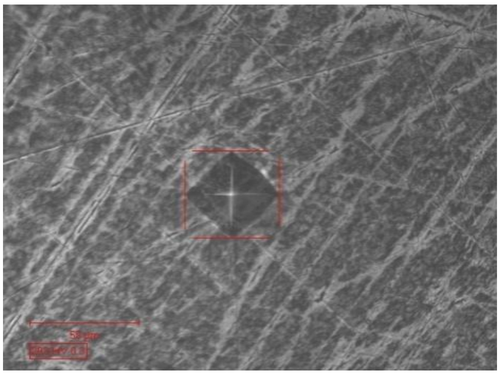

Fig. : Micro hardness of flux 2

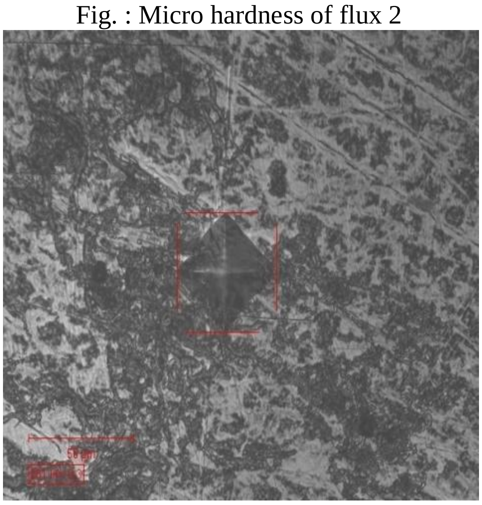

Fig : Micro hardness of flux 3

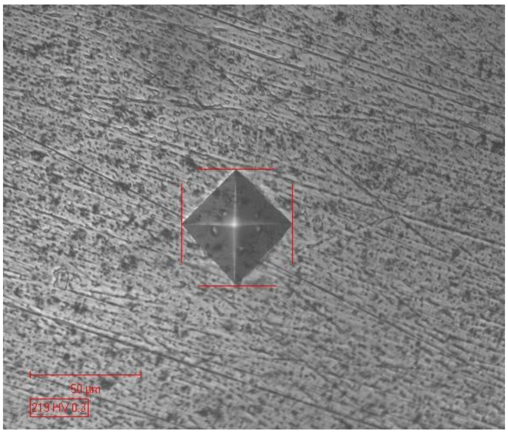

Fig : Micro hardness of flux 4

Discussion of Micro hardness

Micro-hardness measurement was taken at the base metal and weld pool interface. Two readings at each location were taken & average of two readings was considered for the analysis. The max. average micro hardness (Vickers hardness number) was observed at welded region for flux 2, this is due to the presence of carbides constituents present in the flux, hardness value in the weld metal changes with the change in the carbide contents. The increase in micro-hardness at the welding interface is generally due to oxidation processes which took place during welding processes.

TENSILE TEST

Universal tensile testing machine was used to carry out tensile tests. Fig. 5.6 below shows the broken specimen after tensile test.

Fig. : Specimen after tensile test

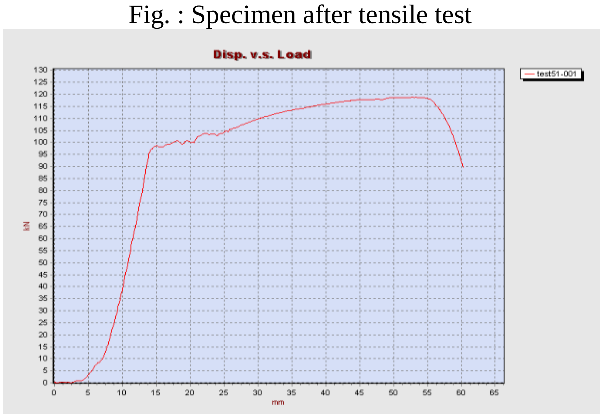

Fig. : Load vs. displacement curve for base metal

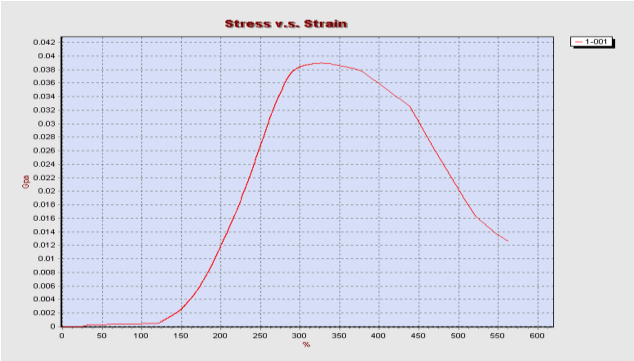

Fig. : Stress vs. strain curve for base metal

Table : Ultimate Tensile Strength Readings

Flux	Basicity Index	Ultimate Tensile Strength (KN)
Base Metal		89.56
1	1.87	41.56
2	1.16	39.95
3	1.02	47.58
4	1.54	45.58

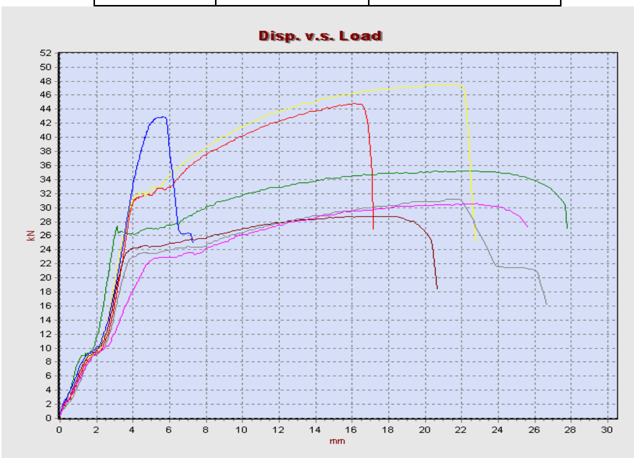

Fig. : Load vs. displacement curve for 4 different welded specimens

Table : Ultimate Tensile Stress Readings

Flux No.	Basicity Index	Tensile Stress Values (Gpa)
Base Metal		0.047
1	1.86	0.055
2	1.45	0.047
3	1.02	0.044
4	2.10	0.058

V. CONCLUSION & FUTURE SCOPE

The present study was carried out to study the effect of composition of flux on mechanical properties of mild steel welds by submerged arc welding by keeping all other variable keeping constant like current, voltage and welding speed.

- The impact toughness values at room temperature increases with increase in basicity index of flux.
- Oxidizing potential of the most reactive fluxes reduced by a significant amount due to the addition of CaF2, while CaF2 has little effect on the more stable oxide components.
- Ultimate tensile strength values are dependent on the basicity index. It can be concluded that more is the basicity index lesser will be the ultimate tensile strength.
- Ultimate tensile strength values were also satisfactory for all weld joints.
- Change in micro hardness values can be observed due to the presence of carbides.

In addition to the present work further work can be done in following directions:

- Different fluxes can be made for different material.
- CaF2 can be replaced by NaF when manufacturing of flux.
- Modeling of submerged arc welding process can be carried out using Finite Element packages.

There are lot of parameters (Current, voltage, welding speed, diameter of electrode) which can be varied individually to see their individual effects and combining these parameters to see their combine effect.

