DETERMINATION OF FLUX CONSUMPTION WHEN REUSE OF SLAG AS FLUX IN SUBMERGED ARC WELDING WHEN WELDING PARAMETERS SELECTED BY RESPONSE SURFACE METHODOLOGY TECHNIQUES

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Abstract

The Objectives of this research is to study the effect of mixture of reused and new flux on chemical composition in weld metal of Submerged Arc Welding process (SAW). Slag generated during submerged arc welding has been recycled by mixing varying percentages of crushed slag with fresh flux to use in subsequent runs. Slag generated during submerged arc welding is normally thrown away as a waste. This poses the problem of storage, disposal, and environmental pollution and needs landfill space apart from exhaust of non-renewable resources. Reusing of slag will not only solve these problems but also be economical. In the present work an attempt has been made to use the submerged arc welding slag as flux in the same submerged arc welding process. Fused slag was crusher to the desired particle size as that of the original flux. 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 weldment. Selection of process parameters has great influence on the quality of a welded connection. Welding input parameters play a very significant role in determining the quality of a weld joint. Slag formed during the welding process

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that is subsequently crushed for use as a welding flux is defined as crushed slag.In Our Research work we used 40 % slag in Virgin Flux and find out the consumption when changing the values of welding parameters accordingly Experiment run order.

Keyword : Submerged arc Welding , Reused Flux , R.S.M Technique ,Design Expert Software.

1. Introduction

The traditional welding flux is costly and the flux used in Submerged Arc Welding (SAW) generates wastages known as Slag. It is generally thrown away as a waste after use. This poses the problem of storage, disposal, and environmental pollution and needs landfill space apart from exhaust of non-renewable resources. If by recycling the used flux can be reused in product yielding same quality parameter as the new flux, then the cost of the input will go down significantly. However, this requires extensive trial and error experimentation because it is often difficult to know how the slag ingredients interact after recycling to determine the operational characteristics of the recycled flux and the final performance of the welded structure. Keeping this in mind an experiment has been conducted in a manufacturing unit with small investment. As far as possible weld qualification tests were performed using recycled flux to get it to be qualified in a National Accreditation Board of Laboratories in the final products made from recycled slag. Submerged arc welding is a versatile welding process in which coalescence is produced by heating the metal with an arc maintained between a bare metal electrode and the workpiece. The arc is shielded by a blanket of granular fusible material known as flux placed over the welding area. Filler metal is obtained from the electrode and sometimes a supplementary welding rod or metallic addition. Flux contributes a major part towards welding cost in submerged arc welding. The Flux is converted into slag during welding which is treated as waste and discarded.

Submerged Arc Welding Slag

Slag after Crushing as Flux Grangular Foam

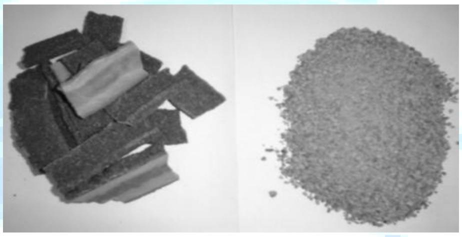
SAW fluxes are granular, fusible mineral compounds of various proportions and quantities, manufactured by several different methods. In addition, some fluxes may contain intimately mixed metallic ingredients to deoxidize the weld pool. Any flux is likely to produce weld metal of somewhat different composition from that of the electrode used with it due to chemical reactions in the arc and sometimes to the presence of metallic ingredients in the flux. A change in arc voltage during welding will change the quantity of flux interacting with a given quantity of electrode and may, therefore, change the composition of the weld metal. Reuse of slag can not only minimize the above problems, but can also save non-renewable mineral resources. The slag is normally reused after its processing & recycling so as to reclaim its original characteristics. However this requires a considerable amount of effort and money to be spent on it. However if this slag is reused as flux again only after crushing it to the normal particle size of the original slag without any new additions/processing, the cost of reuse of this slag will be quite low. However the quality of weld/clad metal obtained using this reused slag needs to be analyzed before recommending its reuse. The preset study aims at exploring the possibility of reused of the crushed slag as flux & effects of use this flux on the chemical composition and weld bead characteristics of the welds/clads obtained using this flux. Ingredients for use in welding fluxes are very carefully chosen to provide specific benefits to the submerged arc welding process, including cleansing the weld metal, providing appropriate weld metal composition (carbon, manganese, silicon, oxygen, nitrogen, etc.), protecting the weld puddle from atmospheric contamination, stabilizing the arc, allowing for ease of slag removal from the weld metal, and providing the appropriate slag viscosity and freezing range for intended applications. When virgin flux is melted by a welding arc, it does not fully reach an equilibrium state. Although the specific elements contained in the slag may be similar, the chemical form of these elements in the generated slag will be significantly different from that of the virgin flux. Blending crushed slag with virgin flux is a common practice by flux processors. Crushed slag is approximately 20% more dense than the virgin flux it was generated from. This will promote segregation of any blends of crushed slag with virgin flux. It can also significantly increase the consumption of welding flux and increase the slag to metal ratio.

