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Prediction and optimization of stainless steel cladding deposited by GMAW process using response surface methodology, ANN and PSO

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ABSTRACT: *Now a day's gas metal arc cladding became an important process because it allows deposition of thick protective coatings on substrates. This article presents an experimental investigation of the influence of processing parameters on clad angle in GMAW process. Because of high reliability, easiness in operation, high penetration good surface finish and high productivity gas metal arc welding (GMAW) became a natural choice for fabrication industries. This paper presents five level four factor central composite rotatable designs with full replication technique to predict critical dimensions of clad angle. The clad angle is determined from mathematical expression relating to clad height and clad width. Using regression analysis a mathematical model is developed. The developed model has been checked for adequacy and significance. The main and interaction effects of process variables and clad angle are presented in graphical form. Using artificial neural network clad angle is predicted. Again using particle Swarm Optimization (PSO) parameters were optimized.*

***KEY WORDS**: GMAW, Weld bead geometry, Multiple Regression, Mathematical model, ANN, PSO.*

I. INTRODUCTION

In order to extend the life of many components such as mould and dies, their surface needs continuous repairing. This will not only increase the life but also reduce the operating cost under desired circumstances. Gas Metal arc welding is a common tool that can repair the defects of die and mould so has to enhance their service life [1]. 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. 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. This is an indication of bead geometry and clad angle. 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 paper highlights the study carried out to develop mathematical, models to predict clad angle, in stainless steel cladding deposited by GMAW [2].

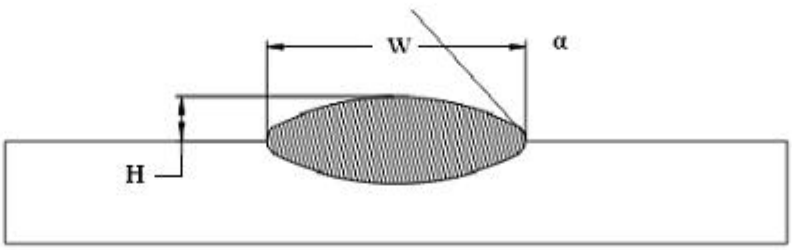

Figure 1: scheme of a typical bead geometry: clad height H ; clad width W and clad angle, α=180-2arctan (2H/W).

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 [3]. 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.

$$\text{Wire feed rate} = 0.96742857 * \text{current} + 79.1 \quad \text{---------------------} (1)$$

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 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

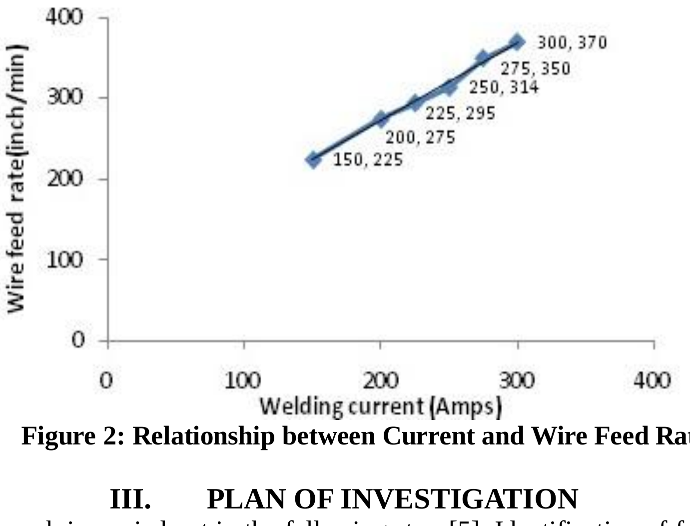

Figure 2: Relationship between Current and Wire Feed Rate

III. PLAN OF INVESTIGATION

The research work is carried out in the following steps[5] .Identification of factors, finding the limit of process variables, development of design matrix, conducting experiments as per design matrix, recording responses, development of mathematical models, checking adequacy of developed models, and predicting the parameters and optimization process parameters using PSO.

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) and bead height (H).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)

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

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 angle. [5].

