American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-09
Volume-02, Issue-05, pp-178-187
www.ajer.us

Research Paper Open Access

Optimization of weld bead geometry for stainless steel cladding deposited by GMAW.

P, Sreeraj[1], T, Kannan[2], Subhasis Maji[3]
[1]Department of Mechanical Engineering, Valia Koonambaikulathamma College of Engineering and Technology, Kerala, 692574 India.
[2]Principal, SVS College of Engineering, Coimbatore, Tamilnadu, 642109 India.
[3]Professor, Department of Mechanical Engineering IGNOU, Delhi, 110068, India.

Abstract: The cladded components quality always depends on clad bead geometry and coefficient of shape of welds and dilution. In order to obtain better quality, good corrosion resistant properties and to reduce manufacturing costs the bead parameters must be optimized. The above objectives can be achieved by developing mathematical equations to predict bead geometry. This paper presents central composite rotatable design with full replication technique was used to obtain four critical dimensions of bead geometry. The developed models have been checked for adequacy and significance. The experiments were conducted by depositing Type ER-308L stainless steel wire on to IS-2062 structural steel plates. The results of confirmation experiments showed that the developed models can be able to predict bead geometry with reasonable accuracy. This study proved that both direct and interaction effect plays a major role in determining bead dimensions and dilution. The process parameters were optimized using response surface methodology (RSM).

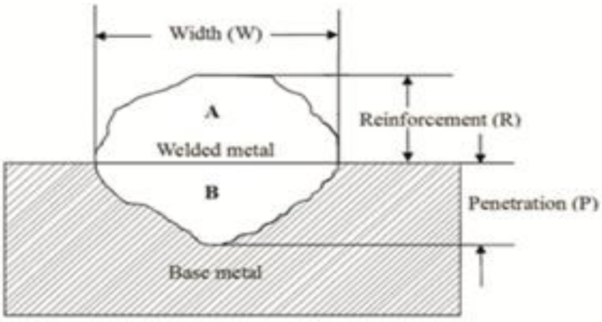
Keywords: *GMAW, Weld bead geometry, RSM, Mathematical equations, stainless steel.*

I. INTRODUCTION

Cladding is a process of depositing a thick layer of filler material on a low carbon steel base metal/Weld cladding finds application in repairing worn out parts for achieving good corrosion resistant surface. Usually gas metal arc welding (GMAW) has been widely used in manufacturing industries, for cladding because of its high productivity, easiness of operation and adaptability to automation. The process parameters of GMAW process must be studied in order to enhance its chance for automation and to get good quality weld. The quality of a weld depends on mechanical properties of the weld metal which in turn depends on metallurgical characteristics and chemical composition of the weld [1]. The mechanical and metallurgical feature of weld depends on bead geometry which is directly related to welding process parameters. In other words quality of weld depends on in process parameters.GMA welding is a multi objective and multifactor metal fabrication technique. The process parameters have a direct influence on bead geometry.

Fig 1 shows the clad bead geometry. Mechanical strength of clad metal is highly influenced by the composition of metal but also by clad bead shape [2]. This is an indication of bead geometry. It mainly depends on wire feed rate, welding speed, arc voltage etc. Therefore it is necessary to study the relationship between in process parameters and bead parameters to study clad bead geometry.

This study was carried out in two steps. In the first step regression models for dilution, coefficient of internal shape and coefficient of external shape were developed from the experimental data [3]. In the second stage the process parameters were optimized using response surface methodology (RSM) optimization technique to get the desired weld bead geometry.



Percentage dilution (D) = [B/ (A+B)] X 100

Fig. 1. Clad bead geometry

II. EXPERIMENTATION

The following machines and consumables were used for the purpose of conducting experiment.

1) A constant current gas metal arc welding machine (Invrtee V 350 – PRO advanced processor with5 – 425 amps output range)
2) Welding manipulator
3) Wire feeder (LF – 74 Model)
4) Filler material Stainless Steel wire of 1.2mm diameter (ER – 308 L).
5) Gas cylinder containing a mixture of 98% argon and 2% of oxygen.
6) Mild steel plate (grade IS – 2062)

Test plates of size 300 x 200 x 20mm were cut from mild steel plate of grade IS – 2062 and one of the surfaces is cleaned to remove oxide and dirt before cladding. ER-308 L stainless steel wire of 1.2mm diameter was used for depositing the clad beads through the feeder. Argon gas at a constant flow rate of 16 litres per minute was used for shielding. The properties of base metal and filler wire are shown in Table 1. The important and most difficult parameter found from trial run is wire feed rate. The wire feed rate is proportional to current. Wire feed rate must be greater than critical wire feed rate to achieve pulsed metal transfer. The relationship found from trial run is shown in equation (1). The formula derived is shown in Fig 2.

Wire feed rate = 0.96742857 *current + 79.1

----------- (1)

The selection of the welding electrode wire based on the matching the mechanical properties and physical characteristics of the base metal, weld size and existing electrode inventory [4]. A candidate material for cladding which has excellent corrosion resistance and weld ability is stainless steel. These have chloride stress corrosion cracking resistance and strength significantly greater than other materials. These have good surface appearance, good radiographic standard quality and minimum electrode wastage. Experimental design used for this study is shown in Fig 3 and importance steps are briefly explained.

