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Design and Development of Submerged Arc Welding Acidic Flux

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ABSTRACT

An acidic flux was intended and developed with the variation of some flux constituents. The basicity index of the flux was kept as 1.84. It was designed to weld the mild steel plates on submerged arc welding machine. A study was done with developed flux on two-level factorial design. Voltage and current were the controlled parameters along with feed rate, nozzle distance and creep feed as uncontrolled parameters selected for experimentation. Eight experiments were performed. Weld bead width and Hardness were the responses measured. Design expert software was used the do the analysis. Finally, it can be determined that travel speed was the most momentous factor for the hardness and weld bead dimensions of the joint.

Keywords: Flux basicity index; Ball mill; Vickers hardness; Weld dimensions.

INTRODUCTION

Since 1930s a wide variety of fluxes has been developed. Flux preparation is a time-consuming process, different techniques were used to design the flux. Basicity index was kept in mind while designing the flux. Some of the investigator recommended that titanium is a deoxidizer along with manganese; it will minimize the oxygen content. The consequence of the study illustrate that the oxygen level of the developed flux was well below than other fluxes (W.J. Lewis et.al,1961). Welding flux plays a vital and complex role in the welding processes.

Fluxes must melt in weld pool at appropriate temperature, must have a density less than the weld deposit. Welding consumables affect the weld deposit chemically and physically (Butler et.al, 1961). The dissolved oxygen-content is beneficial for the impact strength and transition temperature of the welded joint (Palm et.al,1972). The effect of submerged arc welding limitations along with flux basicity index on the weld interaction was studied and finally settled for directing the weld-metal configuration. The results showed that welding current and voltage are influencing the weld composition (Panday et.al, 1994). The study carried out on influence of chemical structure, micro construction and stretchable properties of SAW on AISI 1020 steel was agreed out, the result displays that acicular ferrite was existing in the flux with contents of TiO_2 (Paniagua et.al, 2005). The study carried out on flux mixture and welding parameters for low carbon steel plates shows that flux composition has individual as well and mix effects on responses (Kanji lal et.al,2006). In a twin wire joining process current, voltage, wire thicknesses and polarity are the major issues influencing the flux ingesting (Sharma et.al,2008). voltage and welding speed both will reduce the diffusion in submerged arc welding as suggested by (Vinod et.al,2011). Cost of welding flux is nearly half as compared to other constituents in SAW process. Development of better welding flux in terms of mechanical properties and efficiency, that is cost operative too, was the focus of many scholars (Gautam et.al, 2017). MnO, MgO, NiO in a $CaO\text{-}SiO_2\text{-}Al_2O_3$ arrangement of flux has higher solidity in comparison to Fe-Cr CaO based fluxes (Ajay Kumar et.al, 2012).

FLUX PREPARATION

All the flux constituents were mixed in a ball Mill as shown in Figure 1(a). It consists of number of steel balls, 10 mm in diameter. When the ball Mill rotate at high speed, all the flux constituents start mixing with each other. The flux should be a homogeneous mixture of all the constituents, when steel balls fall on the particles under gravity that makes it as homogeneous. Ball mill should be operated at 60 to 75% of its critical speed for effective operation. Attachment of ball mill is shown in Figure 1(b).