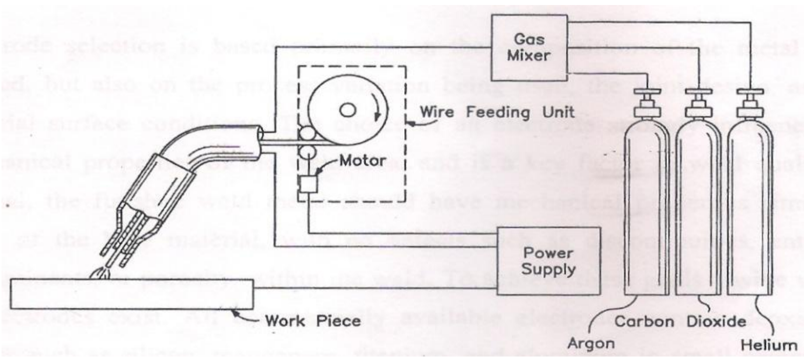

Figure 3: GMAW Circuit Diagram

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
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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

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. 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 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 clad angles is shown in Table 4.

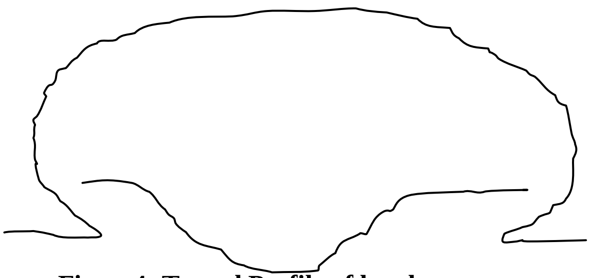

Figure4: Traced Profile of bead geometry

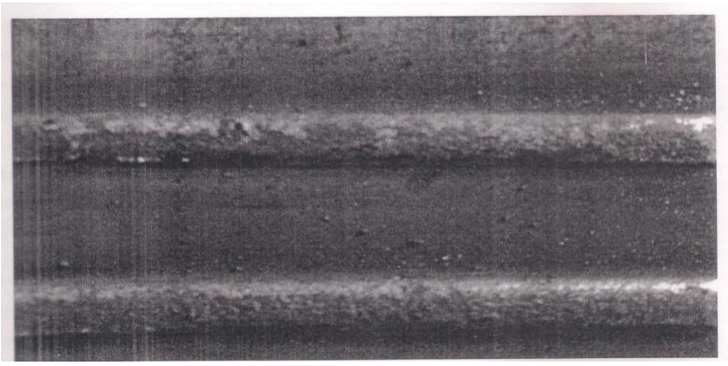

Figure 5: cladded specimen

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

Trial No.	Design Matrix					Bead Parameters		
	I	S	N	T	Ac	W (mm)	H (mm)	Clad Angle(α)
1	-1	-1	-1	-1	1	6.9743	6.0262	120.056
2	1	-1	-1	-1	-1	7.6549	5.88735	123.303
3	-1	1	-1	-1	-1	6.3456	5.4519	120.189
4	1	1	-1	-1	1	7.7635	6.0684	122.605
5	-1	-1	1	-1	-1	7.2683	5.72055	128.574
6	1	-1	1	-1	1	9.4383	5.9169	118.758
7	-1	1	1	-1	-1	6.0823	5.49205	125.444
8	1	1	1	-1	-1	8.4666	5.9467	120.561
9	-1	-1	-1	1	-1	6.3029	5.9059	120.383
10	1	-1	-1	1	1	7.0136	5.9833	119.800
11	-1	1	-1	1	1	6.2956	5.5105	122.923
12	1	1	-1	1	-1	7.741	5.8752	122.633
13	-1	-1	1	1	1	7.3231	5.72095	127.303
14	1	-1	1	1	-1	9.6171	6.37445	120.788

