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ENRICHMENT OF FLUX BY NICKEL TO IMPROVE TENSILE STRENGTH AND HARDNESS IN SUBMERGED ARC WELDING

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ABSTRACT

The world is changing toward a market for productivity benefits highly dependent on technology, which will drive automation in the future. Submerged Arc Welding (SAW) is one of the automatic processes employed in industries. Due to this reason large demand of Submerged Arc Welding equipment and consumables will increase in future. The current work is an effort to study the effect of Nickel metal powder addition in flux, on the tensile strength and micohardness, of IS 2062 steel during submerged arc welding. The effect of Nickel metal powder addition on fluxes by keeping the welding parameters like welding voltage and welding speed constant has been evaluated. Taguchi technique has been used for the design of experiments. The effects of flux, voltage and travel speed have been evaluated on the tensile strength and microhardness. The effect of all the input parameters on the output responses have been analyzed using the analysis of variance (ANOVA).

KEYWORDS: SAW, tensile strength, microhardness, Taguchi technique, ANOVA, S/N ratio.

INTRODUCTION

Submerged arc welding is one of the non pressure electric arc welding process. It requires a continuously fed consumable solid electrode. The molten weld and the arc zone are protected from atmosphere under a blanket of granular flux. The flux exercises a shielding function. When flux becomes molten, it provides more active current path between the electrode and the work. The flux is supplied through a funnel located in front of the filler wire. A continuous electrode is being fed into the joint by automatically powered drive rolls. Electrical current, which produces the arc, is supplied electrode to the electrode through the contact tube. The current can be direct current with electrode positive (reverse polarity), with negative (straight polarity), or alternating current. After welding is completed the weld metal has solidified, the un-fused flux and slag are removed. The solidified slag may be collected, crushed, resized, and blended back into new flux. Generally submerged arc welding are operated in automatic and semi-automatic mode.

After literature study we find that very few efforts have been made to understand mechanical properties using Taguchi Technique and Very little work is made to improve the weld joint strength in single pass. In this experiment we added nickel metal powder in 10 % and 20 % concentration in AUTOMELT B31 flux and investigate its effect on tensile Strength and microhardness. The optimization of result has been done by Taguchi's Philosophy.

EXPERIMENTAL DESIGN

The purpose was to estimate the effect of various process parameters on the tensile strength and microhardness in submerged arc welding. The control factor was selected on the basis of a pilot experiment by varying one factor at a time. Based on the pilot study, voltage, travel speed, and type of flux (with and without nickel powder addition in AUTOMELT B31 flux) were identified as the control factors. The current and electrical stick-out was kept constant during the study.

Voltage: - During the pilot experimentation it was observed that increasing the arc voltage may lead to lack of fusion in the root as the wide arc will not reach the bottom of the root. Reducing the voltage, in this case, will increase the depth of penetration as the narrow arc column is more easily able to reach the bottom of the preparation. An increase

in arc voltage the bead width also increases and reinforcement decrease. Based on the pilot experiment results, the voltage was also set at three levels namely (a) 26 Volt, (b) 30 Volt, and (c) 34 Volt.
Travel speed: - Variations in travel speed at a set current and voltage also affect bead shape. As welding speed is decreased, heat input per length of joint increases, and the penetration and bead width increase. The penetration will increase until molten metal begins to flow under the arc and interfere with heat flow at excessively slow speeds. Based on the pilot experiment results the travel speed was set at 10, 12, and 14 m/h.
Type of flux: - Three types of flux were used for the experimentation. Where 1st flux is (AUTOMELT B31), 2nd flux is (10 % Nickel powder addition in AUTOMELT B31) and 3rd flux is (20 % Nickel powder addition in AUTOMELT B31). The percentage compositions of AUTOMELT B31 flux are given in Table 1. Various levels for the input process parameters, thus selected for experimentation during the study, are given in Table 2.

Table 1 Percentage composition of the AUTOMELT B31 flux

Flux	SiO_2+TiO_2	CaO+MgO	Al_2O_3+MnO	CaF_2
1.	15	20	30	35

Experimental set-up and procedure: - The experiments were conducted on a submerged arc welding machine (Make: ADOR Frontech Ltd, Model: Tornado SAW M-800) and FD 10-200T welding tractor.
The work material used for present study is IS 2062, the dimensions of each piece is 260×130×10mm. We have 18 plates of this dimension for 9 experiments. Work material IS 2062 (composition by weight: 0.1624% C, 0.9917% Mn, 0.1095% Si, 0.01426% P, 0.00752% S, balance Fe) and wire electrode EH-14 (composition by weight 0.14% C, 1.20% Mn, 0.10% Si, 0.002% Ti, 0.007% Nb, 0.002% V, 0.03% S, 0.02% P, balance Fe) were used during the experiment.

