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Investigation on Effect of Welding Hardness of Shielded Metal Arc Welding

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***Abstract*- The aim of this paper is to study the effect of welding polarity of the shielded metal arc welding process on hardness of welding IS2062 mild steel plate. The results show that the experimental investigation of Shielded metal Arc Welding process (SMAW) parameters in welding current, welding speed, wind velocity, wind direction with multi-response criteria using Design Expert software.The Input process parameters such as welding current, welding speed, wind velocity, wind direction are selected using Design Expert software to obtain the desired output. The Analysis of Variance (ANOVA) is also applied to identify the most significant factor.**

***Index Terms*- welding current, welding speed, wind velocity, wind direction, Design of Experiment, Multi-Response criteria, Response Surface and Central Composite Design, ANOVA.**

Nomenclature:

Description	**Unit**	**Identification**
Welding Current	Amps	I
Welding Speed	mm/s	S
Wind Velocity	m/s	V
Wind Direction	Degree	D

I. INTRODUCTION

Welding is commonly used in industries fabrication and to repair damaged structures such as pipelines, heat exchangers and pressure vessels. In Shielded Metal Arc Welding(SMAW) process, the heat for welding is generated by an arc established between a flux-covered consumables electrode and the work piece. The filler metal is deposited from the electrode and uses the decomposition of the flux covering to generate a shielding gas and to provide fluxing elements to protect the molten weld metal.

In this project the mild steel materials used as a base metal. The mild steel plates with 25 numbers are welded here. The dimension is Thickness 6 mm x Width 50 mm x Length 100 mm. The chemical composition of base metal plate IS2062 and the welding consumable used for SMAW is E7018,size of the electrode is 4 mm are shown in table-1.The Design of experiments(DOEs) and statistical techniques are widely used to optimize process parameters. In this investigation an attempt is made to develop an empirical relationship to predict hardness of shielded metal arc welding process joints using statistical tools such as design of experiments, and analysis of variance.

Table -1 Chemical composition of base material and consumable.

MATERIAL	**C**	**Cu**	**Si**	**S**	**P**	**Mn**	**Fe**
IS 2062	0.20	0.350	0.100	0.055	0.055	-	Bal.
E7018	0.04-0.09	-	0.80-1.60	0.030	0.030	0.80-1.60	Bal.

II. METHODOLGY

1.Identifying the important parameters
2. Finding the working limits
3.Developing the process control parameters
4. Conducting the experimental as per the design matrix
5. Recording the result
6. Analysis of variance

Identifying the important parameters

Welding current: 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.Too high a current causes excessive 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.

Welding speed: The combination of welding current and voltage, increase in the welding speed or the speed of arc travel results in lesser penetration, lesser weld reinforcement and lower heat input per unit length of weld.

Wind velocity: wind flow velocity is a fundamental atmospheric rate. Wind speed is caused by air moving from high pressure to low pressure, usually due to changes in temperature

Wind direction: Wind direction is the direction from which the wind is blowing; the direction from which the air is moving. It is not the direction the wind is blowing toward.

Finding the working limits of the parameter

Heat input is a relative measure of the energy transferred per length(unit) of weld.The working range is decided based on inspecting the bead for smooth appearance and the absence of any visible defects. The upper limit of value is coded as +2 and the lower limit is -2 the coded values are calculated from the following relationship.

Table -2.Process control parameters and levels

S.No	Parameter	Notation	Unit	Levels				
				-2	-1	0	1	2
1	Welding current	I	Amps	140	160	180	200	220
2	Welding Speed	S	mm/sec	9	12	15	18	21
3	Wind velocity	V	m/sec	1	3	5	7	9
4	Wind direction	D	Degree	0	90	180	270	360

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

Where Xi is the required coded value of a variable X.When X is any of the variable from Xmin to Xmax.Xmin is the lowest level of the variable.Xmax is the highest level of the variable.The selected process parameters,limits,notations and the units are given in table 2.