15	-1	1	1	1	-1	6.6335	5.554	133.988
16	1	1	1	1	1	10.514	5.4645	119.638
17	-2	0	0	0	0	6.5557	5.80585	119.275
18	2	0	0	0	0	7.4772	6.65505	120.367
19	0	-2	0	0	0	7.5886	6.4069	123.341
20	0	2	0	0	0	7.5014	5.6782	116.783
21	0	0	-2	0	0	6.1421	6.0976	127.193
22	0	0	2	0	0	8.5647	5.63655	124.320
23	0	0	0	-2	0	7.9575	5.8281	122.363
24	0	0	0	2	0	7.7085	6.07515	124.249
25	0	0	0	0	-2	7.8365	5.74915	124.378
26	0	0	0	0	2	8.2082	5.99005	123.355
27	0	0	0	0	0	7.9371	6.0153	126.991
28	0	0	0	0	0	8.4371	5.69895	129.704
29	0	0	0	0	0	9.323	5.57595	129.991
30	0	0	0	0	0	9.2205	5.61485	129.704
31	0	0	0	0	0	10.059	5.62095	131.760
32	0	0	0	0	0	8.9953	5.7052	117.697

W-Width; H– Clad Height; W - Width; $\propto$ –Clad angle

3.6 Development of Mathematical Models

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

$$Y = f(A, B, C, D, E) \qquad \text{----------------------------} \ (3)$$

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 β_{11},β_{22}, β_{33},β_{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 15software. After determining the coefficients, the mathematical model was developed. The developed mathematical model is given as follows.

Clad Angle(α) = $121.049 - 0.1764A + 0.0635B - 0.1099C + 0.4044D - 0.7652E + 0.1324A^2 + 0.9524B^2 + 0.02712C^2 + 0.1822D^2 + 0.1874E^2 + 0.22237AB + 0.5690AC - 0.1737AD + 0.1877AE - 0.02077BC - 0.4371BD + 0.2357BE + 0.0577CD + 0.2429CE + 0.4519DE$ ---------------- (5)

3.7 Checking the adequacy of the developed model.

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 model. The values are shown in Table 5.

Table 5: Analysis of variance for Testing Adequacy of the Model

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	20	385.28	385.28	19.26	1.45	0.266
Linear	5	82.30	82.30	16.46	1.24	0.354
Square	5	59.04	59.04	11.81	0.89	0.520
Interaction	10	243.94	243.94	24.39	1.84	0.166
Residual Error	11	145.91	145.91	13.26		
Lack-of-fit	6	89.77	89.77	14.96	1.33	0.385
Pure Error	5	56.15	56.15	11.23		
Total	31	531.19				

IV. VALIDATION OF MODEL

To test the accuracy of the models in actual application, conformity test were conducted by assigning different values for process variables within their working limits but different from design matrix. Specimens were cut from conformity plates and their bead profiles were measured. The percentage of errors calculated using the equation (10). This is shown in Table 7..It is found that average error is less than three percent.

Error = (□□□□□□ □□□□□−□□□□□□□□□ □□□□□) □ 100 / □□□□□□□□□ □□□□□ .... (10)

Table 7. Validation tests

Test no	Process parameter					ACTUAL	PREDICTED	ERROR (%)
	I	S	N	T	Ac	Clad Angle(α)	Clad Angle(α_p)	(α_E)
1	-1.5	-1.5	-1.5	-1.5	1.5	122.580	124.987	-1.5
2	1.5	-1.5	-1.5	-1.5	1.5	120.087	123.567	-2.34
3	-1.5	1.5	-1.5	-1.5	1.5	125.650	122.678	2.38

V. Artificial Neural Networks

Neural network consists of many non-linear computational elements operating in parallel. Basically it consists of neurons; it represents our biological nervous system. The basic unit of ANN is the neuron. The neurons are connected to each other by link and are known as synapses which are associated to a weight factor. An artificial neuron receives signals from other neurons through the connection between them [11]. Each connection has a synaptic connection strength which is represented by a weight of that connection strength. This artificial neuron receives a weighted sum of outputs of all neurons to which it is connected. The weighted sum is then compared with the threshold for an ANN and if it exceeds this threshold ANN fires. When it fires it goes to higher excitation state and a signal is send down to other connected neurons. The output of a typical neuron is obtained as a result of non-linear function of weighted sum. It is an adaptable system that can learn relationship through repeated presentation of data and is capable of generalizing a new previously unseen data. One of the most popular learning algorithms is the back propagation algorithm. In this study feedback propagation algorithm was used with a single hidden layer improved with numerical optimization technique called Levenbery Marguent approximation algorithm (LM) .The topology of architecture of feed forward three Layers back propagations network is illustrated in Fig 5.