2. Experimental Procedure :

For carrying out this study, experimental procedure consisting of the following steps was followed:-

1. Collection of slag and Crushing and sieving of Slag :

   Slag was generated during the SAW welding process & it was collected free of cost. The slag was crushed using a crusher to convert it into reusable granular flux. Crushed mass was then sieved so that the grains of the reusable flux(slag) should confirm to the particle size of the original flux (10 mesh sieves).



2. Mixing slag with Pure Flux :The crashed & sieved slag mix with pure flux with the ratio of 40 % slag & 60 % Pure flux for the welding on plates.
3. The Preparation of High Strength Low Alloy Steel Plates 250 x 150 x 10 mm .
4. The Preparation of welding electrode for Submerged arc welding , EH 14 (AWS grade EH-14) of diameter 3.2 mm.
5. The Experiment Designed based on BOX-BEHNKEN DESIGN (BBD) using state ease 6.0 Version of design of experiment.
6. The Experiment was conducted as per the design matrix using TORNANDO SAW M-800 equipment at Mullana University Mullana.
7. Reuse slag as Flux consumption measured each 29 experiment run according to design matrix reading.

3. Welding Parameters & Chemical Composition :-

(A) Welding Current :-

In SAW ,Current plays a major role where it controls the melting rate of the electrode and thereby the weld deposition rate. It also controls the depth of penetration and thereby the extent of dilution of the weld metal by the base metal. The current density controls the depth of penetration - the higher the current density the greater the penetration For a given flux, arc stability will be lost below a minimum threshold current density so that if the current for a given electrode diameter is too low arc stability is lost and a rugged, irregular bead is obtained. Too high a current density also leads to instability because the electrode overheats and undercutting may also occur weld reinforcement which is wasteful, and burn-through in the case of thinner plates or in badly fitted joints, which are not provided with proper backing [4]. Excessive current also produces a high narrow bead and undercut. Excessively low current gives an unstable arc, inadequate penetration and overlapping. SAW equipment is usually provided with an ammeter to monitor and control the welding current .

(B) **Voltage Arc**

Voltage affects dilution rather than penetration. Bead on plate welds and square edged closed butt welds have increased width and dilution as the arc voltage increases, but depth of penetration remains the same. If the joint preparation is open, for example in a butt joint with a small angled 'V' preparation, increasing the arc voltage can decrease the penetration. Arc voltage, also called welding voltage, means the electrical potential difference between the electrode wire tip and the surface of the molten weld puddle.

(C) Weld Speed

Welding speed or travel speed controls depth of penetration. Bead size is inversely proportional to travel speed. Faster speeds reduce penetration and bead width, increase the

likelihood of porosity and, if taken to the extreme, produce undercutting and irregular beads. At high welding speeds the arc voltage should be kept fairly low otherwise arc blow is likely too occur [4]. If the welding speed is too slow burn through can occur. A combination of high arc voltage and slow welding speed can produce a mushroom shaped weld bead with solidification cracks at the bead sides.