Table 1: Chemical Composition of Base Metal and Filler Wire

	Elements, Weight %								
Materials	C	SI	Mn	P	S	Al	Cr	Mo	Ni
IS 2062	0.150	0.160	0.870	0.015	0.016	0.031	-	-	-
ER308L	0.03	0.57	1.76	0.021	1.008	-	19.52	0.75	10.02

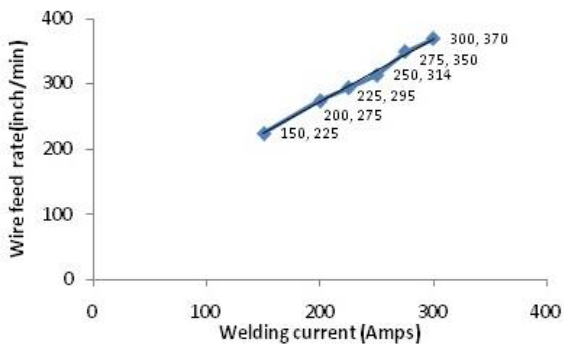


Fig. 2. Relationship between Current and Wire Feed Rate

III. PLAN OF INVESTIGATION

The research work is carried out in the following steps [5].

- Identification of important process variables and finding their upper and lower limits.
- Development of design matrix and conducting experiments as per design matrix,
- Recording responses viz; bead width (W).Penetration(P),Reinforcement(R),calculation of percentage of dilution Coefficient of internal shape and coefficient of external shape.
- development of mathematical models,
- checking adequacy of developed models,
- Conducting conformity tests.
- Optimizing the process parameters using RSM.

3.1 Identification of factors and responses

The basic difference between welding and cladding is the percentage of dilution. The properties of the cladding is the significantly influenced by dilution obtained. Hence control of dilution is important in cladding where a low dilution is highly desirable. When dilution is quite low, the final deposit composition will be closer to that of filler material and hence corrosion resistant properties of cladding will be greatly improved. The chosen factors have been selected on the basis to get minimal dilution and optimal clad bead geometry [1]. These are wire feed rate (W), welding speed (S), welding gun angle (T), contact tip to work to The following independently controllable process parameters were found to be affecting output parameters distance (N) and pinch (Ac), The responses chosen were clad bead width (W), height of reinforcement (R), Depth of Penetration. (P) and percentage of dilution (D). The responses were chosen based on the impact of parameters on final composite model.

3.2 Finding the limits of process variables

Working ranges of all selected factors are fixed by conducting trial run. This was carried out by varying one of factors while keeping the rest of them as constant values. Working range of each process parameters was decided upon by inspecting the bead for smooth appearance without any visible defects. The upper limit of given factor was coded as -2. The coded value of intermediate values were calculated using the equation (2)

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

Where X_i is the required coded value of parameter X is any value of parameter from $X_{min} - X_{max}$. X_{min} is the lower limit of parameters and X_{max} is the upper limit parameters [4].
The chosen level of the parameters with their units and notation are given in Table 2.

Table 2: Welding Parameters and their Levels

Parameters	Factor Levels						
	Unit	Notation	-2	-1	0	1	2
Welding Current	A	1	200	225	250	275	300
Welding Speed	mm/min	S	150	158	166	174	182
Contact tip to work distance	mm	N	10	14	18	22	26
Welding gun Angle	Degree	T	70	80	90	100	110
Pinch	-	Ac	-10	-5	0	5	10

3.3 Development of design matrix

Design matrix chosen to conduct the experiments was central composite rotatable design. The design matrix comprises of full replication of 2^5(= 32), Factorial designs. All welding parameters in the intermediate levels (o) Constitute the central points and combination of each welding parameters at either is highest value (+2) or lowest (-2) with other parameters of intermediate levels (0) constitute star points. 32 experimental trails were conducted that make the estimation of linear quadratic and two way interactive effects of process parameters on clad geometry [5].

3.4 Conducting experiments as per design matrix

In this work Thirty two experimental run were allowed for the estimation of linear quadratic and two-way interactive effects of correspond each treatment combination of parameters on bead geometry as shown Table 3 at random. At each run settings for all parameters were disturbed and reset for next deposit. This is very essential to introduce variability caused by errors in experimental set up. The experiments were conducted at SVS College of Engineering, Coimbatore, 642109, India.

3.5 Recording of Responses

For measuring the clad bead geometry, the transverse section of each weld overlays was cut using band saw from mid length. Position of the weld and end faces were machined and grinded. The specimen and faces were polished and etched using a 5% nital solution to display bead dimensions [6]. The clad bead profiles were traced using a reflective type optical profile projector at a magnification of X10, in M/s Roots Industries Ltd. Coimbatore. Then the bead dimension such as depth of penetration height of reinforcement and clad bead width were measured [6]. The profiles traced using AUTO CAD software. This is shown in Fig 4. This represents profile of the specimen (front side).The cladded specimen is shown in Fig. 5. The measured clad bead dimensions and percentage of dilution is shown in Table 4.