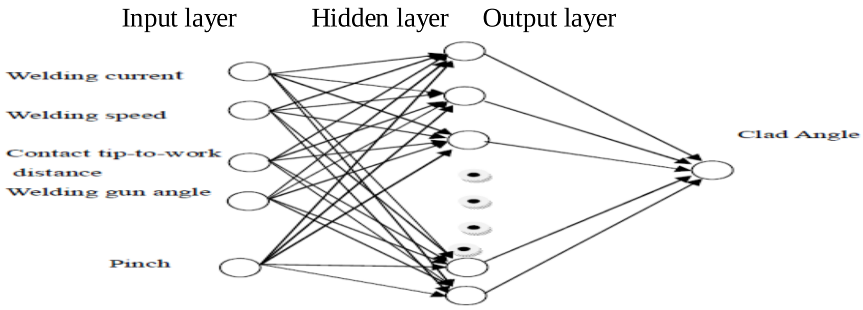

Fig 6 Neural network architecture

MAT LAB 7 was used for training the network for the prediction of clad angle [12]. Statistical mathematical model was used compare results produced by the work. For normalizing the data the goal is to examine the statistical distribution of values of each net input and outputs are roughly uniform in addition the value should scaled to match range of input neurons.

This is basically range 0 to 1 in practice it is found to between 01 and 9. In this paper data base are normalized using the Equation (9)

$$X_{norm} = 0.1 + \frac{(X - X_{min})}{1.25\,(X_{max} - X_{min})} \quad ------------ (7)$$

X_{norm} = Normalized value between 0 and 1
X = Value to be normalized
X_{min} = Minimum value in the data set range the particular data set rage which is to be normalized.
X_{max} = Maximum value in the particular data set range which is to be normalized.

The Levenberg-Marquardt approximation algorithm was found to be the best fit for application because it can reduce the MSE to a significantly small value and can provide better accuracy of prediction. So neural network model with feed forward back propagation algorithm and Levenberg-Marqudt approximation algorithm was trained with data collected for the experiment [13].The data obtained is divided in to two sets, one for training and other for testing the data in order to avoid over fitting and under fitting of data. First eleven data from Table 5 used for testing and next seventeen data for training. The lowest MSE obtained for 11 neurons. So a net work of five input neurons and eleven hidden neurons in a single hidden layer and two output neurons created for the study. The predicted test data is shown in Table 7. [14].

Table. 7. Actual and predicted parameters (Test)

Trial No.	Design Matrix					Bead Parameters			
	I	S	N	T	Ac	W (mm)	H (mm)	α	$α_p$
1	-1	-1	-1	-1	1	6.9743	6.0262	120.056	123.567
2	1	-1	-1	-1	-1	7.6549	5.88735	123.303	126.780
3	-1	1	-1	-1	-1	6.3456	5.4519	120.189	122.870
4	1	1	-1	-1	1	7.7635	6.0684	122.6056	124.897
5	-1	-1	1	-1	-1	7.2683	5.72055	128.5745	125.657
6	1	-1	1	-1	1	9.4383	5.9169	118.758	120.354
7	-1	1	1	-1	-1	6.0823	5.49205	125.444	127.4531
8	1	1	1	-1	-1	8.4666	5.9467	120.561	121.673
9	-1	-1	-1	1	-1	6.3029	5.9059	120.383	120.243
10	1	-1	-1	1	1	7.0136	5.9833	119.800	125.876
11	-1	1	-1	1	1	6.2956	5.5105	122.923	126.453

VI. PARTICLE SWARM OPTIMIZATION

In particle swarm optimization algorithm Pbest is the location of the best solution of a particle achieved so far. Best is the best location of the best solution that any neighbour achieved so far. Initially random numbers are generated for each particle and these values are considered as PBest and weights. Velocity is calculated using the equation (8), and added with the present weights in each link of the neural network. For each particle the newly calculated weights are compared with PBest weights and the minimum error produced by weights are stored in PBest[15]. Initial velocity V is assumed to be 1 and GBest is the weights of minimum error produced particle. New weights are calculated using equation (9).