(D) **Nozzle to Plate Distance**

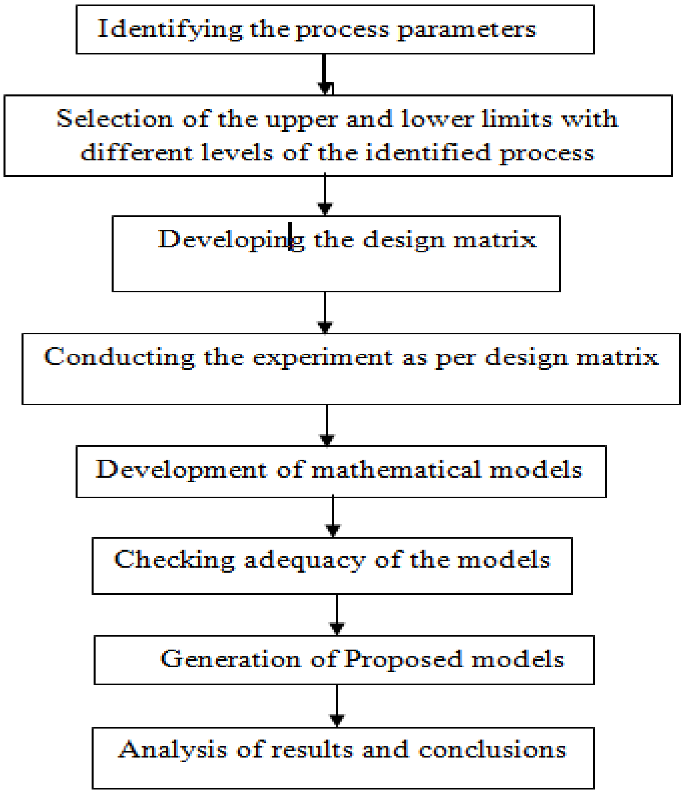
SAW filler material usually is a standard wire as well as other special forms. This wire normally has a thickness of 1/16 in. to 1/4 in. (1.6 mm to 6 mm). In certain circumstances, twisted wire can be used to give the arc an oscillating movement. In SAW welding nozzle to plate distance plays a major role. To operate welding smoothly ,generally in saw welding distance between nozzle to tip and work piece is 15 mm to 30 mm.

Parameters	**Units**	**Limits**				
		-2	-1	0	1	2
Current (C)	amp	300	350	400	450	500
Voltage (V)	volts	26	28	30	32	34
Welding Speed (S)	m/hr	21	24	27	30	33
N.P. Distance (D)	mm	16	18	20	22	24

Type	**Grade**	**Chemical Composition(%)**								
		C	Mn	P	S	Si	Cr	Mo	Ni	Fe
W.Piece	Hsla 945X	0.22	1.35	0.04	0.05	0.90	0.04	0.05	0.87	Bal
Electrode Wire	EH14	0.15	1.9	-	0.05	-	-	-	0.4	Bal

% age	**C**	**Mn**	**Si**	**S**	**P**
With fresh Flux	0.357	0.325	0.188	0.04867	0.4876
With 40 % reused Slag	0.1812	0.4312	0.1071	0.0264	0.0289

4. Methodology



Identification of the process parameters :- The following independently controllable process parameters were identified to carry out the experiments: open-circuit voltage (V); wire feed rate (F); welding speed (S); and nozzle-to-plate distance (N) .

Finding the limits of the process variables:- Trial runs were carried out by varying one of the process parameters whilst keeping the rest of them at constant values [6]. The working range was decided upon by inspecting the bead for smooth appearance and the absence of any visible defects. The upper limit of a factor was coded as +2 and the lower limit as -2, the coded values being calculated from the following relationship:

$$X_i = \frac{2[2X-(X_{max}-X_{min})]}{(X_{max}-X_{min})}$$

where Xi is the required coded value of a variable X; and X is any value of the variable from Xmin to Xmax. The selected process parameters with their limits, units and notations .

