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Prediction and Optimization of Welding Bead Shape Parameters in Stainless Steel Cladding

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ABSTRACT

In this paper, the process parameters for the optimum weld bead in the flux cored arc welding (FCAW) of super duplex stainles steel is posed on mild steel (IS-2062). Conducting the experiment and take the input and out process parameters for the further process. The structure of the welding bead has many consistency characteristics, such as the front height, width, the back height, width and the penetration depth of the welding bead. In order to consider these quality attributes together in the proper selection parameters, the modificatied artifical neural networks approach is used to evalute the optimization of each welding process parameter of weild bead geometry and also to define with optimum weilding bead geometry.

1. INTRODUCTION

Now a day's the development of corrosion resistant materials accelerated because of technological developments demanding high performance materials like stainless steels. Stainless steel has excellent corrosion resistance because of thin adherent self-healing passive chromium oxide layer. The stainless steel are comparatively expensive than the mild steel because of high alloy content. The mild steel possess the required strength but lacks the required corrosion resistance. Stainless steels are sensitive to the microstructure and composition this restricts the processing of the stainless steel by hot working processes like rolling, forging and extrusion. However, cladding offers a cost effective viable solution. Cladding is the method of depositing a proportionately thick layer of material over a normally mild steel substrate. The performance of the clad layer depends on the percentage dilution, which in turn depends on the bead shape parameter like penetration depth, bead width and bead height usually determine the productivity of the process. In order to monitor the process, a relationship must be formed between the process parameters that influence the process and the responses to the regulated process. The relationship established by using the mathematical model and neural network models. Neural network is found to be suitable because of its quick learning and the model can be easily updated.

2. LITERATURE REVIEW

Increasing the efficiency of an welding process while preserving or even bettering the welding quality was the goal of researchers in the area of welding process creation. The concept weld cladding typically refers to the application of a relatively thick layer of welding metal to provide a corrosion-resistant surface. In global industry, the development of clad materials is growing as a way of accomplishing an optimal balance of strength, specific properties of surface and economy.

Rao, P.S., Gupta, O.P., Murty, S.S.N. et al [1] addressed the methods used by Taguchi to design the experiments. Process parameters, i.e., wire feed rate, plate thickness, pulse frequency, pulse current magnitude, and travel speed are selected to create models through multiple regression analysis. The models produced were tested for the suitability. The results of the confirmatory experiments of the designs can predict bead geometry with considerable accuracy.

Ganjigatti, J.P., Pratihar, D.C. And RoyChoudhury, A. [2] attempted to establish by using a regression analysis based on the data acquired in the full-factorial configuration of the experiments to create the input and output relationship of the MIG welding process. The outcomes of these regression approaches are evaluated and some concluding observations are developed.

Xu, Wen-jing and Wu, C.S. De-gang, Zou. [3] concluded on the basis of a hydrostatic model for the liquid metal surface is used to examine the onset of bead undercut flaws in high speed welding and the effect of different welding parameters on the bead undercut tendency, based on the actual welding pool geometry and the dimensions calculated from the numerical model.

Xu, G., Wu, C. [4] Defined on the geometry of the welding pool and its dimension in the globular transfer mode during gas metal arc welding (GMAW) were analyzed numerically using the thermal conduction system, which considered the effect of the deformation of the welding pool surface on the heat transfer in a quasi-steady state. The experiments showed that the results expected were in good agreement with the results measured.

Vasudevan, M. & Kuppuswamy, M. & Bhaduri, A. [5] Designed a computational model using a genetic algorithm (GA) to determine the optimum / near-optimum GTAW process parameters for achieving the intended weld-bead profile through automatic 316LN stainless steel welding. Utilising experimental data produced on the effect of process variables on weld-bead geometry, the regression models compare the weld-bead shape parameters with the process parameters formed to determine the objective function of the GA.

Dey, V., Pratihar, D.K., Datta, G.L. et al. [6] Bead-on-plate welding was explained on Al-1100 Aluminium plates using an electron beam-welding unit. The constrained optimization problem was resolved by using a GA with a penalty function approach. The GA was able to identify optimal weld-bead geometry and to prescribe the appropriate process parameters.

