Parametric optimization of submerged arc welding process by using steepest ascent/Decent method

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Abstract : Submerged Arc Welding or SAW is one of the most occurring arc welding process.optimum ranges of bead parameters are required for better economy and to ensure the desired mechanical properties. The above objectives can easily be achieved by development of mathematical model and execution of the experiments by response surface methodology. The method of steepest ascent direction has been widely accepted for process optimization in response surface methodology (RSM).The RSM practitioner needs to decide a suitable stopping rule such that the optimum point estimate in the search direction can be determined.In common practice, it is convenient to use the simple stopping rules after one to three response deteriorations in a row after a series of fitted linear models used for exploration.Four-factor two-level design matrix used for planning, execution and development of mathematical model. For Experiment [SA-516 (Gr-70)] is used as a base metal. From the experimental results, it is found that speed and voltage plays major role in finding weld bead dimensions.This paper develops a procedure for determining how to adjust and then when to stop a steepest ascent search in response surface exploration

***IndexTerms* -** SAW, optimisation, Regression analysis, Response surface methodology,weld bead geometry **.**

Introduction

The submerged arc welding process is often preferred because it offers high production rate, high melting efficiency, ease of automation and low operator skill requirement.[4] the desired welding parameters are obtained based from charts or handbook value which are difficult cumbersome and they does not ensure that chosen welding parameters are optimal for particular welding environmental.[1]Even smaller change in the welding process parameters may causes unexpected welding performance. Therefore, it is important to study stability of welding parameters to achieve high quality welding. [5] Optimum process parameters selection has been investigated by some significant studies via establishing a mathematical model correlating welding parameters with quality characteristics using different approaches [1]In this study, mathematical relations (empirical equations) between submerged arc welding process parameters and weld bead characteristics were constructed based upon the experimental data obtained by four parameters-two levels factorial analysis. The empirical equations, simulating the submerged arc welding process approximately, were carried out by Multiple Regression Analysis and sensitivity equations were derived from these basic models. An analysis generally requires a definition of an objective function and design parameters. In this study, the objective function (quality function) was chosen as weld bead characteristics (the width, height of the weld bead) whereas process parameters (arc current, voltage, welding speed and stick-out) were selected as the design variables. The present study mainly focuses on the determination of sensitivity characteristics of design parameters and the prediction of fine-tuning requirements, of these parameters in submerged arc welding process. The results revealed considerable information about process parameter tendencies and optimum welding conditions appearance and the absence of any visible defects. For deciding the working range, several trial welds were made. For determining the range of one variable, the other three variables were kept constant during trial runs. A similar procedure was adopted for determining the upper and lower limits for the welding speed and nozzle-to-plate distance. Also, trial welds were made, keeping the values of all the parameters both at their minimum and maximum values to were kept constant during trial runs. A similar procedure was adopted for determining the upper and lower limits for the welding speed and nozzle-to-plate distance. Also, trial welds were made, keeping the values of all the parameters both at their minimum and maximum values to verify quality of the weld bead, after determining the working range of the process parameters, the upper limit was coded as +1 and -1

After determining the working range of the process parameters ,the upper limit was coded as +1 and lower limit as -1.The coded value of the intermediate levels were calculated from the relationship[4-9]

Xi=2 x−(Xmax+Xmin)/(Xmax−Xmin) Where Xi the required coded value of a variable X; and X is is any value of the variable from X min to *X* max. .

3.DEVELOPING THE DESIGN MATRIX:

The selected design matrix, shown in Table 2, factorial design [4] consisting of 16 sets of coded conditions. Design matrix is blocked with their result to reduce irrelevant source of variation. Response variables bead width and reinforcement are measured by using scale and venire caliper.The selected process parameters with their limits, units and notations are given.crosssectional picture of weld bead is given below.