Table 3: Design Matrix

Trial Number	Design Matrix				
	I	S	N	T	Ac
1	-1	-1	-1	-1	1
2	1	-1	-1	-1	-1
3	-1	1	-1	-1	-1
4	1	1	-1	-1	1
5	-1	-1	1	-1	-1
6	1	-1	1	-1	1
7	-1	1	1	-1	1
8	1	1	1	-1	-1
9	-1	-1	-1	1	-1
10	1	-1	-1	1	1
11	-1	1	-1	1	1
12	1	1	-1	1	-1
13	-1	-1	1	1	1
14	1	-1	1	1	-1
15	-1	1	1	1	-1
16	1	1	1	1	1
17	-2	0	0	0	0
18	2	0	0	0	0
19	0	-2	0	0	0
20	0	2	0	0	0
21	0	0	-2	0	0
22	0	0	2	0	0
23	0	0	0	-2	0
24	0	0	0	2	0
25	0	0	0	0	-2
26	0	0	0	0	2
27	0	0	0	0	0
28	0	0	0	0	0
29	0	0	0	0	0
30	0	0	0	0	0
31	0	0	0	0	0
32	0	0	0	0	0

I - Welding current; S - Welding speed; N - Contact tip to work distance; T - Welding gun angle; Ac – Pinch

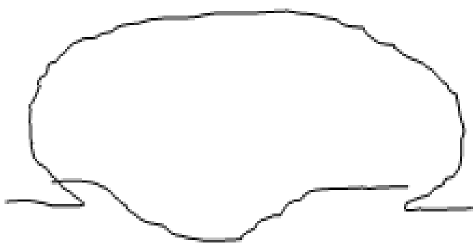


Fig. 3. Traced Profile of bead geometry

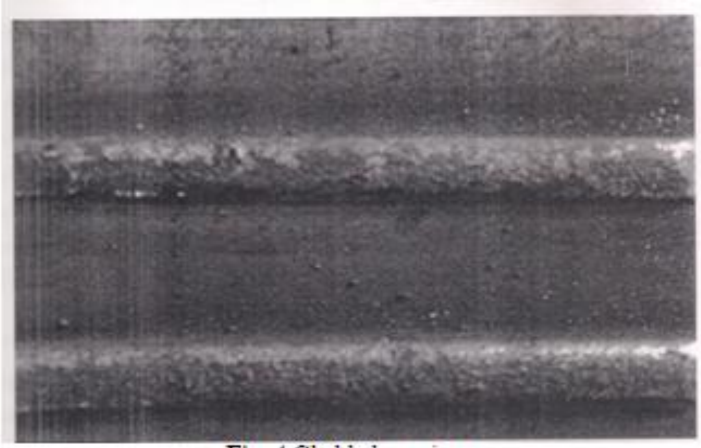


Fig. 4.Cladded specimen

3.6 Development of Mathematical Models

The response function representing any of the clad bead geometry can be expressed as [7, 8, and 9],

Y = f (A, B, C, D, E) ------------- (3)

Where,
Y = Response variable
A = Welding current (I) in amps
B = Welding speed (S) in mm/min
C = Contact tip to Work distance (N) in mm
D = Welding gun angle (T) in degrees
E = Pinch (Ac)

The second order surface response model equals can be expressed as below

$$Y = \beta_0 + \sum_{i=0}^{5} \beta_i X_i + \sum_{i=0}^{5} \beta_{ii} X_i^2 + \sum_{i=0}^{5} \beta_{ij} X_i X_j$$

$Y = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 C + \beta_4 D + \beta_5 E + \beta_{11} A^2 + \beta_{22} B^2 + \beta_{33} C^2 + \beta_{44} D^2 + \beta_{55} E^2 + \beta_{12} AB + \beta_{13} AC + \beta_{14} AD + \beta_{15} AE + \beta_{23} BC + \beta_{24} BD + \beta_{25} BE + \beta_{34} CD + \beta_{35} CE + \beta_{45} DE$ ------ (4)

Where, β_0 is the free term of the regression equation, the coefficient $\beta_1,\beta_2,\beta_3,\beta_4$ andβ_5 is are linear terms, the coefficients $\beta_{11},\beta_{22}, \beta_{33},\beta_{44}$ andβ_{55} quadratic terms, and the coefficients $\beta_{12},\beta_{13},\beta_{14},\beta_{15}$, etc are the interaction terms. The coefficients were calculated by using MINITAB 15. After determining the coefficients, the mathematical models were developed. The developed mathematical models are given as follows.