Table 2 Factors studied with their levels

Factors (unit)	Notation	Levels		
		Level 1	Level 2	Level 3
Voltage (Volt)	A	26	30	34
Travel speed	B	10	12	14
Type of flux	C	AUTOMELT B31flux	10 % Nickel powder addition in AUTOMELT B31 flux	20 % Nickel powder addition in AUTOMELT B31 flux

An orthogonal array provides a set of well balanced (minimum experimental runs) experiments and Taguchi's signal-to-noise ratios, which is logarithmic functions of desired output; serve as objective functions for optimization. This helps in data analysis and prediction of optimum results. The S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The ratio depends on the quality characteristics of the product/process to be optimized. This helps in data analysis and prediction of optimum results.
An orthogonal array provides a set of well balanced (minimum experimental runs) experiments. In this experimental study, three factors are varied to three levels each. So the Orthogonal Array which could be used is L_9 and L_{27}. But L_{27} could not be used due to its repetition of input factor levels. So, to overcome this problem L_9 is used.

Table 3 L_9 design table with trial conditions

Tria No.	Voltage (Volt)	Travel speed (m/h)	Flux
1	26	10	1
2	26	12	2
3	26	14	3

4	30	10	2
5	30	12	3
6	30	14	1
7	34	10	3
8	34	12	1
9	34	14	2

The S/N ratio developed by Dr. Taguchi is a performance measure to select control levels that best cope with noise. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The ratio depends on the quality characteristics of the product/process to be optimized. The standard S/N ratios generally used are as follows: nominal-is-best (NB), lower-the-better (LB), and higher-the-better (HB). (S Datta, A Bandyopadhyay and P.K. Pal (2007)) The S/N ratio for LB, NB and HB can be calculated by:

- Larger is better:

$$\left(S/N\right)_{HB} = -10\log\left(MSD_{HB}\right) \quad \text{Where} \quad MSD_{HB} = \frac{1}{R}\sum_{j=1}^{R}\left(1/y_j^2\right)$$

- Nominal is best:

$$\left(S/N\right)_{NB} = 10\log 10\ \left(MSD_{NB}\right) \quad \text{Where} \quad MSD_{NB} = \frac{1}{R}\sum_{j=1}^{R}\left(y_j - y_o\right)^2$$

- Lower is better:

$$\left(S/N\right)_{LB} = -10\log\left(MSD_{LB}\right) \quad \text{Where} \quad MSD_{LB} = \frac{1}{R}\sum_{j=1}^{R}\left(y_j^2\right)$$

TENSILE TEST AND ITS RESULT

The testing would be carried on computerized Universal Testing Machine (UTM).Table.4 shows the result of Tensile strength and its mean.

Table 4 Results for Tensile strength

Trial No.	Voltage	Travel Speed	Flux	Tensile strength	Mean
1	26	10	1	471	471
2	26	12	2	490	490
3	26	14	3	501	501
4	30	10	2	528	528
5	30	12	3	540	540
6	30	14	1	475	475
7	34	10	3	580	580
8	34	12	1	547	547
9	34	14	2	532	532

In case of single reading mean is calculated. ANOVA has been performed in the statistical software package MINITAB 15. The analysis of variance is carried out at 95% confidence level. The main purpose of analysis of variance is to investigate the influence of the design parameters on Tensile strength by indicating that which parameters is significantly affected the quality characteristics. In our experimentation work, we have generated results for Mean of Tensile Strength.

Table 5 Analysis of variance for mean of Tensile strength

Source	D.O.F	Seq SS	Adj SS	Adj MS	F	P	% age contribution
Voltage	**2**	**6536.2**	**6536.2**	**3268.1**	**28.64**	**0.034**	**61.69**
Travel Speed	2	1089.6	1089.6	544.8	4.77	0.173	10.28
Flux	2	2741.6	2741.6	1370.8	12.01	0.077	25.87
Residual Error	2	228.2	228.2	114.1			2.2
Total	8	10595.6					

Response table for means of Tensile strength is shown in Table 6. The response tables show the average of each response characteristic for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects.

Table 6 Response table for means of Tensile strength

Level	Voltage	Travel Speed	Flux
1	487.3	**526.3**	497.7
2	514.3	525.7	516.7
3	**553.0**	505.7	**540.3**
Delta	65.7	23.7	42.7
Rank	1	3	2

The response table shows the average of each response characteristic for each level of each factor. The delta is the difference between highest and the lowest average for each factor. Minitab 15 assigns ranks based on delta values, rank 1 to the highest delta value, rank 2 to the second highest and so on.