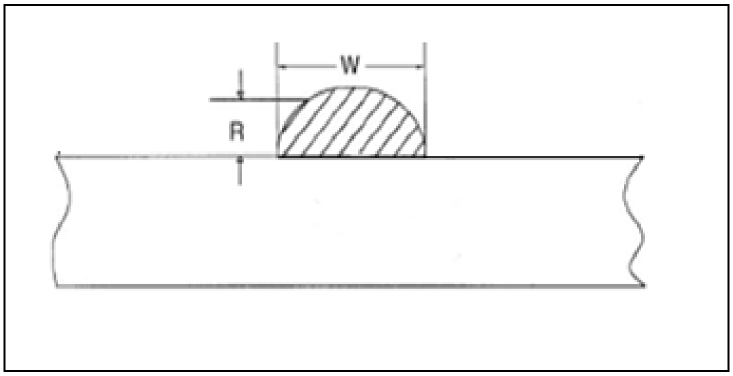

Fig:1Cross-Sectional of weld bead,where W be weld width in mm, R be the Reinforcement in mm.

4.DEVELOPMENT OF MATHEMATICAL MODEL:

The response function representing any of the weld bead dimensions can be expressed as [2-9]

Y=F(S, V, I, N) ………………..eq^n

Where

Y is the response (Bead width, reinforcement)

I is the welding currents, amps

S is the welding speed, Inch/min.

N is the nozzle to plate distance, mm.

The relationship selected being a First degree response surface expressed as follows:

$Y=B_0+B_1X_{1+}B_2X_2+............+B_KX_K+\varepsilon$

5.CHECKING THE ADEQUACY OF THE MODELS DEVELOPED:

The adequacy of the models was tested using the analysis-of-variance technique (ANOVA). As per this technique [2-7]: The estimated coefficients obtained above were used to construct models for the response parameters. The adequacy of the models so developed was then tested by using the analysis of variance technique (ANOVA). Using this technique, it was found that calculated F ratios were larger than the tabulated values at a 95% confidence level; hence, the models are considered to be adequate

The adequacy of a fitted regression model are the coefficient of determination (R'). For the models developed, the calculated R2 and adjusted R2 values were above 80% and 70%, respectively. These values indicate that the regression models are quite adequate the validity of regression models developed were further tested by drawing scatter diagrams. The observed values and predicted values of the responses are scattered close to the 45 ° line, indicating an almost perfect fit of the developed empirical models. To improve the reliability of result, experiments are plan on the basis of response surface methodology (RSM) techniques for statistical design of experiment.

6. EXPERIMENTAL SET UP :

The equipment is conducted on ESAB submerged arc-welding equipment.EH-14, 2. 4mm diameters of welding rods are used. SA-516 Gr-70 steel plates of 500mm× 150mm×12mm size are selected as a working material and bead on joint with single V butt joint with 0.5–1mm root gap is consider. Flux: ADOR make F7P2 granular type is used.

Fig:2 ESAB Submerged Arc Welding Machine

7.Response Surface Methodology:

RSM is sequential procedure often when we are at a point on the response surface that is remote from the optimum; our object here is to lead the experimenter rapidly and efficiently along a path of improvement towards the general vicinity of the optimum. Once the region of the optimum has been found a more elaborate model such as second-order model may be employed& an analysis may be performed to locate optimum. The eventual object of RSM is to determine the optimum operating conditions for the system or to determine a region of the factor space in which operating requirements are satisfied.chemical composition of workpiece is given below.

Table 1

Chemical composition of work piece (SA-516 Gr: 70)

Carbon	Manganese	Phosphorus max4	Sulfur max4	Silicon
0.27	0.79-1.30	0.035	0.035	0.13-0.45

Process parameters and their limits are given below.

Table: 2.

Process control parameters and their limits

Variables	Natural Value		Coded Value	
Speed	20	24	-1	+1
Voltage	32	40	-1	+1
Current	300	360	-1	+1
Distance	22	25	-1	+1

Coded design matrix of weldments are given below.

Table: 3.