$\beta_o = 0.166338((\Sigma X_0 Y) + 0.05679(\Sigma\Sigma X_{ii} Y))$ ---------- (5)
$\beta_i = 0.166338 (\Sigma X_i Y)$ ----------- (6)
$\beta_{ii} = 0.0625 ((\Sigma X_{ii} Y) + 0.06889 (\Sigma\Sigma X_{ii} Y) - 0.056791(\Sigma\Sigma X_0 Y))$---------- (7)
$\beta_{ij} = 0.125 (\Sigma X_{ij} Y)$---------- (8)

Clad Bead Width (W), mm = 8.923 + 0.701A +0.388B + 0.587C + 0.040D + 0.088E – 0.423A^2 – 0.291B^2 – 0.338C^2 – 0.219D^2 – 0.171E^2 + 0.205AB + 0.405AC + 0.105AD + 0.070AE–0.134BC+0.225BD+0.098BE+0.26CD+0.086CE+0.012DE ----------- (9)

Depth of Penetration (P), mm = 2.735 + 0.098A – 0.032B + 0.389C – 0.032D – 0.008E – 0.124A^2– 0.109B^2 – 0.125C^2 – 0.187D^2 – 0.104E^2 – 0.33AB + 0.001 AC + 0.075AD + 0.005AE-0.018BC+0.066BD+0.087BE+0.058CD+0.054CE–0.036DE --------- (10)

Table 4: Design Matrix and Observed Values of Clad Bead Geometry

Trial No.	Design Matrix					Bead Parameters					
	I	S	N	T	Ac	W (mm)	P (mm)	R (mm)	D (%)	□a	□e
1	-1	-1	-1	-1	1	6.9743	1.67345	6.0262	10.72091	4.167493	1.149547
2	1	-1	-1	-1	-1	7.6549	1.9715	5.88735	12.16746	3.88278	1.300306
3	-1	1	-1	-1	-1	6.3456	1.6986	5.4519	12.74552	3.735782	1.163263
4	1	1	-1	-1	1	7.7635	1.739615	6.0684	10.61078	4.464347	1.273122
5	-1	-1	1	-1	-1	7.2683	2.443	5.72055	16.67303	2.984928	1.270511
6	1	-1	1	-1	1	9.4383	2.4905	5.9169	15.96692	3.789721	1.599387
7	-1	1	1	-1	-1	6.0823	2.4672	5.49205	16.5894	2.443377	1.102509
8	1	1	1	-1	-1	8.4666	2.07365	5.9467	14.98494	4.082656	1.423647
9	-1	-1	-1	1	-1	6.3029	1.5809	5.9059	10.2749	3.986906	1.066553
10	1	-1	-1	1	1	7.0136	1.5662	5.9833	9.707297	4.477814	1.171354
11	-1	1	-1	1	1	6.2956	1.58605	5.5105	11.11693	3.982792	1.130716
12	1	1	-1	1	-1	7.741	1.8466	5.8752	11.4273	4.192029	1.317527
13	-1	-1	1	1	1	7.3231	2.16475	5.72095	15.29097	3.382885	1.264594
14	1	-1	1	1	-1	9.6171	2.69495	6.37445	18.54077	3.56863	1.508671
15	-1	1	1	1	-1	6.6335	2.3089	5.554	17.23138	2.873013	1.194364
16	1	1	1	1	1	10.514	2.7298	5.4645	20.8755	3.851564	1.922894
17	-2	0	0	0	0	6.5557	1.99045	5.80585	13.65762	3.29423	1.115212
18	2	0	0	0	0	7.4772	2.5737	6.65505	15.74121	2.905234	1.119526
19	0	-2	0	0	0	7.5886	2.50455	6.4069	15.77816	3.029926	1.136205
20	0	2	0	0	0	7.5014	2.1842	5.6782	16.82349	3.434392	1.321134
21	0	0	-2	0	0	6.1421	1.3752	6.0976	8.941799	4.469517	1.007298
22	0	0	2	0	0	8.5647	3.18536	5.63655	22.94721	2.688567	1.519507
23	0	0	0	-2	0	7.9575	2.2018	5.8281	15.74941	3.614088	1.401462
24	0	0	0	2	0	7.7085	1.85885	6.07515	13.27285	4.191454	1.280376
25	0	0	0	0	-2	7.8365	2.3577	5.74915	16.63287	3.298884	1.359229
26	0	0	0	0	2	8.2082	2.3658	5.99005	16.38043	3.48535	1.368228
27	0	0	0	0	0	7.9371	2.1362	6.0153	15.18374	3.714433	1.320193
28	0	0	0	0	0	8.4371	2.17145	5.69895	14.82758	3.886228	1.480695
29	0	0	0	0	0	9.323	3.1425	5.57595	22.8432	2.967218	1.672287
30	0	0	0	0	0	9.2205	3.2872	5.61485	23.6334	2.804819	1.642323
31	0	0	0	0	0	10.059	2.86605	5.62095	21.55264	3.506629	1.788256
32	0	0	0	0	0	8.9953	2.72068	5.7052	19.60811	3.306985	1.575858

W-Width; R - Reinforcement W - Width; P - Penetration; D - Dilution %

Height of Reinforcement (R), mm = 5.752 + 0.160A – 0.151B – 0.060C + 0.016D – 0.002E + $0.084A^2$ + $0.037B^2$ – $0.0006C^2$ + $0.015D^2$ – $0.006E^2$ + 0.035AB + 0.018AC – 0.008AD – 0.048AE–0.024BC–0.062BD–0.003BE+0.012CD–0.092CE–0.095DE.-----------(11)