Table 7 Optimum combinations of parameters

Voltage	Travel speed	Flux
Level 3	Level 1	Level 3
34V	10 m\hr	3

So these are optimum welding parameters on which we have attain the higher tensile strength of IS 2062 mild steel welds. Main Effect Plot for Tensile Test also generated by this software is shown in Fig. 1

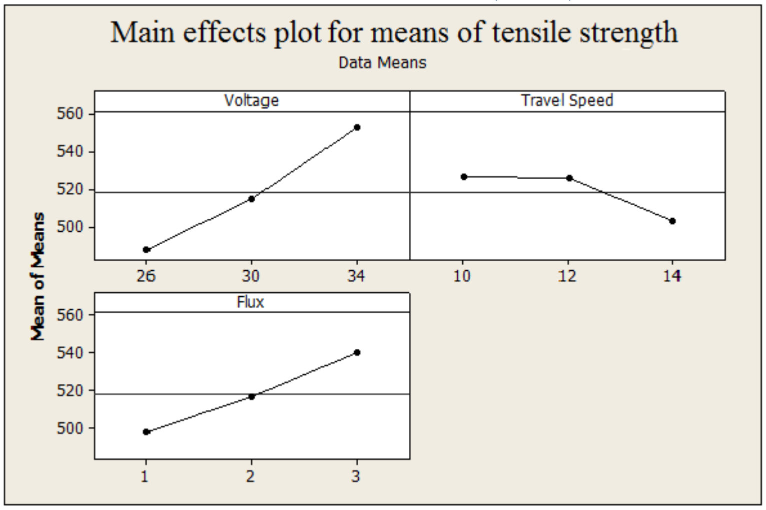

Fig. 1 Main Effect Plot for means

So, on the basis of main effect plot we can say that Tensile Strength of mild steel of grade IS 2062 will be the Maximum when we using voltage 34 V, travel speed 10 m\h and flux 3. So these are optimum welding parameters on which we can attain the higher tensile strength of IS 2062 mild steel welds.

HARDNESS TEST AND ITS RESULT

The testing would be carried on computerized Vickers Hardness test machine. Table 8 shows the result of hardness.

Table 8 Results for Hardness

Trial No.	Voltage (v)	Travel Speed (m/h)	Fux	On base Metal (hvn)	On Welding (hvn)	On HAZ (hvn)	Mean (hvn)	S/N ratio
1	26	10	1	166	204	192	187.33	45.3538
2	26	12	2	168	233	158	186.33	45.0442
3	26	14	3	167	246	194	202.33	45.7976
4	30	10	2	168	259	205	210.66	46.0711
5	30	12	3	165	291	199	218.33	46.0911
6	30	14	1	169	211	172	184.00	45.1676
7	34	10	3	165	299	235	233.00	46.5742
8	34	12	1	166	255	183	201.33	45.6581
9	34	14	2	167	241	184	197.33	45.6009

ANOVA for S/N ratios of Hardness: - Table 9 shows the result of Analysis of variance for S/N ratios of Hardness.

Table 9 Analysis of variance for S/N ratios of Hardness

Source	D.O.F	Seq SS	Adj SS	Adj MS	F	P	%age contribution
Voltage	2	0.46902	0.46902	0.23451	4.98	0.167	24.57
Travel Speed	2	0.39541	0.39541	0.19771	4.20	0.192	20.71
Flux	2	0.95034	0.95034	0.47517	10.09	0.090	49.78

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Residual Error	2	0.09418	0.09418	0.04709			4.93
Total	8	1.90895					

Response table for S/N ratios of Hardness is shown in Table 10. The response tables show the average of each response characteristic for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects.

Table 10 Response table for S/N ratios of Hardness

Level	Voltage	Travel Speed	Flux
1	45.40	**46.00**	45.39
2	45.78	45.60	45.57
3	**45.94**	45.52	**46.15**
Delta	0.55	0.48	0.76
Rank	2	3	1

Main Effect Plot for S/N ratios of Hardness also generated by this software is shown in Fig. 2.