Velocity[]=wVelocity[]+C1rand1(PBest[]-present[])+C2xrand2(GBest[]-present[])................(8)
Present [] =present [] +velocity []... (9)

Where C1 and C2 are two positive constants named learning factors.rand1 and rand2 are two random functions ranging from [0, 1].w is an inertia weight to control over the impact of previous history of velocities on current velocities. The operator w plays the role of a balancing the global search and the local search; and was proposed to decrease linearly with time from a value of 1.4-.5. As such global search starts with a large weight and then decreases with time to favour local search over global search. When the number of iterations is equal to the total number of particles, the goal is compared with the error produced by GBest weights. If the error produced by GBest weights are less than or equal to goal weights in GBest are used for testing and prediction otherwise weights of minimum error are stored in GBest and iterations are repeated until goal is reached. Optimization procedure is shown in Fig7.A program with objective function as equation (10) and constraints taken from Table 2 is written in MATLAB.7 code which is used for optimization in this study

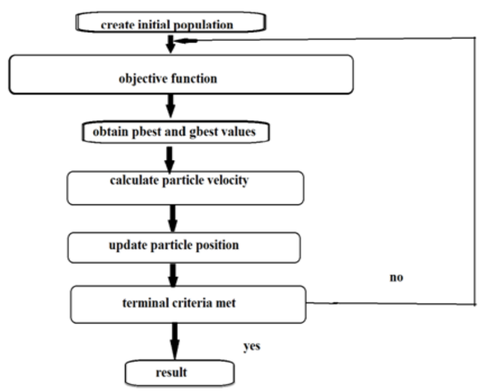

Figure 7 Procedure for proposed PSO to optimize GMAW process parameters

rand1 and rand2 are two random functions in the range [0,1] where C1 and C2 are two positive constants named learning factors taken as 2 and 'w' is the inertial weight taken as 0.5.The parameters used for PSO optimization are shown in Table 7.

Table 8 Parameters for PSO optimization

Population size	30
Dimension size	5
Inertia weight	0.4–0.9
Velocity factors C1, C2	1.4
Number of iteration allowed	100

6.1. Method for developing PSO model

- Initiate each particle.
- Calculate fitness value of each particle. If the fitness value is better than the best fitness value (Pbest) in history. Set the current value as new Pbest.
- Calculate Gbest.
- For each particle calculate the particle velocity.

6.2. Numerical illustration for developed PSO model.

The numerical illustration for the developed model to find optimal parameters for percentage of dilution as summarised below [16].

Welding current	$I = I_{min} + (I_{max} - I_{min})$ -rand()
Welding speed	$S = S_{min} + (S_{max} - S_{min})$- rand()
Contact tip to work distance	$N = N_{min} + (N_{max} - N_{min})$ - rand()
Welding gun angle	$T = T_{min} + (T_{max} - T_{min})$ - rand()
Pinch	$P = P_{min}+ (P_{max} - P_{min})$ - rand()

These values are substituted in equation (8) and clad angle is obtained.

X (1) = A = Welding current (I) in Amps

X (2) = B= Welding Speed (S) in mm/min

X (3) = C = Contact to work piece distance (N) in mm

X (4) = D = Welding gun angle (T) in degree

X (5) = E = Pinch (Ac)

Objective function for percentage of dilution which must be minimized was derived from equation 5. The constants of welding parameters are given Table 2.

Subjected to bounds

$$200 \leq X(1) \leq 300$$
$$150 \leq X(2) \leq 182$$
$$10 \leq X(3) \leq 26$$
$$70 \leq X(4) \leq 110$$
$$-10 \leq X(5) \leq 10$$

6.3. Objective Function

f(x)=121.049-0.1764*x(1)+0.0635*x(2)–0.1099*x(3)-0.4044*x(4)-0.7652*x(5)–0.1324*x(1)^2+0.952*x(2)^2+0.0271*x(3)^2 + 0.1822*x(4)^2 + 0.1874*x(5)^2 + 0.22237*x(1)*x(2) + 0.5690*x(1)*x(3) - 0.1737*x(1)*x(4) + 0.1877*x(1)*x(5) - 0 .02077*x(2)*x(3) - 0.4371*x(2)*x(4) + 0.2375*x(2)*x(5) + 0.0577*x (3)*x(4) + 0.2429*x (3)*x (5) + 0.451*x(4)*x(5)   ------ (10)