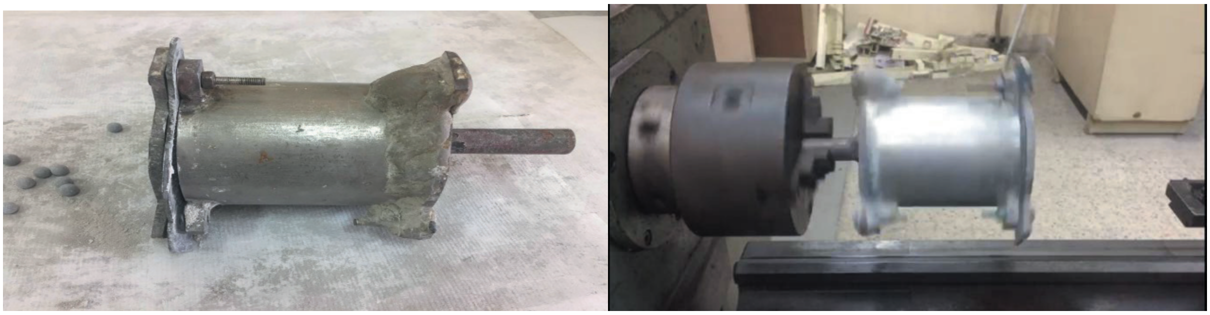

Fig 1. (a) Ball Mill (b) Ball Mill Setup

Table 1 shows water and binder composition used for the preparation of the flux. Composition with weight percentage of different components used for making the fluxes is given in Table 2. Total (940 g) powdered chemicals was used. Binder (potassium silicate) and hot water approximately (360 + 630 ml) respectively was then sprayed on the mixture. The whole mixture was then mixed with hands to form the small granules. When it became granular then the mixing progression was at a standstill. Flux was aloof and spread on flat piece of paper for 48 hrs. The dried flux was parched in a muffle kiln for 2 hrs at 600^0 C. It was then permitted to cool down at room environment. Figure 2(a) and Figure 2(b) shows that how to mix the flux constituents manually. The muffle furnace used for baking of the flux is shown in Figure 2(c)

Table 1. Binder and Water composition

S No.	Type of Flux	Water	Binder (Potassium silicate)
1.	Acidic	0.4	0.5

Table 2. Flux constituent's compositions

S No.	Type of Flux	Acidic flux constituent's compositions (Weight Percentage)					Basicity Index
		Al_2O_3	$CaCO_3$	MgO	TiO_2	NiO	
1.	Acidic	44.0	22	25	7	-	1.84

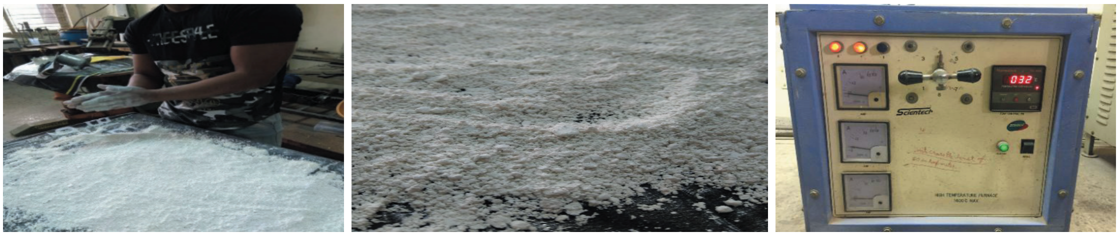

Figure 2. (a) Constituents Mixing (b) Granular Flux (c) Electric Furnace

CALCULATION OF BASICITY INDEX

Categorization of submerged arc welding fluxes can be on the basis of the basicity index, (B.I) It is the proportion of amount of basic oxides to acidic oxides. The formula used for calculation is shown as:

$$BI \text{ (Basicity Index)} = \frac{CaO + MgO + BaO + SrO + Na_2O + K_2O + Li_2O + CaF_2 + 1/2(MnO + FeO)}{SiO_2 + 1/2(Al_2O_3 + TiO_2 + ZrO_2)}$$

Acidic fluxes have different applications then basic fluxes these are preferred for single-pass welding. In calculation, acidic flux usually has additional resistance to basic fluxes to plate contamination by grease and corrosion.

DESIGN METHOD

In this design process, factorial designs were used because in this process each level of independent variable with each level of others to give all possible combination. These plans are often used as initial point for very intricate response surface modelling also. In this effort 2^2 plan was used.

WELDING TECHNIQUE

In this research work, bead on plates as revealed in Figure 4 were produced by using semi-automatic submerged arc welding method as per the design matrix shown in Table 8. The copper coated electrode of 3.15 mm diameter was used. Mild steel plates were used to make the bead on plates arrangement with fixed welding parameters as shown in Table 3. On the basis of weld appearance, good slag detachability, arc initiation, and arc stability the fixed welding parameters were selected. Each pass of weld was preceded by thorough cleaning and removal of slag form the joint. In this way, total eight plates were welded. Four are revealed in Figure 3. The two manageable features were welding voltage and travel speed. The first issue welding voltage was ranged between 40-60 Volt. Other feature trolley travel speed was ranged between 30-70 cm/min. The Design matrix is produced in design expert software as revealed in Table 8. The matching answers were recorded the result are publicized in Table 6. The variable parameters are specified in Table 4. The chemical arrangement of welding plate and welding probe is specified in Table 5.