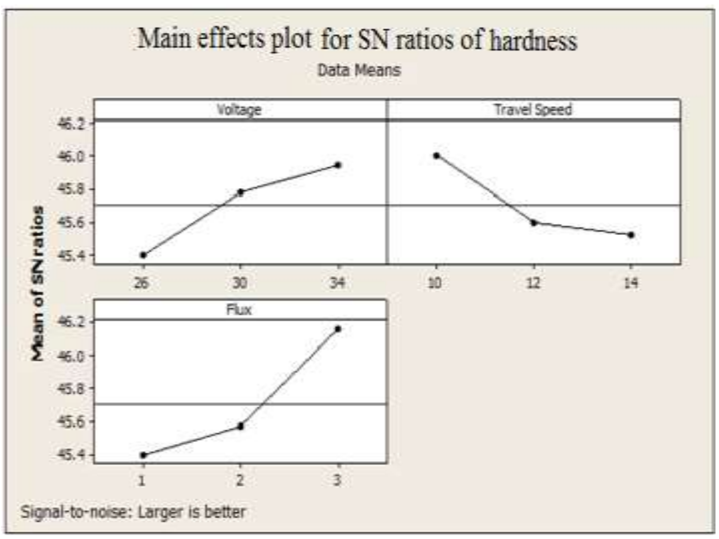

Fig. 2 Main Effect Plot for S/N ratios of Hardness

ANOVA for mean of Hardness: - Table 11 shows the result of Analysis of variance for S/N ratios of Hardness.

Table 11 Analysis of variance for mean of Hardness

Source	D.O.F	Seq SS	Adj SS	Adj MS	F	P	%Age contribution
Voltage	**2**	**535.14**	**535.14**	**267.57**	**19.30**	**0.049**	**25.37**
Travel Speed	2	373.80	373.80	186.90	13.48	0.069	17.72
Flux	**2**	**1172.32**	**1172.32**	**586.16**	**42.28**	**0.023**	**55.59**
Residual Error	2	27.73	27.73	13.86			1.31
Total	8	2108.99					

Response table for mean of Hardness is shown in Table 12. The response tables show the average of each response characteristic for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects.

Table 12 Response table for mean of Hardness

Level	Voltage	Travel Speed	Flux
1	192.0	**210.3**	190.9
2	204.3	202	198.1
3	**210.6**	194.6	**217.9**
Delta	18.6	15.8	27
Rank	2	3	1

The optimum combinations of parameters is shown in Table 13

Table 13 Optimum combinations of parameters

Voltage	Travel speed	Flux
Level 3	Level 1	Level 3
34 V	10 m\h	3

Main Effect Plot for mean of Hardness also generated by this software is shown in Fig. 3.

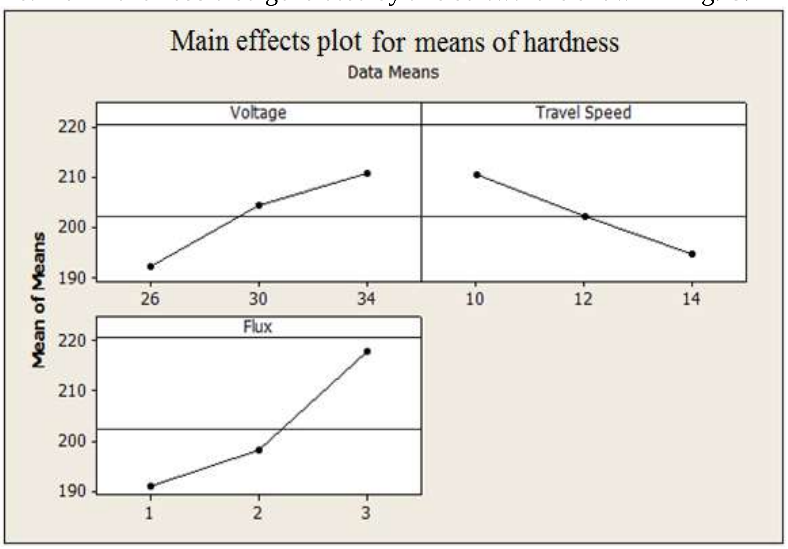

Fig. 3 Main Effect Plot for mean of Hardness

DISCUSSIONS ON TENSILE STRENGTH

Voltage has significant effect on the tensile strength with contribution of 61.69 %, whereas travel speed and flux have insignificant effected the tensile strength with contribution of 10.28 % and 25.87 %. Tensile strength is maximum when voltage 34 V, travel speed 10 m\hr and flux 3.

DISCUSSIONS ON HARDNESS

Flux and voltage have significant effect on the hardness with contribution of 55.59 % and 25.37%, whereas travel speed has insignificantly effected with contribution of 17.72 %. Hardness of mild steel of grade IS 2062 will be the maximum when we using voltage 34 V, travel speed 10 m\hr and flux 3.

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