Percentage Dilution (D), % = 19.705 + 0.325A + 0.347B + 3.141C – 0.039D – 0.153E – $1.324A^2$ – $0.923B^2$ – $1.012C^2$ – $1.371D^2$ – $0.872E^2$ – 0.200AB + 0.346 AC + 0.602 AD + 0.203AE+0.011BC+0.465BD+0.548BE+0.715CD+0.360CE+0.137DE ---------- (12)

Coefficient of internal shape (φ_a)= 3.6189 - 0.08077A +0.208B + 0.1300C - 0.09460D + 0.0255E – $0.07585A^2$ – $0.0389B^2$ $+0.044C^2$ – $0.1239D^2$ – $0.048E^2$ -0.06144AB - 0.1050AC +0.07987AD-0.050AE–0.0822BC+0.12261BD-0.0045BE-0.14596CD-0.2552CE-0.08994DE ------------------ (13)

Coefficient of external shape (φ_e)= 1.3065 -0.04433A +0.0614B - 0.0462C + 0.01345D - 0.06922E + $0.0189A^2$ $+0.0390B^2$ – $0.0514C^2$ + $0.04665D^2$ – $0.00479E^2$ + 0.05719AB + 0.05270AC + 0.06324AD + 0.05633AE–0.05465BC-0.05404BD+0.00510BE+0.00410CD+0.05573CE-0.04192DE---(14)

Co-efficient of the above polynomial equation where calculated by regression as given by equations (5) to (8)

3.7 Checking the adequacy of the developed models

Analysis of variance (ANOVA) technique was used to test the adequacy of the model. As per this technique, if the F – ratio values of the developed models do not exceed the standard tabulated values for a desired level of confidence (95%) and the calculated R – ratio values of the developed model exceed the standard values for a desired level of confidence (95%) then the models are said to be adequate within the confidence limit [10]. These conditions were satisfied for the developed models. The values are shown in Table 5.Residual plots are shown in Fig 10.

Table 5: Analysis of variance for Testing Adequacy of the Model coefficient of internal shape (φ_e)

Source	DF	Seq	SS	Adj SS	MS	F	P
Regression	20	4.8722	4.8722	0.2436	0.59	0.850	
Linear	5	1.8328	1.8328	0.3666	0.89	0.518	
Square	5	0.8061	0.8061	0.1612	0.39	0.844	
Interaction	10	2.2333	2.2333	0.2233	0.54	0.826	
Residual Error	11	4.5122	4.5122	0.4102			
Lack-of-Fit	6	1.9651	1.9651	0.3275	0.64	0.699	
Pure Error	5	2.5472	2.5472	0.5094			
Total	31	9.3844					

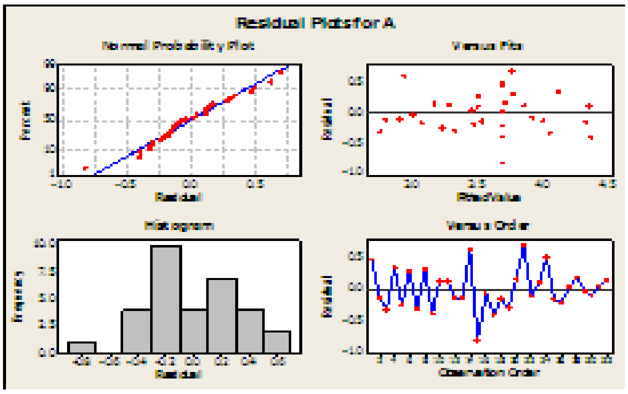


Fig. 5. Residual plots for coefficient of internal shape (A)

IV. CONFIRMATION EXPERIMENTS

Experiments were conducted to verify the regression equations 4-7.Three weld runs used at different values welding current, welding speed, contact tip to work distance, welding gun angle and pinch other than that used in the design matrix. The results obtained found to be satisfactory and the results presented Table 6

.

Table 6. Results of confirmation experiments

Experiment no	Measured values			Predicted values			Error		
	D (%)	φ_a	φ_e	D (%)	φ_a	φ_e	D (%)	φa	φ_e
CON 1	12.8	4.5	3.4	12.4	4.3	3.2	3.1	4.4	8
CON2	12.7	4.8	4.7	12.8	3.9	4.2	-.8	14	11
CON3	12.9	4.3	4.2	12.8	4.8	4.1	.8	-11	.2

V. RESULTS AND DISCUSSIONS

5.1 Direct effects of welding variables on bead parameters.

Based on the mathematical models developed for predicting the bead geometry and dilution the effect of welding process parameters on the above bead parameters were calculated and have presented graphically in Fig 6-9.The effects of various process variables on the bead geometry are presented under various headings [11].

5.1.1 Effects of process variables on percent of dilution (D).

Effect of welding current and welding speed on dilution is depicted in fig 6.This shows that dilution increases first and then decreases. This may be due to the fact that weight of the deposited metal per unit of length decreases when the welding speed increases. Percentage of dilution with increase with increase in welding current but effects are not much significant.