Table 3. Welding Constraints

Constraints kept fixed	Unit of Limits
Trolley travel speed	6 cm/sec
Nozzle Distance	3 mm
Wire Feed rate	3 cm/min

Table 4. Limitations Varied

Plates	Voltage(V)	Travel Speed(cm/min)	Current(A)
I	40	30	475
II	40	70	450
III	60	30	550
IV	60	70	471

Table 5. Configuration of Probe and Weld Plates

Configuration	C	Mn	Si	Ni	Cr	S	P	Mo	Cu	W	Fe
Electrode EL-8	0.08	0.5	0.05	0.33	0.83	-	-	-	-	-	
Base plate	0.30	0.598	0.31	0.11	0.040	0.014	0.063	0.088	0.083	0.153	98.04

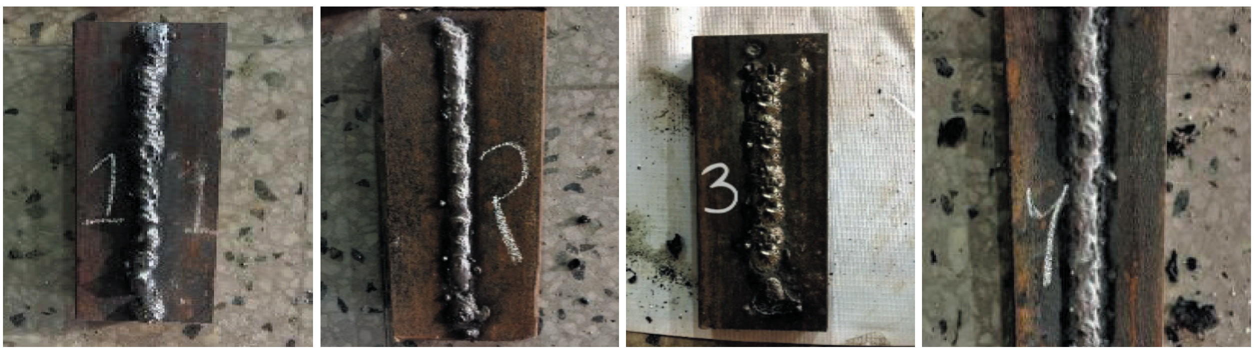

Figure 3. Welded Plates

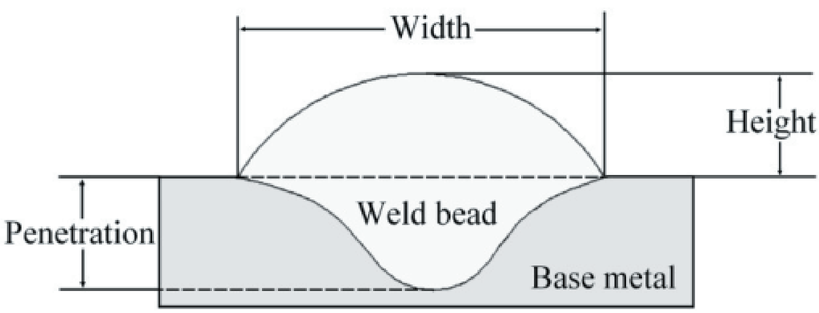

Figure 4. Bead on plate arrangement

RESPONSE 1: WELD BEAD GEOMETRY

Weld bead dimensions i.e., height, width and penetration are important physical characteristics of a welded joint, dimensions of the prepared specimen are shown in Table 6.

Table 6. Weld bead dimensions

Type of Flux	Welding Voltage(V)	Trolley speed (cm/min)	Mean of weld bead dimensions (mm)		
			Bead Height	Bead Width	Penetration
Acidic	40	30	4.2	11.8	4.4
	40	70	2.5	12.7	3.4
	60	30	3.7	15.1	4.2
	60	70	2.2	10.6	3.5

RESPONSE 2: VICKERS HARDNESS

Hardness of the weld beads was restrained on VHN Testing machine with diamond indenter by putting 30 kgf weight on the ready specimens (10x50x20 mm) as shown in Fig 8 and mean of four readings from various samples is revealed in Table 7.