Benyounis, K. & Olabi, Abdul Ghani. [7] Discussed on the application of DOE, the evolutionary algorithm and the conceptual network are commonly used to establish a mathematical relationship between the input parameter of the welding parameter and the output variable of the welding joint in order to implement this process in the field of welding. This analysis is categorized according to the welding performance function. i.e., the geometry of the bead and the mechanical characteristics of the welds.

P.E.Murray [8] Defined on the relationship in welding parameter and the process variable developed by the regression and dimensional analysis of experimental results. These relationships were used to define the range of stable welding parameters and to find the welding parameter by regulating the length and welding bead geometry to ensure arc stability, appropriate welding bead size and adequate joint penetration.

Kannan, T., Yoganandh, J. [9] Described on the experimental study carried out to introduce a mathematical model to predict the geometry of clad beads and their relationship of shape to the austenitic stainless steel claddings provided by the process of GMAW. The experiment was performed on the basis of a four-factor, five-level central rotatable composite system with complete study model.

3. PROBLEM IDENTIFICATION

Corrosion is a issue that causes the steel framework to collapse. It cannot be absolutely removed. It can be minimized to some degree by creating a protective layer of corrosion resistance over base metal. Generally, this is a concern in factories like chemical-based industries, fertilizer, food processing, petrol, steam and nuclear power plants.

3.1 Object of the present research

1. Minimum dilution with desired microstructure in order to preserve the alloy content and to have the desired composition resulting the corrosion resistance of the deposited layer matches that of the weld metal.
2. Dilution of the base metal minimized to a very low value without sacrificing the joint integrity.
3. Weld bead free from defects such as porosity, crack, discontinues more depth penetration.

3.2. System Specification

Hardware Requirement

- Automatic wire feed rate
- Inverter base welding machine
- Manipulator for table movement
- Shielding gas supply

Software Requirement

- MAT LAB & C Language are used for the artificial neural network (ANN)
- Optimizations using Microsoft-solver
- Artificial neural network (ANN)

4. FLUX CORE ARC WELDING

FCAW Welding

FCAW is known as flux core arc welding and it was semi - automated or fully automated welding process where a continuous and consumable wire electrode and shielding gas are fed by a welding gun.

Table 1. Composition of stainless steel 316

S.No	Materials presents	% of material present
1	Carbon	0.03%
2	Chromium	20%
3	Nickel	10%
4	Molybdenum	0.75%
5	Magnesium	2%
6	Silicon	0.50%
7	Phosphorus	0.03%
8	Sulphure	0.03%
9	Copper	0.75%
10	Ferrous	Remaining

Figure 1. shows the welding profile and work pieces of weld bead

Cladding

The cladding typically involves in the application of a relatively thick layer (approx. 3 mm) of welding metal to provide corrosion-resistant surface. In manufacturing society, the use of clad materials is increasingly being made as a way of accomplishing an optimal strength, special properties of surface and economy. Among all the different welding processes used, the GMAW was a cost-effective option for small and medium cladding areas owing better efficiency, all positioning capabilities and easy mechanization.

5. DESIGN OF EXPERIMENT

5.1. Introduction

DOE is a mathematical method used to analyse several variables at the same time. Sir, sir. R. A. Fisher of England brought DOE in the early 1920s. The primary objective was to find the optimum water, rain, sunlight, fertiliser and soil conditions required to grow the best crop. Using the DOE method, Fisher was able to lay out all the combination of factors used in the experimental analysis.

5.2. Purpose of Experimentation

DOE have many possible applications to enhance processes and items, including:

- Compare the alternatives.
- Define the significant inputs (factors) influencing the output response.
- Elimination of variability.
- Minimization, Maximization or Targeting of Output (Response).
- Enhancement of process or product Robustness.
- Balance of trade-offs.