Developing the experimental design matrix

It is decided to use of factors, levels central composite design matrix to optimize the experimental conditions.Table -3 shows the 30 sets of coded condition used from the design matrix.All welding variables at the intermediate(0) level constitute the center points while the combination of each welding variables at either their lowest(-2) or highest(+2) with the other three variables of the intermediate levels constitute the star points.Thus the 30 experimental conditions allowed the estimation of the linear,quadratic,cubic and two-way interactive effects of the welding variables on weld weld bead geometry of the SMAW.For the convenience of recording and processing experimental data,upper and lower levels of the factors have been coded as+2 and -2 respectively.

Conducting the experiments as per the design matrix

The experiments are conducted according to the design matrix at random to avoid systematic errors creeping in to the system.As per the DOE ,30 beads on plate weldments are made.The welding carried out using electric welding machine and welding plates are shown in Figure-1 and Figure-2

Fig.1. Electric welding machine.

Fig.2. Welding plates.

Measurement methods

Metallographic etching is a technique used to highlight features of metals at microscopic levels. To create the contrast between the elements of the metal's microstructure, chemical solutions known as etchants are used to selectively corrode some of those elements, which show up as darker regions. This is possible because differences in the composition, structure or phase of metal will create electrochemical potentials that alter the relative rates of corrosion when exposed to an etchant. These specimens are prepared by the usual metallurgical polishing methods and etched with 5% nital.The structure measured by optical microscope shown in Figure-3.

Fig.3. Optical Microscope

The different phase of microstructures correspond to different mechanical properties and if the microstructural changes in the Hear Affected Zone(HAZ)are not controlled as a result of improper selection of welding variables, undesirable metallurgical structures may be produced, consequence of which may lead to loss of weld joint quality and eventual failure of material in service.Therefore, selecting suitable process is a primary means by which acceptable HAZ properties can be achieved. A number of studies have been carried out on microstructural and mechanical behavior of welded Carbon steel, particularly in the weld joints, while onlylimited information on microstructural and mechanical behavior in the HAZ is available. This is in spite of the criticality of HAZ to service performance of welded structures, and if the reliability of large scale structures under varied loading conditions is ensured, fundamental understanding of the effects of welding variables on HAZ micro structural and mechanical properties is required. Therefore, effort was made in this work to study the effects of welding speed and power input at different ranges on the microstructures are shown in Figure-4,5,6 and hardness property in the HAZ of IS 2062 mild steel

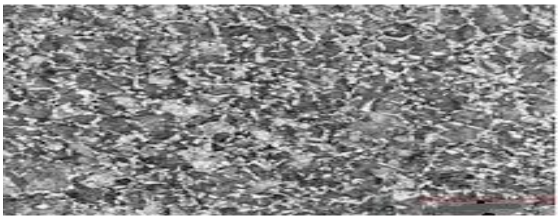


Fig.4. A Structure consists of columnar grains with carbide

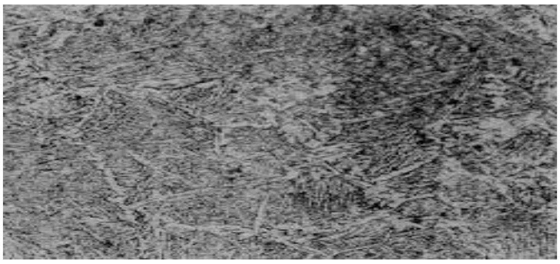


Fig.5. A Structure consists of Tempered Bainite

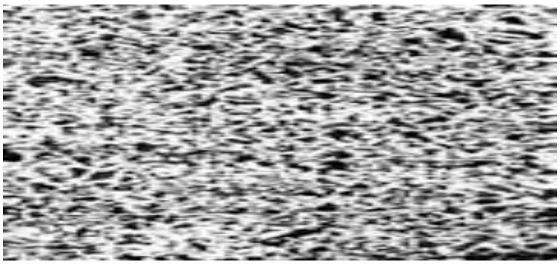


Fig.6. A Structure consists of Banded polygonal grains of Ferrite and and pearlite