5.1.2 Effect of process variables on coefficients of shape of welds

The weld shape coefficients give an indication of bead geometry. The coefficient of internal shape is the width to depth of penetration ratio and the coefficient of external shape is the ratio of width to height of reinforcement. Response surface graphs have been drawn to visualize the nature of response and the give satisfactory explanation about the interaction effects of process parameters on bead geometry. Fig 8 shows the interaction effect of contact tip to work distance (N) and welding current on percent of dilution (D).it is evident that when welding current id increased dilution is seems to be decreasing.Fig11depicts the effect of welding current(I) and welding speed (S) on coefficient of internal shape. It is evident from the figure that when welding speed is increased for all values of I but at the same time for a given speed the value of coefficients of internal shape decreases as the welding current is increased. Fig 13 depicts the interaction effects of welding current and welding speed on coefficient of external shape. Coefficient of external shape is increased with the increases of welding current. Other interaction surface plots of various process parameters are shown in fig 6-9.Fig 11-12 shows interaction effect of process parameters on coefficient of external and internal shape

.

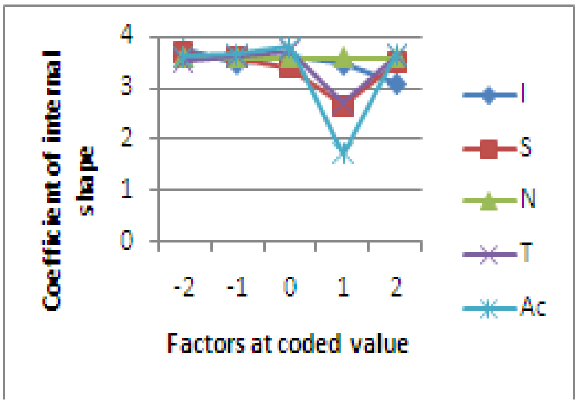


Fig. 6.Direct effects of process parameters on φ_2

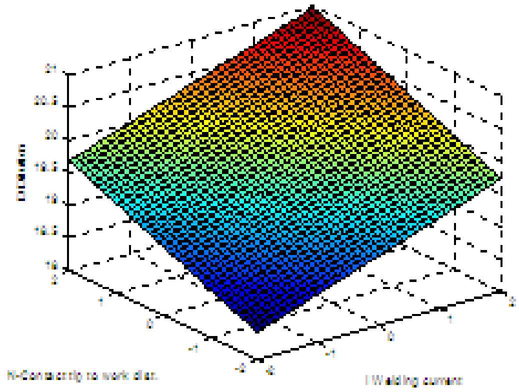


Fig 8. Surface plots for interaction effect of current (I), Contact tip to work distance (N) on percent of dilution (D)

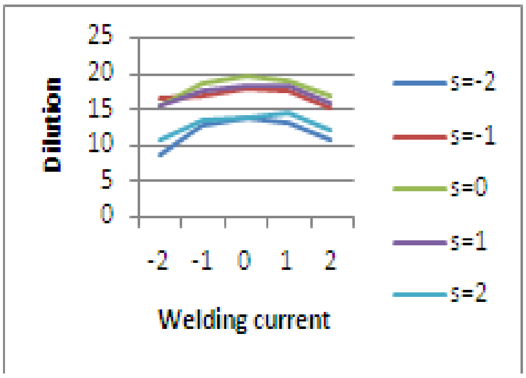


Fig. 7. Direct effect of process parameters on φ_2

Fig 9. Interaction effect of welding current (I), Welding speed(S) on percent of dilution (D).

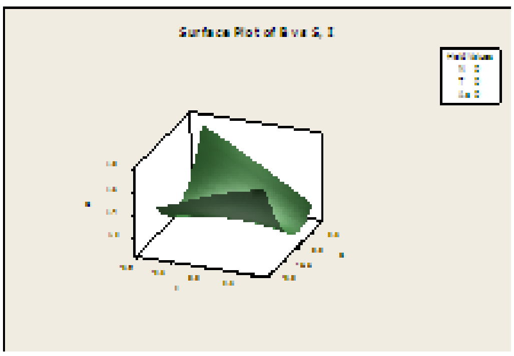


Fig 10.Surface plot for interaction

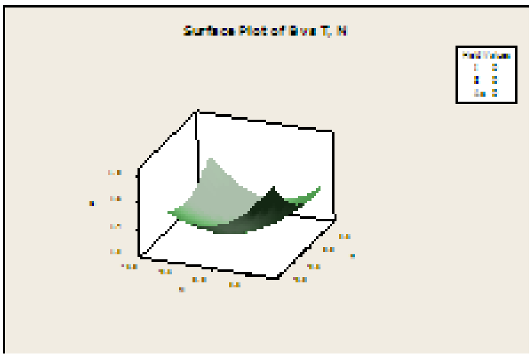


Fig. 11. Surface plot for the interaction effects

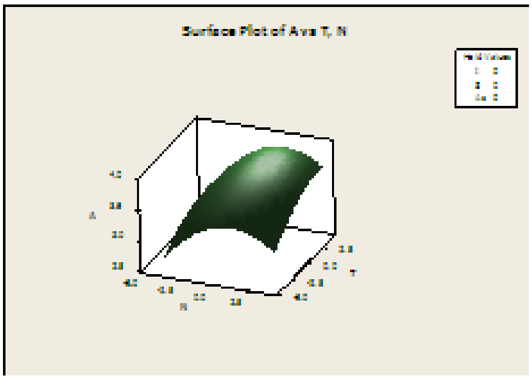


Fig.12. Surface plot for interaction effect on Welding gun angle (T), contact tip to Work distance (N) on coefficient of internal shape