Developing the design matrix :- The selected design matrix, is a central composite rotatable factorial design consisting of 31 sets of coded conditions. It comprises a full replication of 24 (=16) factorial design plus seven center points and eight star points. All welding variables at the intermediate level (0) constitute the center points and the combinations of each of the welding variables at either its lowest (-2) level or highest (+2) level with the other three variables at the intermediate levels constitute the star points.[8] Thus the 29 experimental runs allowed the estimation of the linear, quadratic and two-way interactive effects of the process parameters on the bead geometry

Conducting the experiment as per the design matrix :- The experiments were conducted as per the design matrix at random, to avoid the possibility of systematic errors infiltrating the system.

Recording of the responses :- During the experiments flux consumption was measured after each run. Measured quantity of flux was put into the flux hopper before taking the bead and again measured after taking the bead. Difference of the two quantities was taken as the flux consumption.

Development of mathematical models :-

The response function representing any of the weld bead dimensions can be expressed as : Y= f (V, F, S, N). The relationship selected being a second degree response surface expressed as follows:

$$Y=b_0+b_1V+b_2F+b_3S+b_4N+b_{11}V2+b_{22}F2+b_{33}S2+b_{44}N2+b_{12}VF+b_{13}VS+b_{14}VN+b_{23}FS+b_{24}FN+b_{34}SN$$

Checking the adequacy of the models developed :-

The adequacy of the models was tested using the analysis of variance technique (ANOVA). The calculated value of the F-ratio of the model developed should be greater than the standard tabulated value of *F*-ratio for a desired level of confidence (say 95%) for the model to be significant.

	Experiment	Process Parameters				Responses Factors
Standard	Run	Current	Voltage	Welding Speed	Nozzle to Plate Distance	Reuse Slag as Flux Consumption
Limits	Numbers	(Amperes)	(Volts)	(M/hr)	(M.M)	(Gms)
1	11	300	26	27	20	43.0
2	26	500	26	27	20	89.0
3	17	300	34	27	20	55.0
4	19	500	34	27	20	65.0
5	9	400	30	21	16	38.0
6	23	400	30	33	16	45.0
7	6	400	30	21	24	48.0
8	7	400	30	33	24	52.0
9	28	300	30	27	16	37.0
10	3	500	30	27	16	82.0
11	25	300	30	27	24	52.0
12	20	500	30	27	24	67.0
13	27	400	26	21	20	44.0
14	12	400	34	21	20	41.0
15	8	400	26	33	20	47.0
16	2	400	34	33	20	48.0
17	15	300	30	21	20	42.0
18	4	500	30	21	20	56.0
19	18	300	30	33	20	27.0
20	14	500	30	33	20	84.0
21	5	400	26	27	16	52.0
22	24	400	34	27	16	47.0
23	1	400	26	27	24	54.0

24	16	400	34	27	24	51.0
25	21	400	30	27	20	51.0
26	29	400	30	27	20	52.0
27	10	400	30	27	20	48.0
28	13	400	30	27	20	52.0
29	22	400	30	27	20	44.0

5. Results

Interaction effects :-The difference in effect of one variable when a second variable is changed from one level to another is known as interaction effect and study of interaction effects of process variables on bead dimensions is interesting and very useful for understanding the process behavior. In this study, the effect of welding current, arc voltage, welding speed and distance between tip of nozzle & work piece on the reused slag as flux consumption. These figures shows results of the slag as flux consumption according to the welding parameters.