Recording the responses

Fig.7. Rockwell Hardness Machine

The prepared welded plates are cross sectioned at their mid points to obtain test specimens of 10 mm wide Standard approaches and machines were used to measure the hardness property of the Machined surfaces of the (as received and HAZ) samples with dimensions 50mm length, 20 mm breadth and 5 mm thickness were properly ground to give it flat and stable surface using a hand grinder. Thereafter, hardness measurement was made using Digital Rockwell hardness shown in Figure-7.The tester with 0.4064m indenter and 0.6N indenting load with a dwell time of 10s. The hardness measurement was taken in three different locations and the average values were 3 considered

Table-3 Design matrix and experimental results

Expt. No	Coded values				Original values				Hardness value in HRB
	I	S	V	D	I	S	V	D	
1	-1	-1	-1	-1	160	12	3	90	79.0
2	1	-1	-1	-1	200	12	3	90	81.5
3	-1	1	-1	-1	160	18	3	90	86.0
4	1	1	-1	-1	200	18	3	90	71.0
5	-1	-1	1	-1	160	12	7	90	85.0
6	1	-1	1	-1	200	12	7	90	92.0
7	-1	1	1	-1	160	18	7	90	86.0
8	1	1	1	-1	200	18	7	90	74.0
9	-1	-1	-1	1	200	12	3	270	83.0
10	1	-1	-1	1	200	12	3	270	74.0
11	-1	1	-1	1	160	18	3	270	86.0
12	1	1	-1	1	200	18	3	270	76.0
13	-1	-1	1	1	160	12	7	270	88.0
14	1	-1	1	1	200	12	7	270	82.0
15	-1	1	1	1	160	18	7	270	88.0
16	1	1	1	1	200	18	7	270	79.0
17	-2	0	0	0	140	15	5	180	85.0
18	2	0	0	0	220	15	5	180	80.0
19	0	-2	0	0	180	9	5	180	89.0
20	0	2	0	0	180	21	5	180	56.0
21	0	0	-2	0	180	15	1	180	88.0
22	0	0	2	0	180	15	9	180	70.5
23	0	0	0	-2	180	15	5	0	86.0
24	0	0	0	-2	180	15	5	360	84.5

25	0	0	0	0	180	15	5	180	77.0
26	0	0	0	0	180	15	5	180	82.0
27	0	0	0	0	180	15	5	180	93.0
28	0	0	0	0	180	15	5	180	88.0
29	0	0	0	0	180	15	5	180	76.0
30	0	0	0	0	180	15	5	180	92.0

ANALYSIS OF VARIANCE

The experimental results are analyses with analysis of variance (ANOVA), which is used for identifying the factors significance of various factors like welding current in Amps(I),welding speed in mm/s(S), wind velocity in m/s(V) and wind direction in degree(D) analysis of variance(ANOVA) is performed on experimental data.The Tables-4 shows the results of the ANOVA.

ANOVA RESPONSE TABLE

Table-4ANOVAforResponseSurfaceReducedCubicModel
Analysis of variance table [Partial sum of squares - Type III]

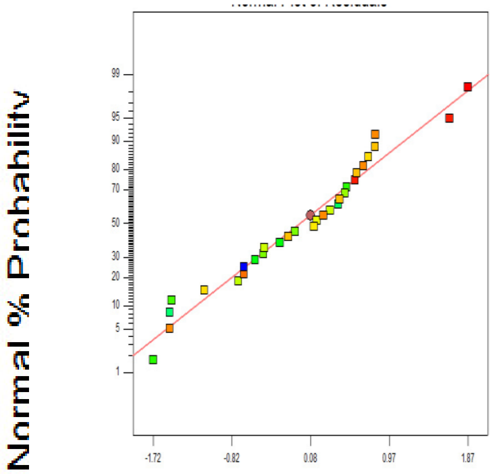
Source	**Sum of squares**	**df**	**Mean square**	**F value**	**p-value prob>F**
Model	1388.50	13	106.81	4.37	0.0033(significant)
A-current	157.59	1	157.59	6.45	0.0219
B-speed	544.50	1	544.50	22.28	0.0002
C-velocity	153.13	1	153.13	6.27	0.0235
D-direction	0.094	1	0.094	3.836E-003	0.9514
A	102.52	1	102.52	4.19	0.0573
AC	8.27	1	8.27	0.34	0.5690
AD	17.02	1	17.02	0.70	0.4163
BD	31.64	1	31.64	1.29	0.2719
A	20.53	1	0.53	0.022	0.8846
B2	197.75	1	197.75	8.09	0.0117
ABD	66.02	1	66.02	2.70	0.1198
A2B2	68.38	1	268.38	10.98	0.0044
A2C2	40.76	1	240.76	9.85	0.0063
Residual	391.04	16	24.44		
Lack of Fit	115.70	11	10.52	0.19	0.9894(notsignificant)
Pure Error	275.33	5	55.07		
Cor Total	1779.54	29			

