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OPTIMIZATION OF HEAT AFFECTED ZONE IN SUBMERGED ARC WELDING

Dr. Brijpal Singh

MSIT,C-4 Janakpuri, New Delhi (India)

ABSTRACT

In this study the fluxes has been suggested for low heat affected area and low width of heat affected zone. The properties in the HAZ area are severely affected due to change in the microstructure of the nearby area. In this study the fluxes have been designed using ternary phase diagrams and were made by the agglomeration technique. The study reveals that the optimized values of CaF_2, FeMn and NiO are each as 5%.

Keywords- SAW, HAZ,Pearlite, Ferrite

I. INTRODUCTION

Submerged arc welding is also known as hidden arc welding as the arc produced between the electrode and the work piece is hidden under the cover of a heap of flux.The arc is not visible to the operator. Both types of the welding, manual or automatic can be done in SAW. A large quantity of the flux is used to make the joint. The fluxing powder is fed from a hopper that is carried on the working head. The flux is of sufficient depth to submerge the arc column and the arc is protected from the atmospheric contamination. The joints made by This welding process gives high quality joint as double protection is obtained from atmospheric gases [1,2]. This welding process is suitable for welding low alloy, high tensile steel as well as low and mild steel and other non-ferrous metals.

. The SAW fluxes contain lime, silica, manganese oxide, calcium fluoride and other compounds. Fluxes can be classifies as agglomerated, fused and mechanical .The basic functions of the fluxes are to protect the weld pool from the atmospheric contamination and to get a weld pool of desired properties.[3]. In agglomerated fluxes the ingredients are dry mixed in a container and potassium or calcium silicate is used as a binder for providing the strength to the flux. After making the mixture, the wet mixture is pelletized and baked at a temperature lower than that for fused fluxes. After this, the pellets are broken up, screened to size and packaging is done. The basic advantage of the agglomerated flux is that the additives can be added easily. While, in fused fluxes the ingredients are melted and the additives are not easily added to the base fluxes. However, the main drawback of these fluxes is that these easily absorb the moisture from the atmosphere so, these are stored in air tight jars and are reheated before use [3].

II. LITERATURE REVIEW

Heat affected Zone is the area of base metal which is not melted but its properties are affected by the heat of welding. The heat transfer and subsequent cooling may change the properties of the base metal by changing the

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microstructure. The extent and magnitude of property change depends on the base metal, welding process, heat input by the welding process [4]

The heat affected zone may have two regions; the high temperature region in which major structural changes such as grain growth takes place and in the low temperature region secondary effects such as precipitation hardening may take place. The grain growth in the weld metal depends on temperature achieved, time of heating and cooling (Lancaster, 1987, 1999). The grain growth can cause embrittlement. Besides this because of weld thermal cycle other properties of the weld metal are also altered. The coarse grained region is the poorest zone in micro alloyed steels.

Adler et. al., 1975 and Fisher, 1952[5,6] have studied the effect of welding process parameters on HAZ area. They used the statistically design of experiments for the study. Other researchers Gunaraj and Murgan, 2002, Linert, 1994 Lee et al. 2000), [7,8,9]have studied the effect of welding process parameters on HAZ microstructure and width. Hari Om studied the effect of polarity and welding process parameters on HAZ area and width. They also studied the effect of heat input on dilution.They concluded that for low HAZ at a given heat input, high current, low voltage and high welding speed is desired. Gunaraj and Murugan (2002)[7] discussed the effect of process variables and heat input on HAZ dimensions and other metallurgical characteristics. The study suggests that the HAZ size can be reduced by proper selection of process variables and good quality weld may be obtained. The study reveals that heat input and feed rate both have positive effect on HAZ size and welding speed has a negative effect. Mathematical models were developed to study the effect of process variables and heat input on HAZ width, grain refinement and other metallurgical aspects.Ghosh and Bhattacharaya 2011[10] studied the issues associated with the uncertainties involved in the HAZ area. They did this by seeing the grain size in the welded zone. Digital image processing techniques were used to measure the grain structure. The conclusion was that the grains were of smaller variety and large size grins were very less in number in HAZ area.