(This is the percentage of dilution)

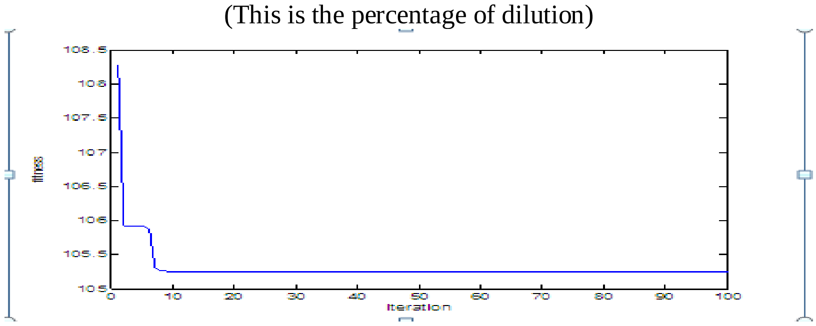

Fig 8. Fitness function graph of clad angle

Table 9 Optimal process parameters

Parameters	**Range** (Coded Value)	**Actual**
Welding current (I)	2	300 A
Welding speed (S)	2	182 mm/min
Contact tip to work distance (N)	2	26 mm
Welding gun angle (T)	-1.4	76 degree
Pinch (Ac)	2	10

Clad angle obtained is 105.2532 and optimal process parameters shown in Table 9.

