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Correlation of flux ingredients with area of penetration in SAW weldments

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Research Article

Abstract

The purpose of this study was to evaluate the effect of flux ingredients on area of penetration in SAW weldments of low carbon steel welds. The fluxes were designed using RSM and base fluxes were designed based on binary and ternary phase diagrams. The fluxes were made by agglomeration technique and CaF_2, $FeMnandNiO$ *were added as ingredients to the base fluxes to know the effect of these on the area of penetration.*

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1 Introduction

The submerged arc process which may be done automatically or manually creates an arc arc column between a bare electrode and the work piece. The arc, the end of the electrode and the molten weld pool are submerged in a finely divided powder known as flux [1]. SAW is widely used because of its inherent quality of good finish, high deposition rate, double protection from the atmospheric contamination and easy control on process variables [2]. This welding process differs from the other welding processes due to the fact that in this process, the arc is submerged and invisible. The flux is supplied from a hopper, which travels with the torch. No shielding gas is needed because the molten metal is separated from the air by molten slag and granular flux. Submerged arc welding is a versatile production welding process capable of making welds up to 2000 amperes.

Basicity Index: It is defined as the ratio of weight % of basic oxides to the acidic oxides present in the fluxes. It is commonly used to describe the metallurgical behaviour of a welding flux. It is related to the ease with which oxide component dissociates into cation and oxygen anion [3]. The BI of the flux has a significant effect on area of reinforcement, total cross sectional area of the weld, WPSF and WRFF [4]. Patchet and Dancy[5] reported that penetration increases with increase in slag viscosity and surface tension. Higher penetration is obtained with fluxes having low basicity index [6].

2. Weld penetration and area of penetration

It is defined as the distance that the fusion extends in to the base metal. The more is the penetration, the less no of passes are required to complete the weld and consequently the higher production rate.

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The penetration is influenced by flux composition, welding speed, polarity, travel speed, electrode stick out, basicity index and physical properties of the flux. Generally it is assumed that the depth of penetration depends upon the heat input by the arc. It is also reported that the diameter of the electrode affects the penetration and other aspects of the bead geometry [7]. The area of penetration is the area of the fused metal into the base metal. The bead shape and geometry decides the load taking capacity of the joint and it depends upon composition of flux, base metal and weld bead shape [8]. The BSG is decided by the Width/Depth of the bead and it is used to measure the profile of the weld. In acceptable weld bead this ratio should not be very high or very low [9].

The Fig. 1 and 2 show the bead on plate welds and area of penetration. Various researchers [10-12] have studied the effect of welding parameters on bead geometry. Apart from the process parameters, the flux composition also affects the bead geometry significantly but its effect has not been reported.

Fig. 1 Photographs of the welds

Fig. 2 Area of penetration

3. Experimental procedure

The fluxes were prepared by agglomeration technique, the base constituents CaO, SiO_2 and Al_2O_3 were mixed in the ratio 7:10:2 based on ternary and binary phase diagrams. The additives CaF_2, FeMn and NiO were selected as control parameters. To investigate the effects of additives systematically, twenty fluxes were designed using response surface methodology. The design matrix in the coded form is given in Table 1.Bead on plate welds using submerged arc welding were made on 18 mm thick plates, while keeping Voltage 30 volt, Current at 475 amp and travel speed 20 cm per minute as constant. After making beads, the plates were cut transversely with power hacksaw. Polishing was done with emery paper followed by etching using 5% natal solution. The bead profiles were measured with caliper pro software attached with a computer interfaced stereozoom microscope having magnification 10X. The three factors and their levels are given in Table 2.The measured parameters are given in Table 3.

Table 1.Design matrix in coded form.

No of Experiment	CaF_2 wt %	$FeMn$ wt%	NiOwt %
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

Table 2. Showing factors and levels.