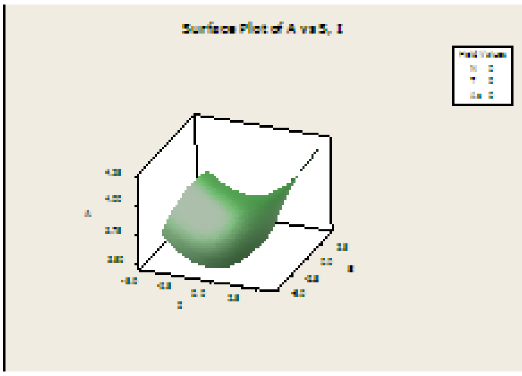


Fig. 13. Surface plot for the interaction effects welding current (I), welding speed(S) on coefficient of internal shape (A).

VI. OPTIMIZATION OF PROCESS PARAMETER USING RESPONSE SURFACE METHODOLOGY

Optimization procedure in RSM is initiated by picking several starting point, from which, searching for optimal factors continued. Two types of solutions are obtained for the search. First is local solution for each starting point there is a local solution. These solutions are best combinations for each factor settings found for the particular starting point. Next is global solution, there is only one global solution which is the best of all local solutions. Global solution is the best combination of factor settings for achieving desired responses. The optimum operating conditions for achieving desirable weld bead geometry are obtained using the statistical software, MINITAB 15.

6.1 Results of optimization

6.1.1 Single objective optimization

(1) Objective: Minimization of depth of penetration. Optimum process parameters are I=225amp, S=182mm/min, N=26mm, T=110degree, Ac=10and Predicted response, P=1.6mm.

(2). Objective: Maximizing the reinforcement. Optimum process parameters I=300amo, S=182mm/min, N=26mm, T=110degree, Ac=-10Predicted response, R=7.2875mm.

(3). Objective: Maximizing the Bead width. Optimum process parameters I=300amp, S=150mm/min, N=26mm, T=70 degree, Ac=-10Predicted response W=15mm.

(4). Objective: Maximizing the Coefficient of external shape. Optimum process parameters I=280amp, S=148mm/min, N=24mm, T=68degree, Ac=-8Predicted response, **(φ_e)** = 1.3.

(5) Objective: Minimizing coefficient of internal shape .Optimum process parameters. I=300amp, S=150mm/min, N=26mm, T=70degree, Ac=-10Predicted response, **(φ_a)** = 3.9.

(6) Objective: Minimizing percent of dilution. Optimum process parameters are I=300amp, S=150mm, N=26mm, T=70deg, Ac=-10 Predicted response, D%=11.2.

The typical (sample) optimization plots for single objective optimization are shown in Fig 14 and Fig 15.

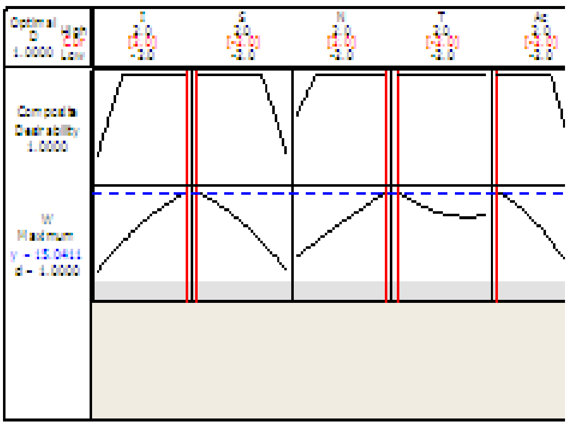


Fig 14.Optimization plot for Bead width

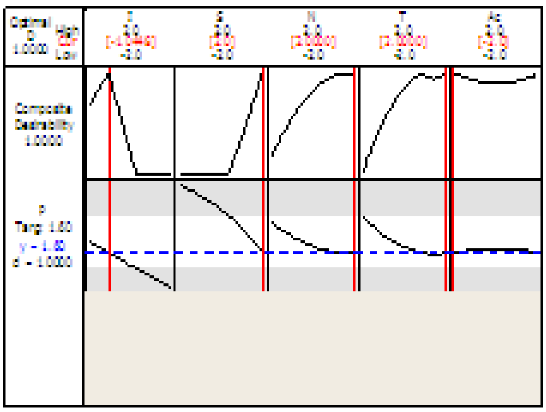


Fig 15 Optimization plot for penetration

6.2 Multi –objective optimization.

As for cladding is concerned the desirable weld bead geometry is one which has maximum depth of penetration minimum bead width, minimum reinforcement and minimum percentage of dilution .This can be achieved by adopting multi objective optimization procedure. To identify the combination of input that jointly optimizes the responses such as penetration, reinforcement, and bead width, dilution, coefficient of external and internal shape were optimized using RSM.