Coded design matrix of weldments

Weld	Block I						Weld	Block II					
conditions	Sp	Vot	Cu	Dis	Rein	Width	Cindition	Sp	Vot	Cu	Dis	Rein	Width
1	-1	-1	-1	-1	1.5	20.02	2	1	-1	-1	-1	1.3	17.66
4	1	1	-1	-1	1.0	18.42	5	-1	-1	1	-1	1.6	20
6	1	-1	1	-1	2.4	18.1	8	1	1	1	-1	1.8	19
7	-1	1	1	-1	1.4	18.6	9	-1	-1	-1	1	1.2	19.26
10	1	-1	-1	1	1.9	18.14	11	-1	1	-1	-1	2.1	18.54
11	-1	1	-1	1	2.1	18.20	12	1	1	-1	1	1.4	18.08
13	-1	-1	1	1	2.0	17.60	14	1	-1	1	1	2	18.06
16	1	1	1	1	1.9	19.20	15	-1	1	1	1	2.2	18.60

7.1Regression Analysis [With blocking]

The regression equation for Block-I is

Reinforcement$_2$ = 1.78-0.0250sp2-0.150 vol2+0.200cu2+0.325dis2

Table 5.3

Significance table

Predictor	Coef	SE coef	T	P
Constant	1.77500	0.04330	40.99	0.000
Sp2	-0.02500	0.04330	-0.58	0.604
Vol2	-0.1500	0.04330	-3.46	0.041
Cu2	0.20000	0.04330	4.62	0.019
Distance2	0.32500	0.04330	7.51	0.005

S=0.122474 R-Sq=96.8% R-SQ(adj)=92.5%

Then the regression equation for Block-II is

$Reinforcement_3$=1.70-0.225sp3-0.100vol3+0.100cu3+0.225dis3

Table 5.4

Significance table

Predictor	Coef	SE Coef	T	P
Constant	1.70000	0.04564	37.25	0.000
Sp3	-0.22500	0.04564	-4.93	0.016
Vol3	-0.10000	0.04564	-2.19	0.116
Cu3	0.10000	0.04564	2.19	0.116
Dist3	0.22500	0.04564	4.93	0.016

S=0.129099 R2=95.1% R-SQ(adj)=88.6%

By comparing First block and second block it is seen that Voltage, Current, distance is significant and its R-Sq=96.8% R-SQ(adj)=92.5%,whereas in block-II Speed and distance is significant whereas its R2=95.1% R-SQ(adj)=88.6% so comparing Block I and Block-II, Block-I gives better results so further result analysis is done with Block-I

7.2 Result analysis of Reinforcement using steepest ascent/Decent method.

The regression equation becomes.

Regression Eqn= 1.78-0.150voltage+0.2 current+0.325 distance.

In this equation Speed is not considered because its p value is 0.604 which is greater than 0.05 so its effect is not considered.

Slop A=1

Slop B =-0.2/-0.150=-1.3

Slop C=0.325/-0.150=-2.1

Table 5.5

Process data for fitting first order model.

	Natural Value		Coded Value	
Speed	20	24	-1	+1
Voltage	32	40	-1	+1
Current	300	360	-1	+1
Distance	22	25	-1	+1

$X1$= (€−$Mean$) /a………eq^{n}2

-1= $(20-22)/a$

a=2

In the Same manner calculate the value a forX1,X2, X3.

so by putting further value of X1,X2,X3,.Calculate respective €1,€2,€3 which is as Follows