Factors	Additives	Low Level %	Mid Level %	High Level %
A	CaF_2	2	5	8
B	$FeMn$	2	5	8
C	NiO	2	5	8

4. Effect of $CaF_2, FeMn\ and\ NiO$ on area of penetration

The area of penetration decreases with increase of CaF_2additive in the flux. This can be seen from the Fig 3. This can be attributed to the reduction in depth of penetration with the addition of CaF_2additive in the flux. Another possible reason may be the quantity of weld oxygen content. At low oxygen, the area of penetration is also low and it increases with increasing weld oxygen content as shown in the Fig. 4.The area of penetration is low in both the cases when the oxygen is either very low or very high. However, the area of penetration is not much changed with increasing FeMn. This has been given in Fig. 5. This may be explained on the basis of the quantity of the weld oxygen content. There is a very small decrease in the area of penetration with increase of NiO content in the flux although, the depth of penetration increases with increasingNiO. So from this it can be said that a finite correlation between the penetration and area of penetration cannot be established. This has been shown in the Fig 6. This can also be attributed to the change of oxygen content and Ni contents in the weld with increasingNiO.

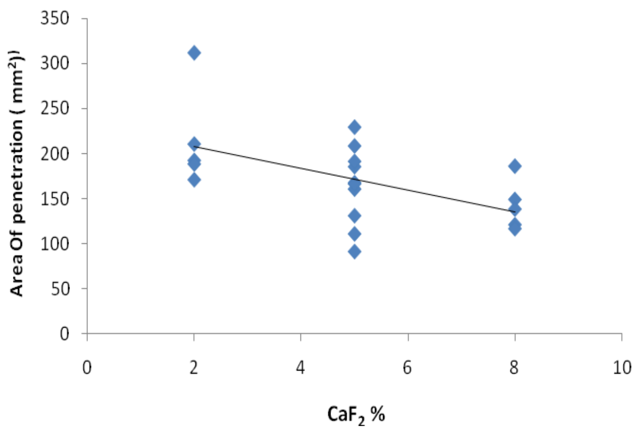

Fig. 3 Effect of CaF_2 on area of penetration

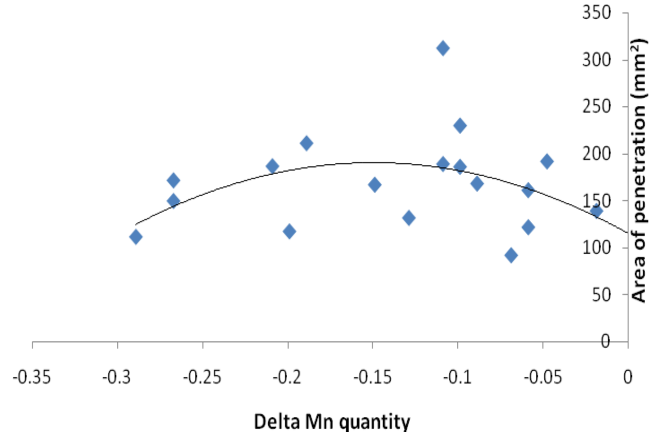

***Fig.:**Error! No text of specified style in document.**Effect of oxygen content on area of penetration**.*

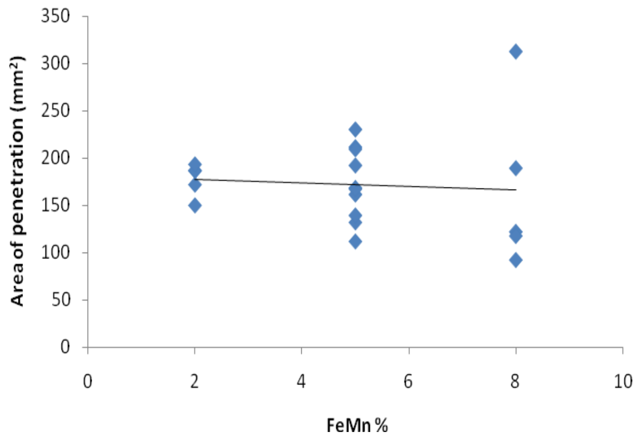

Fig. 5 Effect of FeMn on area of penetration

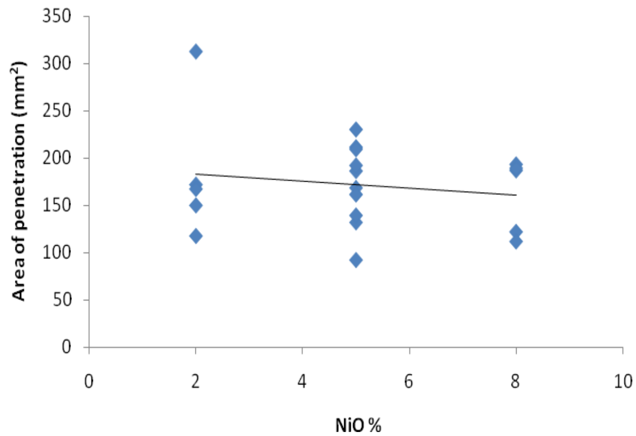

Fig.6 Effect of NiO witharea of penetration.