5.3. Input Parameters

The following input parameters chosen for the analysis

- The rate of wire feed
- Welding velocity
- Nozzle to the distance of the plate
- The angle of the weld gun
- Rate of gas flow

5.4. Output Responses

The following were the output responses chosen for the analysis

- Penetration depth
- Bead width
- Bead height

5.5. Limits of Parameters

The design matrix chosen for the experiment is five and five-level core composite rotatable designs. The appropriate design matrix with a total of 32 experimental tests was established for five parameters of welding: WFR,WS NTPD, GFR and WGA. The upper (+2) and lower (-2) grades of all five factors as shown in table were calculated by the test run prior to actual welding to ensure that the deposited are exempt from various visual defects like discontinuity, cracking, porosity etc. of the appropriate welding bead. The intermediate grades of-1, 0, +1 of all factors were determined by using formula.

$$X1 = \frac{2[2X - (Xmax + Xmin)}{(Xmax - Xmin)}$$

Where,

Xi = necessary coded value of the X parameter.
X = parameter value of Xmin to Xmax,
Xmin, Xmax = lower and upper limit of parameter, Design of Matrix with parameter:

Table 2. Limits of Parameters

Factor Level	-2	-1	0	1	2
WFR Inch/Min	200	225	250	275	300
WS mm/Min	100	120	140	160	180
NTPD mm	14	16	18	20	22
WGA Deg	90	100	110	120	130
Lit/Min	15	17.5	20	22.5	25

Pinch and the welding volt are constant parameters.
Welding volt= 25
Pinch= 0
The parameters used in the design matrix are
GFR-Gas Flow Rate
WFR-Wire Feed Rate
WS-Welding Speed
NTPD-Nozzle to plate Distance
WGA-Weld Gun Angle
HI-Heat Input
In this design matrix there are
Experimental Run : 16
Centre Point : 6
Star Point : 10
Total : 32

Table 3. Design Matrix

Design matrix for five factor Central composite rotatable design, k=5

S.No	GFR	WFR	WS	NTPD	WGA	HI
1	0	0	0	0	0	1.74
2	-1	1	-1	1	-1	1.508
3	0	0	0	2	0	1.74
4	0	0	0	0	0	1.889
5	0	0	0	-2	0	2.274
6	0	0	0	0	0	1.74
7	0	0	2	0	0	1.353
8	1	1	-1	-1	-1	1.508
9	0	-2	0	0	0	1.466
10	1	-1	1	-1	-1	1.109
11	0	0	0	0	0	1.74
12	1	-1	-1	-1	1	1.479
13	-1	-1	1	-1	1	1.109
14	0	0	0	0	0	1.74
15	0	0	0	0	2	1.74
16	1	1	-1	1	1	1.508
17	2	0	0	0	0	1.74
18	0	0	-2	0	0	2.436
19	-1	1	1	1	1	1.131
20	-1	1	-1	-1	1	1.508

21	-2	0	0	0	0	1.74
22	1	-1	1	1	1	1.109
23	0	0	0	0	0	1.74
24	1	-1	-1	1	-1	1.479
25	-1	-1	-1	1	1	1.479
26	1	1	1	-1	1	1.131
27	-1	-1	-1	-1	-1	1.479
28	-1	-1	1	1	-1	1.109
29	0	0	0	0	-2	1.74
30	1	1	1	1	-1	1.131
31	0	2	0	0	0	1.926
32	-1	1	1	-1	-1	1.131

6. RESULTS AND DISCUSSION

After the welding process was over then the next step is prediction. The software used to find the prédiction value SAS JMP 8 and the module is Artificial neural networks. let see the procedure for these processes.

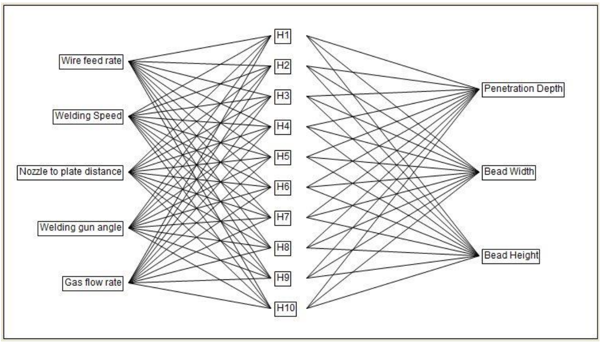

Figure 2. Shows the Input and output paramètres in Neural network

From the above figure the WFR, WS, NTPD, WGA, GFR are all act as a input process parameter and it is selecting as a X-factor. The penetration depth, bead width, bead height are all act as a output parameter and it is selecting as a Y-factor. While the prediction process is going on that time the one hidden layer has ten nodes (H1-H10).