For example

$X1$= (€−$Mean$)/a

-1= $(20-22)/a$

1= (€−36)/4

€=35.6 which is €1

Table:5.6

Steepest Ascent experimental readings

Steps		Coded Value			Natural Value		
	X1	X2	X3	€1	€2	€3	Y
Origin	0	0	0	36	330	23.5	
Δ	1	-1.3	-2.16	4	30	1.5	
Origin-0.1Δ	-0.1	0.13	2.16	35.6	327	23.35	1.89
Origin-0.2Δ	-0.2	0.27	0.43	35.2	324	23.2	2.00
Origin-0.3Δ	-0.3	0.40	0.65	34.8	321	23.05	2.12
Origin-0.4Δ	-0.4	0.53	0.86	34.4	318	22.09	2.23
Origin-0.5Δ	-0.5	0.67	1.08	34	315	22.75	2.34
Origin-0.6Δ	-0.6	0.80	1.30	33.6	312	22.6	2.45
Origin-0.7Δ	-0.7	0.93	1.51	33.2	309	22.45	2.56
Origin-0.8Δ	-0.8	1.06	1.73	33.8	306	22.3	2.67
Origin-0.9Δ	-0.9	1.20	1.94	32.4	303	22.15	2.79
Origin-1Δ	-1	1.33	2.16	32	300	22	2.90

Table 5.7

Analysis data by using steepest assent method.

Steps	**Coded Value**			**Natural Value**			
	X1	X2	X3	€1	€2	€3	Y
Origin	-0.4	0.52	0.864	34.4	345.06	24.79	
Δ	1	-1.3	-2.16	4	30	1.5	
Origin-0.01Δ	-0.41	0.55	0.89	34.36	317.7	23.49	2.24
Origin-0.02Δ	-0.42	0.56	0.91	34.32	317.4	23.47	2.25

Optimization Value

Conducting Experiments with optimality loss the optimize value becomes

Table 5.8

Optimization Value

Voltage	Current	Distance	Reinforcement
34	300	23.5	2.3

Manual calculation by using steepest ascent/Decent method, for width, then the regression equation becomes

Width =18.5-0.445Speed+0.425Voltage

Slop A=1

Slop B=0.425/-0.445=-0.96

Table:5.9

Steepest Ascent experimental readings

Steps	Coded Value		Natural Value		
	X1	X2	€1	€2	Y
Origin	0	0	22	36	
Δ	1	-0.96	0.02	0.04	18.5
Origin+0.1Δ	0.1	-0.10	22.2	36.4	18.41
Origin+0.2Δ	0.2	-0.19	22.4	36.8	18.33
Origin+0.3Δ	0.3	-0.29	22.6	37.2	18.24
Origin+0.4Δ	0.4	-0.38	22.8	37.6	18.16
Origin+0.5Δ	0.5	-0.48	23	38	18.07
Origin+0.6Δ	0.6	-0.58	23.2	38.4	17.99
Origin+0.7Δ	0.7	-0.67	23.4	38.8	17.90
Origin+0.8Δ	0.8	-0.77	23.6	39.2	17.82
Origin+0.9Δ	0.9	-0.86	23.8	39.6	17.73
Origin+1Δ	1.0	-0.96	24	40	17.65

Table:5.10

Analysis of data using steepest assent method.

Steps	Coded Value		Natural Value		
	X1	X2	€1	€2	Y
Origin	0	0	22	36	
Δ	0.5	-0.48	23	34.08	
Origin+0.01Δ	0.51	-0.96	23.02	34.04	18.06
Origin+0.02Δ	0.52	-0.19	23.04	34.00	18.06
Origin+0.03Δ	0.53	-0.29	23.06	33.96	18.05
Origin+0.04Δ	0.54	-0.38	23.08	33.93	08.04
Origin+0.05Δ	0.55	-0.48	23.1	33.89	18.03
Origin+0.06Δ	0.56	-0.58	23.12	33.85	18.02
Origin+0.07Δ	0.57	-0.68	23.14	33.81	18.01
Origin+0.08Δ	0.58	-0.76	23.16	33.77	18.01
Origin+0.09Δ	0.59	-0.86	23.18	33.72	18.00
Origin+0.10Δ	0.6	-0.58	23.2	33.68	17.99

Optimization Value

By conducting Experiments with optimality loss the optimise value becomes

Table 5.11

Optimization Value

Voltage	Current	Width
23	34	18

Results: Mathematical model is used to predict the weld bead geometry by substituting the values in the coded form of the respective factors. also by substituting the values of the desired bead geometry, the value of the control factor in coded form can be obtained. In general the result show convincing trends between cause & the effect.

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