Table 7 Average Hardness value

Type of Flux	Welding Voltage(V)	Travel speed (cm/min)	Hardness (VHN)(Mean)
Acidic	40	30	182.545
	40	70	224.337
	60	30	207.630
	60	70	234.335

The hardness of base plate was found to be approximately as 132.

Figure 5. Specimens for Hardness Test

Table 8. Design Matrix for Acidic flux

Std	Run	Factor 1 A:Voltage V	Factor 2 B:Travel Speed cm/min	Response 1 Bead Width mm	Response 2 Bead Penetration mm	Response 3 Bead Height mm	Response 4 Hardness HV
5	1	40	30	11.8	4.4	4.2	182.545
1	2	40	30	13	3.6	4.2	181.23
8	3	60	70	10.6	3.5	2.2	238.42
7	4	40	70	13.6	3.4	2.6	224.337
2	5	60	30	15.1	4.2	3.7	207.63
4	6	60	70	11	3	2.5	234.335
3	7	40	70	12.7	3.4	2.5	241.419
6	8	60	30	14.9	4	3.8	198.75

MODELLING OF VICKERS HARDNESS

The result of (ANOVA) is shown below in Table 9. It shows that the model is significant. The F-value of the model is 27.48 and its p-value is 0.0040. It in fact shows that model is statistically important at 99 % confidence level. Also, the fit of the model was verified by the coefficient of determination R^2. which was found to be 0.9537, thus directing out that only 4.63 %, of the total disparities in the reply was not determined by the study.

Table 9 Hardness

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	4009.01	3	1336.34	27.48	0.0040	significant
A	307.57	1	307.57	6.32	0.0657	
B	3542.97	1	3542.97	72.85	0.0010	
AB	158.47	1	158.47	3.26	0.1454	
Pure Error	194.53	4	48.63			
Cor Total	4203.54	7				

Equations to forecast the behaviour is shown below:

$$\text{Hardness} = 213.58325 + 6.2005(A) + 21.0445(B) - .45075(A*B) \quad ---(1)$$

The normal plan of residuals and plan of actual and forecasted hardness is shown in Figure 6 (a) and (b) respectively. These graph shows that all the points are very near to the straight line means that there is a very small variation in the data. Equation 1 provides the information of hardness of model in the coded form where A is voltage and B is travel speed.

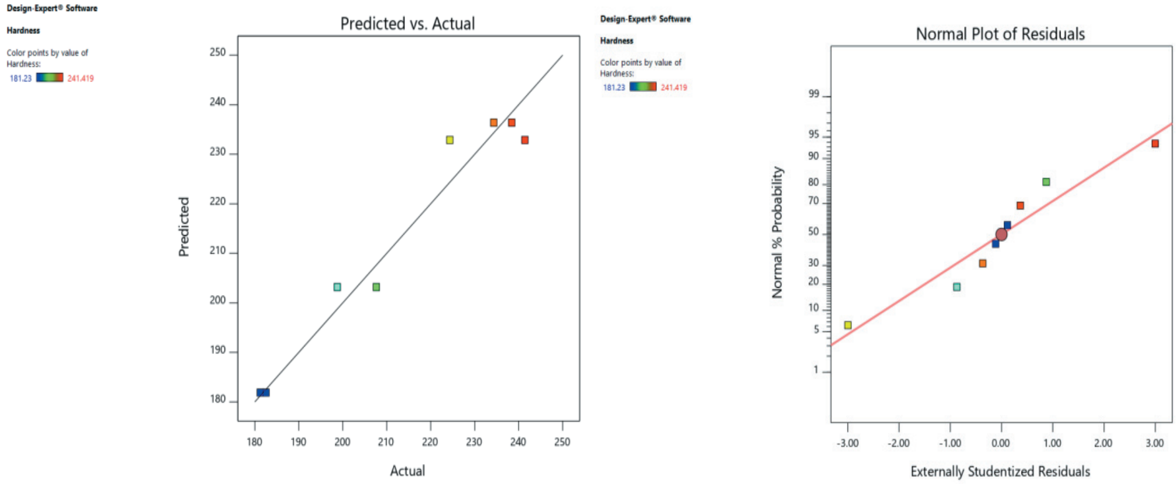

Figure 6. (a) Actual and predicted Hardness (b) Normal plots of residuals

Analysis of Bead Geometry

ANOVA for Bead width is revealed in Table 10. It shows that the model is significant. The F-value of the model is 19.85 and its p-value is 0.0073. It in fact predicts that models is statistically important at 99% confidence level. Also, the acceptance of the model was verified by the quantity of R^2 originating to be 0.9370, thus stating that only 6.30 %, of the total change in the result was not determined by the model.