III. EXPERIMENTAL PROCEDURE

The fluxes were prepared by agglomeration technique. The base constituents CaO, SiO_2, and Al_2O_3 were designed based on ternary phase diagrams. From the phase diagrams according to the melting point of low carbon steel, it was decided that the ratio of above constituents should be 7:10:2. The additives CaF_2, FeMn and NiO were selected as control parameters. To investigate the effects systematically, twenty fluxes were designed using response surface methodology. The concentrations of the additives were varied in the range 2-8%. The control parameters (additives) and their levels are shown in the coded form in the table 1. The three levels of the aforesaid additives are shown in table 2.The composition of wire and base plate are given in Table3. The welding parameters were made constant for all the welds. These parameters are given in Table4. All the components, base constituents and additives were mixed in a container and Potassium silicate was used as a binder for making these fluxes. After preparation the fluxes were heated in a furnace up to 400^0C for more than six hours to remove any traces of moisture. Before making weld the fluxes were again heated up to 100^{0c}. $CaCO_3$ was used in place of CaO because of its hygroscopic nature. The measured parameters were measured

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ferom a software known as calliper pro..These parameters are given in Table5 and polished samples of bead and HAZ width are shown in Figure 1(a) and (b).

Table 1 Design Matrics

No of Experiment	CaF_2wt%	FeMn wt%	NiO wt%
1	+1	-1	-1
2	0	+1	0
3	+1	-1	+1
4	-1	-1	-1
5	0	0	0
6	0	0	0
7	+1	+1	+1
8	0	0	0
9	0	-1	0
10	+1	0	0
11	0	0	+1
12	-1	-1	+1
13	0	0	0
14	0	0	0
15	+1	+1	-1
16	-1	0	0
17	0	0	0
18	0	0	-1
19	-1	+1	+1
20	-1	+1	-1

Table2 Three Factors and Levels

Factors	Additives %	Lower Level (-1)	Middle Level (0)	High Level (+1)
A	CaF_2	2	5	8
B	FeMn	2	5	8
C	NiO	2	5	8

Table 3: showing wire and plate composition.

Composition	Carbon %	Silicon %	Manganese %	Sulphur %	Phosphorus %	Nickel %
Base Plate	0.03	0.07	0.34	0.017	0.022	-
Wire	0.11	0.09	0.45	0.021	0.021	-

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Table 4: Welding Parameters.

S.No.	Voltage	Current	Travel speed
1	30 volts	475 ampere	20 cm/minute.

Figure: 1(a) Photographs of bead on plate welds.

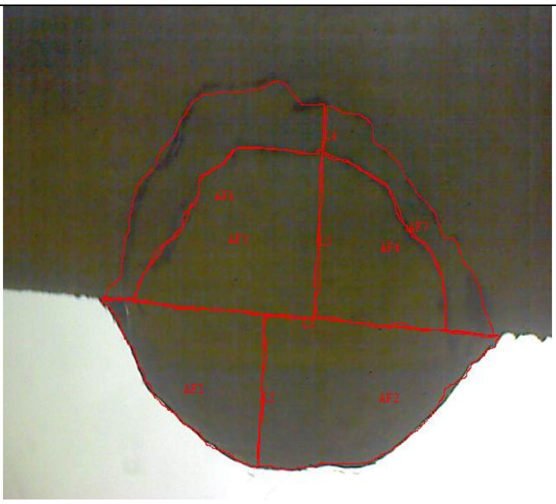

Figure: 1(b)Showing width of HAZ.

Table5 Measured parameters

Flux NO	CAF_2 (%)	FeMn (%)	NIO (%)	Heat affected Area(mm^2)	HAZ width(mm)
1	8	2	2	170.21	3.45
2	5	8	5	202.58	3.16
3	8	2	8	274.64	4.38
4	2	2	2	162.35	2.63
5	5	5	5	98.0	2.19
6	5	5	5	100.0	1.91
7	8	8	8	213.0	2.35
8	5	5	5	37.8	1.77
9	5	2	5	174.91	2.17
10	8	5	5	167.86	3.56
11	5	5	8	97.48	1.28
12	2	2	8	148.99	3.80

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13	5	5	5	105.0	1.75
14	5	5	5	157.5	2.23
15	8	8	2	206.12	5.10
16	2	5	5	118.62	3.68
17	5	5	5	95.0	2.25
18	5	5	2	121.79	2.02
19	2	8	8	212.6	2.64
20	2	8	2	330.0	6.036