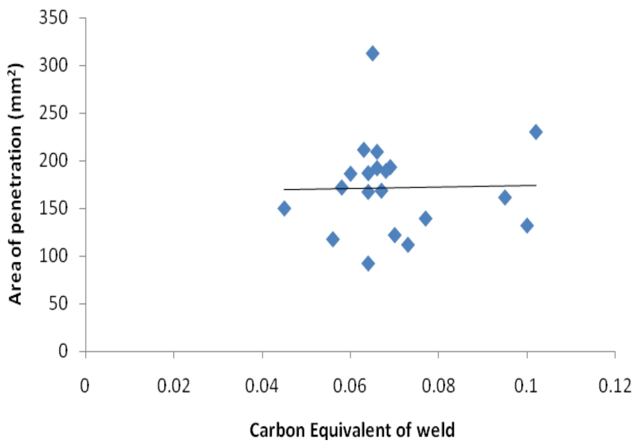

Fig. 7 Effrect of CE on area of penetration

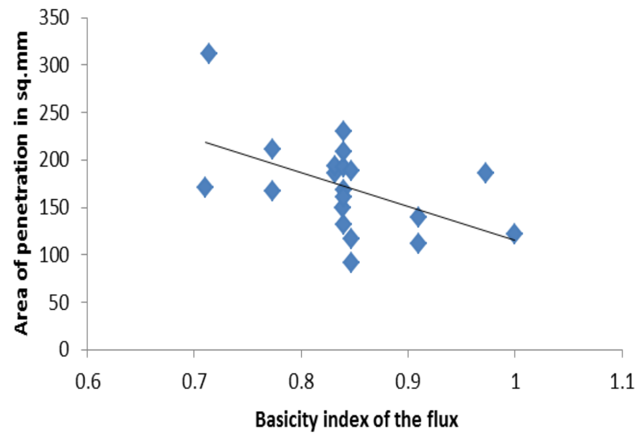

Fig. 8 Effect of BI on area of penetration

Table 3 Measured responses

Flux No	CaF_2(%)	$FeMn$ (%)	NiO (%)	AP (mm^2)	BI	ΔMn

1	8	2	2	149.51	0.839	-0.267
2	5	8	5	91.68	0.847	-0.069
3	8	2	8	186.48	0.973	-0.209
4	2	2	2	171.42	0.71	-0.269
5	5	5	5	168.04	0.84	-0.089
6	5	5	5	131.46	0.84	-0.129
7	8	8	8	121.48	1.00	-0.059
8	5	5	5	229.77	0.84	-0.099
9	5	2	5	185.91	0.832	-0.099
10	8	5	5	138.87	0.91	-0.019
11	5	5	8	111.31	0.91	-0.289
12	2	2	8	192.85	0.832	0.131
13	5	5	5	161.01	0.84	-0.059
14	5	5	5	191.7	0.84	-0.049
15	8	8	2	117.11	0.847	-0.199
16	2	5	5	211.05	0.773	-0.189
17	5	5	5	208.88	0.84	0.061
18	5	5	2	166.82	0.773	-0.149
19	2	8	8	188.83	0.847	-0.109
20	2	8	2	312.27	0.714	-0.109

5. Effect of carbon equivalent and BI on area of penetration

The effect of carbon equivalent on area of penetration shows that it is not much changed with increasing carbon equivalent. This has been shown in the Figure 7.The possible reason may be the combined effect of various elements transfer to the weld and the quantity of oxygen present in the weld. The weld penetration area is decreased with increase of basicity index. This is shown in the Figure 8. This may be attributed to the oxygen present in the weld.

6. Conclusions

1. The CaF_2 additive has a definite effect on area of penetration and it is is reduced with increasing CaF_2 additive.
2. The Femn and NiO both show little effect on area of penetration.
3. After increasing to an extent, the area of penetrati decreases with increasing weld oxygen.The area of penetration is low when the weld oxygen is either very low or high.
4. The area of penetration is reduced with increasing BI while, CE does not show any effect on area of penetration.

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