Table 10 Response 2: Bead Width

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	18.23	3	6.08	19.85	0.0073	significant
A	0.0312	1	0.0312	0.1020	0.7654	
B	5.95	1	5.95	19.43	0.0116	
AB	12.25	1	12.25	40.00	0.0032	
Pure Error	1.23	4	0.3063			
Cor Total	19.46	7				

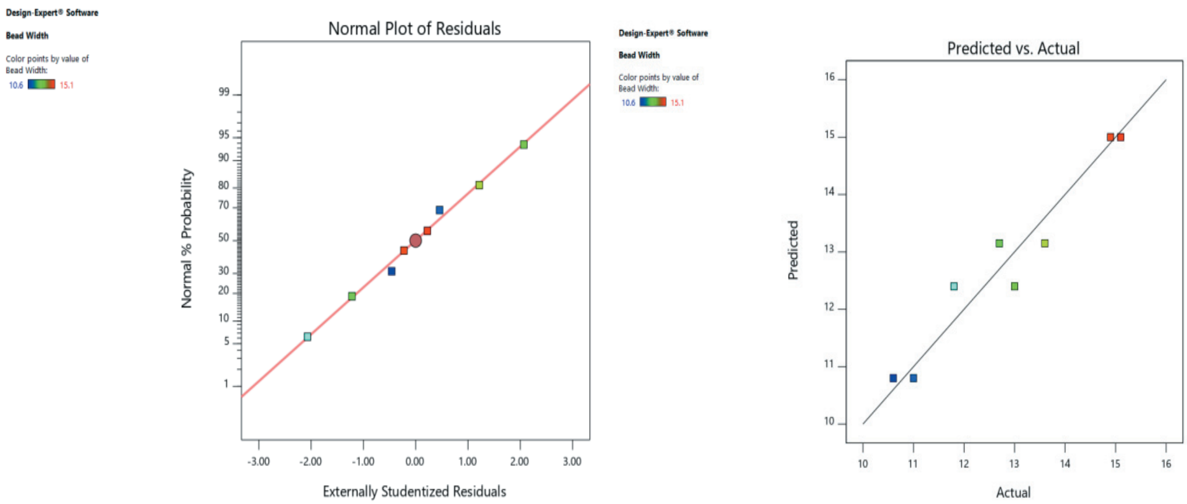

Figure 7. (a) Graph of residuals (b) Graph of predicted vs actual bead width

Equations to forecast the behaviour in coded form is shown as:

Bead Width =12.8375 + 0.0625(A) - 0.8625(B) - 1.2375(A*B)---------(2)

The graph of residuals along with graph of predicted vs actual bead width is given in Figure 7 (a) and (b) respectively. All the points on the graph are very near to the straight line which shows that there is very small variation in the predicted and actual values. Equation 2 provides the information of bead width of model in the coded form where A is voltage and B is travel speed.

CONCLUSION

In the present study, agglomerated flux for the SAW was designed and developed in the lab. The mechanical property such as hardness of welded joints, for developed flux was analysed. The experimental results were analysed and correlated with the help of standard data and modelling. On the basis of results the following conclusions were drawn.

From this study, it is resolved that the changes in of the voltage and travel speed interrupts the hardness of bead during submerged arc welding process. This will be helpful to achieve the desired hardness of the welded joint while designing the flux for the various applications. On the contrary, the hardness of the weld bead was greater than that of base metal. So, the speed travel becomes the major factor for the hardness control of the such joints.

The result of the study quantified that weld bead width was very close to the values of the developed agglomerated flux. Hence it is proved that width of weld bead can also controlled by travel speed.

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