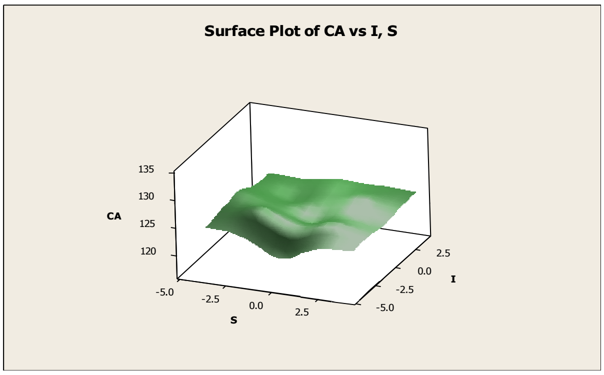

Fig 9.Surface plot of clad angle (CA) Vs welding current ad welding speed

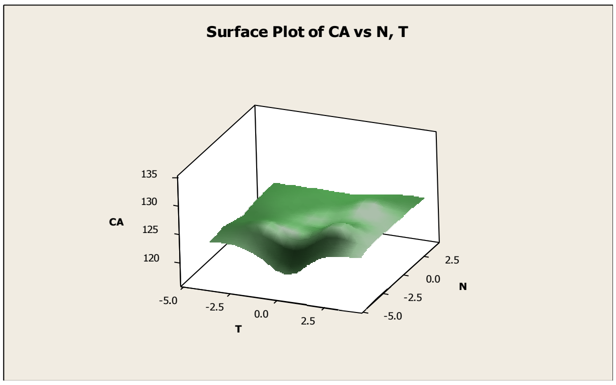

Fig 10.Surface plot of clad angle (CA) Vs T and N

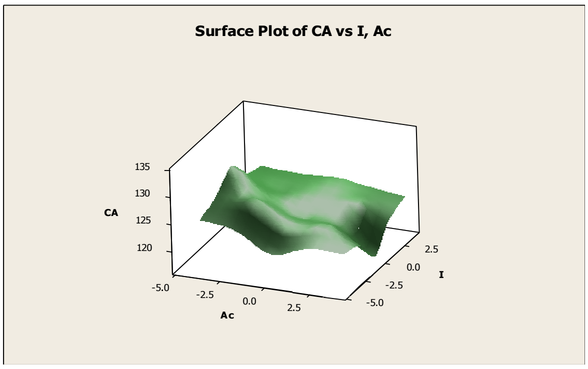

Fig. 11. Surface plots of clad angle (CA) Vs I and Ac

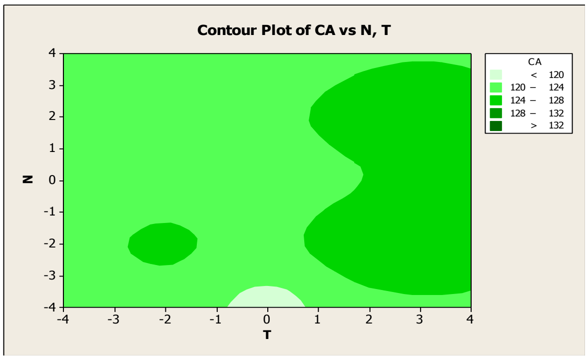

Fig. 12. Contour plot of clad angle(CA) Vs Nand T

VII. RESULTS AND DISCUSSIONS

a. A five level five factor full factorial design matrix based on central composite rotatable design technique was used for the mathematical development of model to predict clad angle of austenitic stainless steel deposited by GMAW.
b. PSO tool available in MATLAB 7 software was efficiently employed for optimization of clad angle.
c. In cladding by a welding process clad bead geometry is very important for economising the material. This study effectively used regression and PSO models to predict and optimize clad angle.
d. IN this study two models artificial neural network and PSO system for prediction and optimization of clad angle in GMAW welding process. In this study it is proved that PSO model is more efficient.
e. Fig 9-11 shows various interaction effects of process parameters on clad angle. Fig 12 shows contour plot of clad angle, welding gun angle and contact tip to work distance. The optimum clad angle obtained is 105.5 and optimal process parameters shown in Table 9.

VIII. CONCLUSIONS

Based on the above study it can be observed that the developed model can be used to predict clad angle within the applied limits of process parameters. This method of predicting process parameters can be used to get optimum clad angle. In this study ANN and PSO was used for achieving optimal clad bead dimensions. In the case of any cladding process bead geometry plays an important role in determining the properties of the surface exposed to hostile environments and reducing cost of manufacturing. In this approach the objective function aimed for predicting clad angle within the constrained limits.

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REFERENCES

[1] Kannan,T.;Murugan,N.(2006).Effect of flux cored arc welding process parameters on duplex stainless steel clad quality ,journal of Material Processing Technology vol.176 pp 230-239.
[2] Kannan,T.; Murugn,N.(2006).Prediction of ferrite number of duplex stainless steel clad metals using RSM, *Welding Journal*. pp. 91 - 99.
[3] 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.
[4] 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.
[5] Godfrey. C. Onwubolu, Paulo Davim.J,Carlos Oliveira,Cardoso.A Prediction of clad angle in laser cladding by powder using response surface methodology and scatter search (2007).*Optics & Laser Technology. Vol (39)* pp.1130-1134.
[6] Serdar Karaoglu.; Abdullah Secgin. (2008). Sensitivity analysis of submerged arc welding process parameters,*Journal of Material Processing Technology.* Vol-202, pp 500-507.
[7] Ghosh, P,K.; Gupta, P,C.; Goyal, V,K. (1998) . Stainless steel cladding of structural steel plate using the pulsed current GMAW process, *Welding*-314.
[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] Edwin Raja Dhas,J.;Kumaanan,S.(2001). Optimization of process parameters of submerged arc welding using non conventional techniques, Applied soft computing 11, 5198-5204
[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.
[13] Siva, K.; Murugan,N.;Logesh, R. (2009). Optimisation of Weld Bead Geometry in Plasma Transferred Arc Hard faced Austenitic Stainless Steel Plates using Genetic Algorithm, *International Journal of Advanced Manufacturing Technology,* 4:pp. 24-30.
[14] Riccardo Poli;James Kennedy; Tim Blackwell.(2007).Particle swarm Optimization an overview , Swarm intelligence 11, pp33-57
[15] Kim, I,S;Basu,A; Siores, E; (1996) Mathematical Models for control of weld weed penetration in the GMAW Process, *International Journal of Advanced Manufacturing Technology,*12:pp. 303-401.
[16] Farhad Kolahan.; Mehdi Heidari; (2010). A New Approach for Predicting and Optimising Weld Bead Geometry in GMAW, *International Journal of Mechanical System Science and Engineering, 2:2*: pp.138 -142.