IV. GREY RELATIONAL ANALYSIS

As GRA is a technique which is based on the grey theory. This theory was developed by Deng (1989). In this study two responses HAZwidth of the weld and HAZ area considered.As per the requirement, width should be minimum and the HAZ area also should be low. In this method, first all the input data are normalized so that their units may not show any effect on the out put. After normalization, the deviation for each data is calculated and finally the grey relational coefficients are calculated for each experiment. The following formulas are used for the above. For maximization and minimization of the responses the following relation given in equation 1 and 2 are used.

For maximizing the responses (Vijayan and Rao, 2014).

$$x_i^*(k) = \frac{x_i^0(k) - \max x_i^0(k)}{\max x_i^0(k) - \min x_i^0(k)} \quad (1)$$

$$x_i^*(k) = \frac{\max x_i^0(k) - x_i^0(k)}{\max x_i^0(k) - \min x_i^0(k)} \quad (2)$$

The grey relational coefficients are calculated from the given below equation no3. This is represented by ξ (k) and can be calculated from the given relation in equation 3.

$$\xi(k) = \frac{\Delta_{min} + \xi\Delta_{max}}{\Delta_{oi}(k) + \xi\Delta_{max}} \quad (3)$$

After calculating the grey relational coefficients, the grey relational grades are calculated by taking the average of coefficients of various factors.

V. RESULT AND DISCUSSION

On the basis of grey relational analysis the rank of all the twenty fluxes has been shown in Table 6. This table shows that experiment no 8 has rank 1. So, it can be said that this is the optimum flux for minimum HAZ width and area. The corresponding composition is given in table 5.

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Table 6 Rank of various fluxes

Flux No	Haz W	Nor.	Dev.	GRC	HAZ Area	Nor.	Dev.	Grc	GRG	Rank
1	3.45	0.544	0.456	0.523	170.21	0.547	0.453	0.525	0.524	15
2	3.16	0.605	0.395	0.558	202.58	0.436	0.564	0.470	0.514	17
3	4.38	0.348	0.652	0.434	274.64	0.189	0.811	0.382	0.408	19
4	2.63	0.716	0.284	0.638	162.35	0.574	0.426	0.540	0.589	10
5	2.19	0.809	0.191	0.723	98	0.794	0.206	0.708	0.716	5
6	1.91	0.868	0.132	0.791	100	0.787	0.213	0.701	0.746	4
7	2.35	0.775	0.225	0.690	213	0.400	0.600	0.455	0.572	11
8	1.77	0.897	0.103	0.829	37.8	1.000	0.000	1.000	0.915	1
9	2.17	0.813	0.187	0.728	174.91	0.531	0.469	0.516	0.622	9
10	3.56	0.521	0.479	0.511	167.86	0.555	0.445	0.529	0.520	16
11	1.28	1.000	0.000	1.000	97.48	0.796	0.204	0.710	0.855	2
12	3.8	0.470	0.530	0.486	148.99	0.619	0.381	0.568	0.527	14
13	1.75	0.901	0.099	0.835	105	0.770	0.230	0.685	0.760	3
14	2.23	0.800	0.200	0.715	157.5	0.590	0.410	0.550	0.632	8
15	5.1	0.197	0.803	0.384	206.12	0.424	0.576	0.465	0.424	18
16	3.68	0.495	0.505	0.498	118.62	0.723	0.277	0.644	0.571	12
17	2.25	0.796	0.204	0.710	95	0.804	0.196	0.719	0.714	6
18	2.02	0.844	0.156	0.763	121.79	0.713	0.287	0.635	0.699	7
19	2.64	0.714	0.286	0.636	212.6	0.402	0.598	0.455	0.546	13
20	6.036	0.000	1.000	0.333	330	0.000	1.000	0.333	0.333	20

VI. CONCLUSIONS

GRA can be applied successfully to select the flux for minimum heat affected zone width. The study reveals that flux no8 is producing minimum HAZ width in the welds. The composition of the flux shows that the optimal flux composition is CaF_2, FeMn and NiO each 5% .Such prediction may help to select a flux for minimum heat affected zone.

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