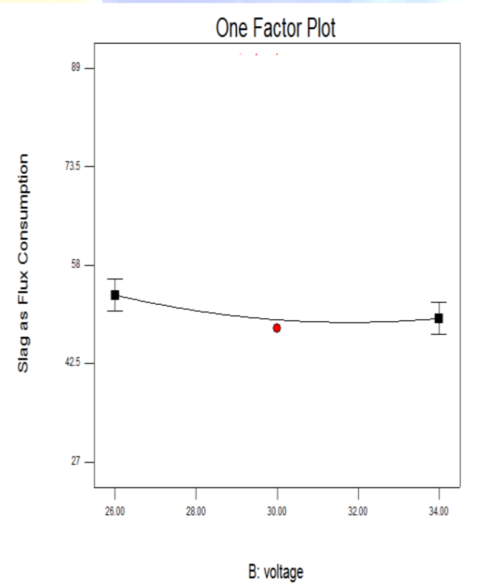


Fig 5.1

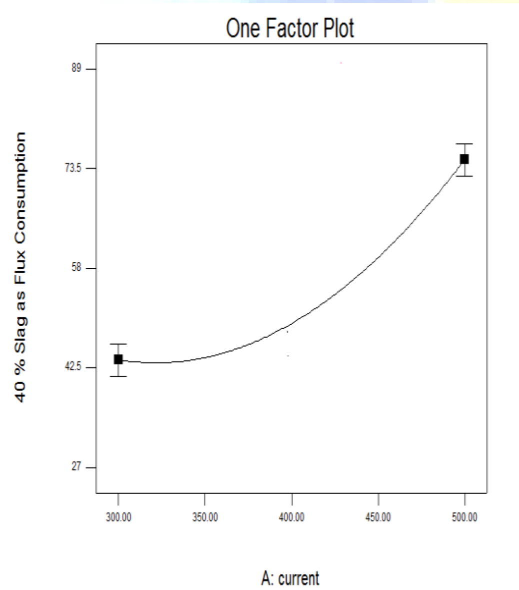


Fig 5.2

Figure 5.1 shows Slag as flux consumption Decreases when increases the Voltage , while Figure 5.2 shows Slag as flux consumption Increases when welding current increases .

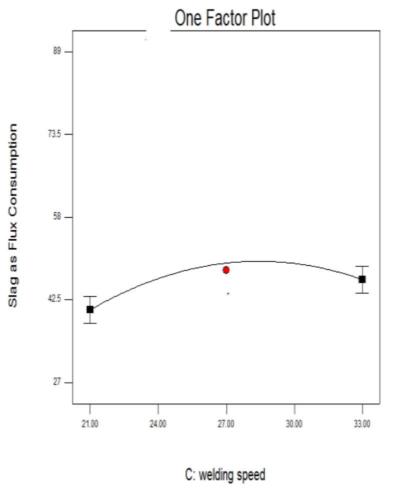


Fig 5.3

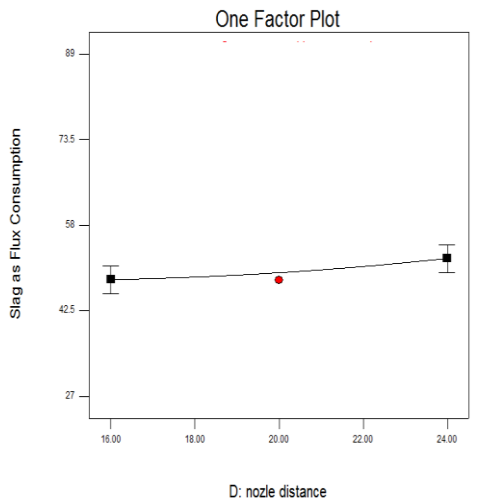


Fig 5.4

Figure 5.3 shows Slag as flux consumption Increases when increases the welding speed , while Figure 5.4 shows Slag as flux consumption Increases when Nozzle to plate distance increases .

Interaction effect

The difference in effect of one variable when a second variable is changed from one level to another is known as interaction effect and study of interaction effects of process variables on bead dimensions is interesting and very useful for understanding the process behavior. In this study, to avoid complexity two way interactive effects of the variables are selected.