INPUT DATA

There are 5 main data given for this process they are 10 hidden nodes, over fit penalty, number of tours, maximum iterations, converge criterion. While the process is taking place on that time the hidden layer contains 10 hidden nodes, the 10 hidden nodes was helping the process to match the actual valve to the predicated valve.

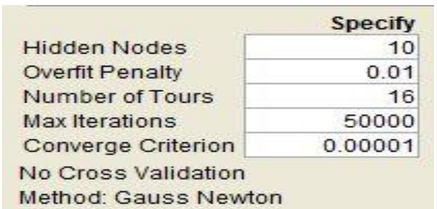

Figure 3. Shows Input Data for prédiction

The over fit penalty is almost like the tolerance valve that will increase the accuracy of the results. The number is tours is 16. Maximum number of operations was taken in the process is 50000. And finally, the converge criterion which is nothing but the percentage of error and the data give to the converge criterion is 0.00001. in this method there is no cross validation and the method used for the process is NEWTON GAUSS These is about the input data.

Formula to find the over fit penalty is

To find the over fit penalty = {weight x Input parameter}+Bias

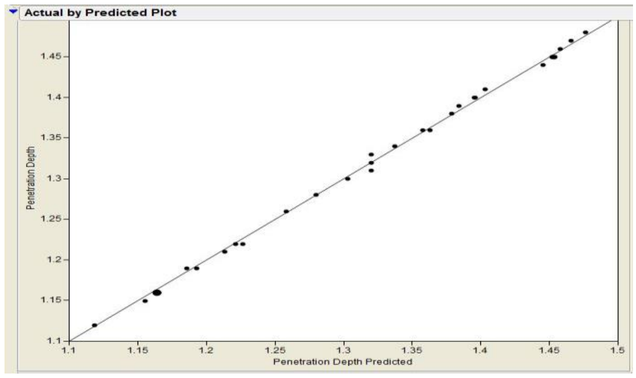

Figure 4. Scatter diagram of Actual penetration depth Vs Penentration depth predicted

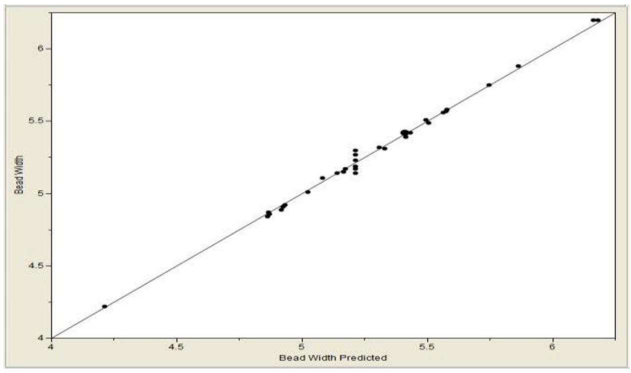

Figure 5. Bead width Vs Bead width predicted

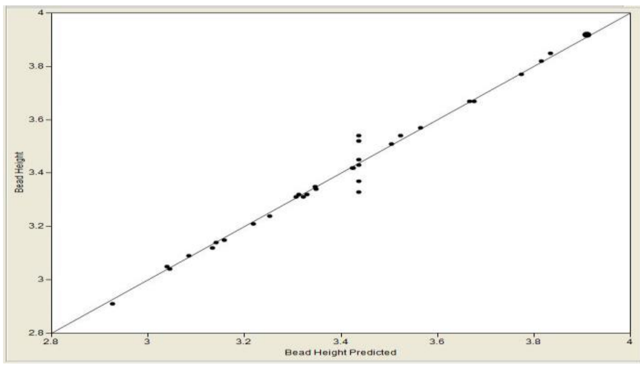

Figure 6. Bead height Vs Bead height predicted

The scatter diagram was drawn between the actually valve and the predicted valve, and the scatter diagram was drawn for the output process parameter are penetration depth, bead width, bead height. In the scatter diagram there was a line pass, the line angle is 450 and the points are valve. In the scatter diagram both the valve actually valve and the predicted valve are lies 900 (ie., perpendicular to each other). And center of the diagram some points are away from the center line that is the (zero) 0 valve in the design matrix.