The optimization procedure was carried out using MINITAB 15 with multiple objectives as maximizing penetration and coefficient of external shape, minimizing reinforcement, dilution, bead width and coefficient of internal shape. The optimum parameter setting so obtained for achieving the objectives are I=300amps.S=166mm/min, N=12mm, T=75 degree, Ac=-5. And the optimization plot is depicted in fig 16.

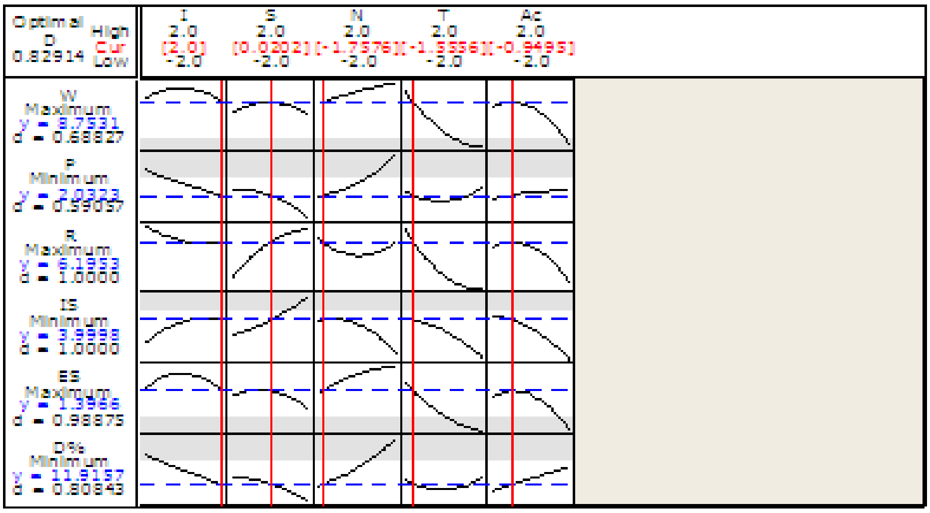


Fig. 12.Optimization plot for combined optimization of weld bead geometry

VII. CONCLUSIONS

1. Regression models were developed using RSM to predict weld bead geometry for 317L stainless steel wire on to IS 2062 structural steel plates.
2. Confirmation experiments showed that developed models are reasonably accurate.
3. It was found that welding current plays an important role in influencing bead geometry.
4. Multi objective optimization by RSM using MINITAB 15 was efficiently carried out.

VIII. ACKNOWLEDGEMENT

The authors sincerely acknowledge the help and facilities extended to them by the department of mechanical engineering SVS college of Engineering, Coimbatore, India.

REFERENCE

[1]. Kannan,T.;Murugan,N.(2006).Effect of flux cored arc welding process parameters on
[2]. duplex stainless steel clad quality, Journal of Material Processing Technology vol.176 pp 230-239.
[3]. Kannan,T.; Murugn,N.(2006).Prediction of ferrite number of duplex stainless steel clad metals using RSM, Welding Journal. pp. 91 - 99.
[4]. Gunaraj,V.; Murugan, N. (2005).Prediction and control of weld bead geometry and shape relationships in submerged arc welding of pipes, Journal of Material Processing Technology. Vol. 168, pp. 478 – 487.
[5]. Kim, I,S.; Son, K,J.; Yang, Y, S.; Yaragada, P, K, D,V. (2003).Sensitivity analysis for process parameters in GMA welding process using factorial design method, International Journal of Machine tools and Manufacture. Vol.43, pp. 763 - 769.
[6]. Cochran, W,G.; Coxz, G,M. (1987).Experimental Design. pp.370, New York, John Wiley & Sons.
[7]. Serdar Karaoglu.; Abdullah Secgin. (2008).Sensitivity analysis of submerged arc welding process parameters,Journal of Material Processing Technology. Vol-202, pp 500-507.
[8]. Gunaraj, V.; Murugan, N.(1999) .Prediction and comparison of the area of the heat effected zone for the bead on plate and bead on joint in SAW of pipes,Journal of Material processing Technology. Vol. 95, pp. 246 - 261.
[9]. Montgomery,D,C.;(2003).Design and analysis of Experiments,John Wiley & Sons (ASIA) Pvt. Ltd.
[10]. Kannan,T.; Yoganath.(2010).Effect of process parameters on clad bead geometry and shape relationships of stainless steel cladding deposited by GMAW,Int. Journal of Manufacturing Technology.Vol-47, pp 1083-1095.
[11]. Palani.P.K;Murugan.N(2007).Optimization of weld bead geometry for stainless steel claddings deposited by FCAW, Journal of material processing Technology Vol-190,pp 291-299.
[12]. Giridharan, P,K.; Murugan,N.; (2009). Optimization of pulsed GTA welding process parameters for the welding of AISI 304 L stainless steel, International Journal of Advanced Manufacturing Technology 40: pp.478 - 489.