The Model F-value of 4.37 implies the model is significant. There is only a 0.33% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, C, B2, A2B2, A2C2 are in significant model terms. When Values greater than 0.1000 indicate the model terms are not significant. The normal probability plots graph shown in Figure-8 and the Correlation graph shown in Figure-9.

model reduction may improve your model. The "Lack of Fit F-value" of 0.19 implies

The validity of this regression models developed is further tested by scatterdiagrams. .

Normal plot of Residuals



Externally studentized Residuals

Fig.8. Normal probability plots

Predicited vs Actual

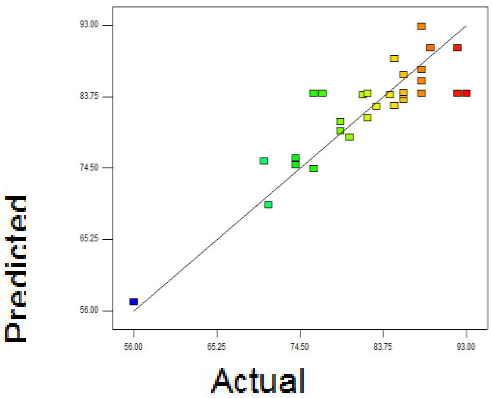


Fig.9. Correlation graph

The Lack of Fit is not significant relative to the pure error. There is a 98.94% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good -we want the model to fit.

Final Equation in Terms of Actual Factors:

HRB=+84.13542*current-2.56250* speed-8.25000*velocity-4.37500*direction-0.062500 * current * speed -2.53125* current*velocity+0.71875*current* direction1.03125*speed*direction+1.40625* current^2-0.13672 * speed^2 -2.63672 * current*speed*direction+2.03125*current^2 *speed+7.09375*current^2*velocity+6.7187

Final Equation in Terms of Coded Factors:

HRB=+84.14-2.56*A-8.25* B-4.38 *C-0.063*D-2.53* A * B +0.72* A * C-1.03 *A* D+1.41*B*D-0.14* A-2.6* B2+2.03* A*B * D+7.09 *A2 * B+6.72* A2 * C

The Diagnostics Case Statistics Report has been moved to the Diagnostics Node.

In the Diagnostics Node, Select Case Statistics from the View Menu.Proceed to Diagnostic Plots (the next icon in progression).Be sure to look at the:

1) Normal probability plot of the studentized residuals to check for normalityofresiduals.
2) Studentized residuals versus predicted values to check for constant error.
3)Externally Studentized Residuals to look for outliers, i.e., influential values.
4)Box-Cox plot for power transformations.If all the model statistics and diagnostic plots are OK, finish up with the Model Graphs icon.

The observed values and predicted values of the responses are scattered close to the 45ºline indicating almost perfect fit of the developed model.

III. CONCLUSION

An empirical relationship is developed to predict the hardness of the shielded metal arc welding using response surface methodology and the Design of Experiment software. The software is used for analysis the output values . The developed model can be effectively used

to predict the weld hardness of shielded metal arc welding confidence level. The welding parameters are welding current(I), Welding speed(S),wind velocity(V),and wind direction(D) have the significant contribution on the response are microstructure and hardness.

1.When the current is decreased ,the HRB rate is also decreased1.When the current is decreased ,the HRB rate is also decreased

2. When the current is increased ,the HRB rate is also increased.

3. When the speed is decreased ,the HRB rate is increased.

4. When the speed is increased ,the HRB rate is decreased.

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