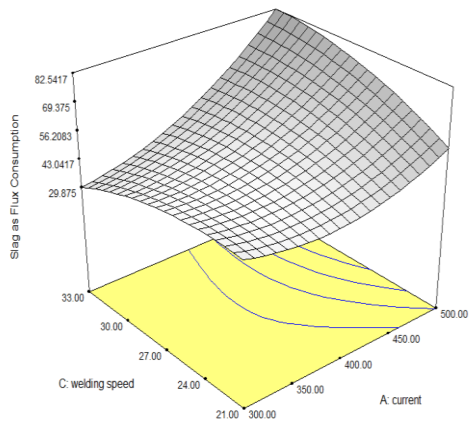


Fig 5.5

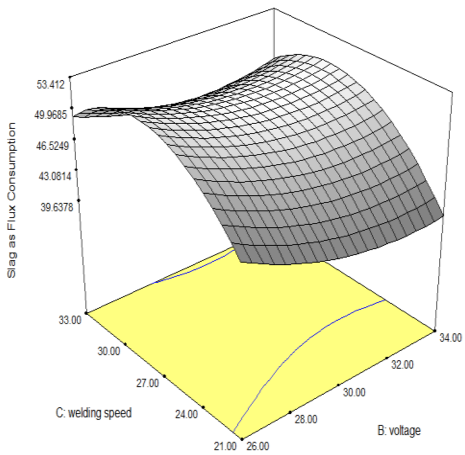
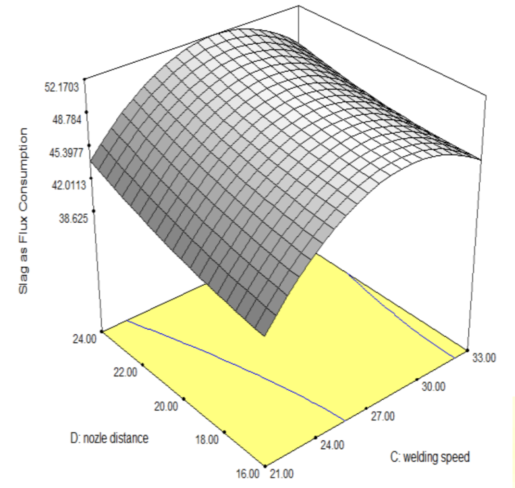


Fig 5.6



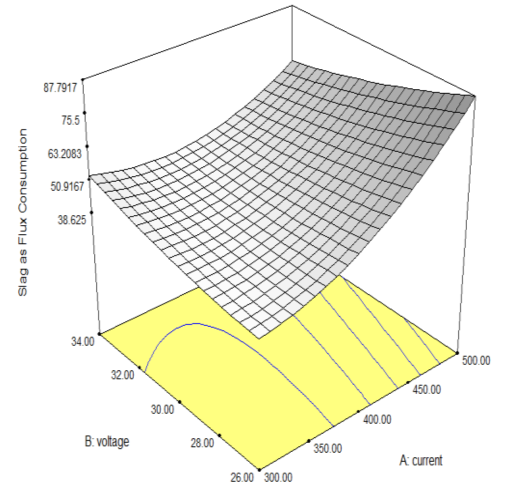


Fig 5.7 **Fig 5.8**

CONCLUSIONS :-

On the basis of present study the following conclusions can be drawn:

1. RSM can be used effectively in analyzing the cause and the effect of process parameters on response. The RSM is also used to draw contour graphs for various responses to show the interaction effects of different process parameters.
2. Arc Stability & slag detachability were acceptable and SAW slag can be reused as welding flux after crushing & sieving and mixing with pure flux .
3. Flux consumption increased with the increase in open circuit voltage and very small increases with increases in current , Welding speed has negative effect on flux consumption.
4. Flux consumption also small decreases with the increase in nozzle to plate distance.

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