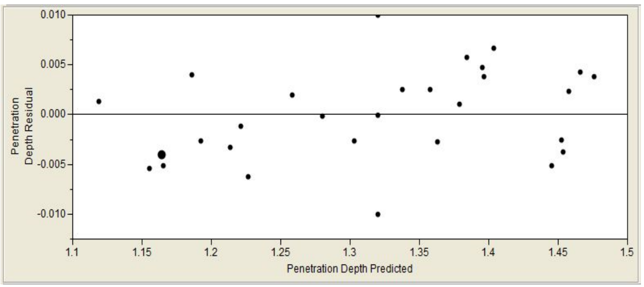

Figure 7. Penetration depth Residual

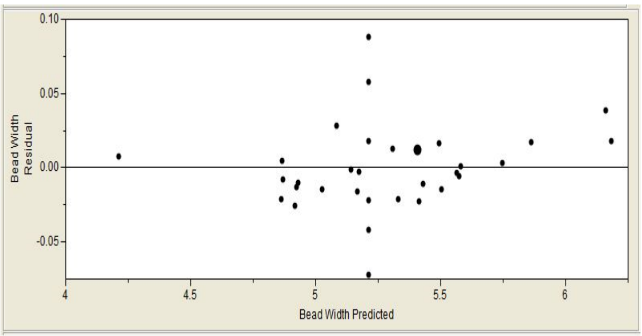

Figure 8. Bead width Residual

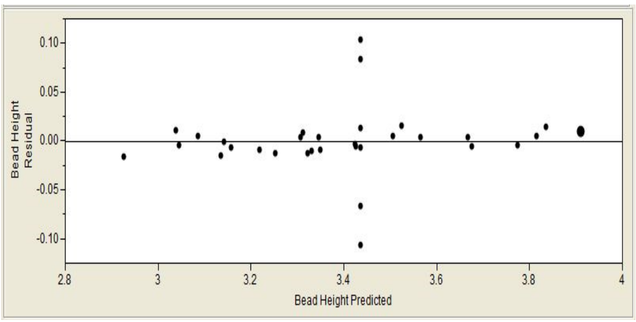

Figure 9. Bead height Residual

The above residual diagram was drawn to find the error, here also the parameter let us consider is penetration depth, bead width, bead height. The center line in the diagram is nil error (ie., zero error) based on the line the error will be decide to the points. And the center of the diagram some points are away from the center line that is the (zero) 0 valve in the design matrix.

These are obtained valve which come through the prediction software for the penetration depth, bead width, bead height.

Current Fit Results

	Objective		
SSE	0.806018313	1	Converged At Best
Penalty	2.5311910728	15	Converged Worse Than Best
Total	3.3372093858	0	Stuck on Flat
N	32	0	Failed to Improve
Nparm	93	0	Reached Max Iter

Y	SSE	RMSE	SSE Scaled	RMSE Scaled	RSquare
Penetration Depth	0.0007796206	0.00609301	0.0709272475	0.05811616	0.9977
Bead Width	0.0256824094	0.03497101	0.1608240007	0.08751163	0.9948
Bead Height	0.0357506719	0.04126031	0.5742670649	0.16536641	0.9815

Fit History

Nodes	Penalty	RSquare
10	0.01	0.99133

Figure 10. Shows the fit results and fit history

7. CONCLUSION AND FUTURE SCOPE

The investigation with the aid of the neural network has made it possible to predict the penetration of the welding bead. Based on this research, it can be inferred with the built model which can be used to accurately predict not only the penetration of the welding bead, but also the width of the bead and the height of the bead within the defined limits of the process parameters. It has the required data for the construction of Artificial neural network and validates model will be used for the prediction of the responses mentioned above. The prediction has done well but the optimized result using the optimization software is to get much better in result accuracy considered as the future work.

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