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PREDICATION OF WELDBEAD GEOMETRY USING ARTIFICIAL NEURAL NETWORK OF AL 6061 ALLOY

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ABSTRACT

MIG has been a functional welding tool due to accuracy for joining metal parts. In any industrial applications, a good quality weld bead geometry is required. In the present work, Taguchi technique was adopted to carry out experiments and established an interrelationship between input parameters and weld bead geometry through an artificial neural network (ANN) for Al6061 alloy. The Levenberg-Marquardt algorithm was used to model for back propagation and the adequacy of modeled neural network is checked by validating data from trained data. The predictions of the model of artificial neural network obtained are closer to experimental result, which reveals that modeled neural network is feasible means for predicting weld bead geometry.

KEYWORDS: MIG, ANN & Weld Bead Geometry

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Original Article

INTRODUCTION

MIG welding is the welding method used to join two metals without contamination of impurity in weld bead. It gives higher quality output at very faster rate and accuracy to weld bead. In every joining process of welding, the field of monitoring and controlling of both input parameters have significant role in determining the quality weld bead. Therefore the concentration must be given to the controlling parameters of welding which affects the MIG welding. The physical structures of weld bead are Back width, Back height, Front height, Front width and depth of geometry. And these above outputs are affected by angle of torch, wire feed rate, standoff distance, welding speed and welding current. In this view many researchers carried out investigations to find effect of input parameters on output results using different source of modeling tool.

LITERATURE REVIEW

Linga Raju and Narasa Raju [1] made an investigation to know effect of rotating electrode wire, voltage and current using pulsed MIG welding on weld bead geometry and reported that there is improvement in weld bead geometry and mechanical properties due to rotation of electrode, however it was noticed that there is decrease in depth of penetration. The further illustrated stated that by increasing voltage and current, the deposition of electrode wire increased.

K. Abbasi et al., [2, 3] has focused on weld bead geometrical changes and its shape factor as a result of changes in welding parameters. In his study reported that there is an increase in heat generated which intern inclines the penetration of depth until the optimum welding speed reached later the heat generated declines which in turn results in decreasing penetration due to further incline in welding speed. Author also mentioned that it improved in shape factor at higher velocity of welding and heat input. The author also worked on metal inert gas welding to know the effect of welding input parameters on mechanical properties of Al 6061 material and reported that increasing inert gas flow rate pressure along with voltage simultaneously at constant gas pressure (230 bars) resulted in good weld bead and increase in strength of weld bead. Sagar et al., [4, 5] made an effort to study influence of welding current, welding voltage and speed of welding on Al 6061 on penetration of depth and tensile strength and reported that current is most influencing factor compared to voltage and welding speed on tensile strength, depth of penetration and toughness. The author further stated that grain size has significant effect on material properties whereas the larger size of grain obtained caused loss in mechanical properties, with increase in hardness.

Y. T. IC et al., [6] worked for the optimization in MIG welding utilizing, DOE and programming of goal methods. The main purpose of investigation is to know a critical GMAW variable for optimized properties. It deals with the methodology for study of GMAW process with multiple objectives utilizing full factorial approach, and result in the fact that proposed experimental plan provides accuracy and quality of weld bead.

S. W Campbell et al., [7] made an approach to study weld bead geometries produced by MIG welding using artificial neural network by utilizing different types of shielding gases. The report results showed that the application of alternative shielding gases caused increase in penetration of depth and effective thickness of fillet weld while the length was declined, and it also reported that welding speed plays a critical role on heat input. The study of sensitivity analysis of the shielding gas configurations had the less influence on the output of the weld bead. The use of alternative shielding gases like argon and CO_2 does not showed much difference in the weld bead geometry.

W Zhang et al., [8] made an investigation to know effect of welding parameters on backside bead width which measures the penetration of depth during welding. The experiments carried under various welding conditions has been performed to produce complete penetration welds with various backside bead widths and get hold of resultant images for reconstructing the weld pool surface and calculate to candidate characteristic parameters. It was noticed that the width, length, and convexity of the 3D weld pool surface provide the optimal model to predict the backside bead width with acceptable accuracy. Sefika Kasman et al ., [9] made investigation on control factors like speed, direction, frequency and fill spacing of LASER micro milling on quality of surface of milling specimen, surface roughness and milling depth. The optimization of output is to reduce roughness surface and maximizing milling depth using Taguchi technique. The analysis results shows that the speed has more influence on the surface roughness, then the beam scan direction and fill spacing and also, the direction has the less significant effect on the depth of milling, which can be ignored.

Shang Jing et al., [10] made investigation to study the cause of joining temperature on micro structure and properties of diffusion bonded Mg/Al joints of Al6061 alloy. It was reported that as joining temperature increases thickness of each layer and width also increases causing changes in microstructure. M Sen et al., [11] made an investigation to know the effect of process inputs in double pulsed MIG on weld bead geometry using design of experiments such as Taguchi technique and RSM. In the authors work, it was observed that high welding current and pulse frequency produced increase the penetration of depth with lower and moderate weld bead geometry. The optimization of process parameters was also conducted using RSM and parameter was compared with experimental trials.

R. A. Ribeiro et al., [12] in their work attempted to achieve optimized weld bead geometry using MIG by adopting statistical methodologies to obtain accuracy in experiments. To increase in depth of penetration a cold wire is added at weld pool during welding and studied curvilinear regressive and sensitivity analyses. The input parameters are federate, welding current and output are weld geometry. The major aim was to know accuracy comparison between sensitivity analysis and curvilinear and results reported showed that regressive analysis can give better accuracy than the sensitivity analysis. Z Wang et al., [13] adopted weld pool surface as input to study weld bead geometry with help of high velocity camera –based vision system to predict weld penetration. A relationship was established between weld depth of pool surface and change in welding voltage in gas metal arc welding. The results analyzed during peak current period there is change in arc voltage and in depth penetration. The modeled result indicated that the change in welding voltage during welding current can provide an true prediction for the depth of the weld penetration during GMAW-P.

Arka Sen and Sudip Mukherjee [14] made an attempt to know the effect of input parameters on weld bead geometry of low carbon mild steel using MIG by adopting design of experiments to carry out experiments using multiple regression method and the equation is simulated to know the effect of parameters on weld bead. Finally, optimization of weld bead geometry is carried out by obtaining a set of input parameters from four different sets. Jawdat A. Al-Jarrah et al., [15] concentrated on design of experiments to minimize the number of experiments by using central composite rotatable design with four factors and five levels in FSW. The parameters considered are rotational velocity, welding ve; locit, welding tool shoulder diameter and welded plate thickness with respect to tensile strength and hardness. It was reported that the hardness inclines with variation in thickness and further, tensile strength decreases with comparing base material.

Ajay N. Boob and G. K. Gattani [16] in their work reported variation of width of HAZ with various parameters such as heat input & welding velocity, and selecting proper values for process variables is necessary in order to control heat-affected zone (HAZ) dimensions and get the required weld bead size and quality. Susheel kumar sharma and Syed Hasan Mehdi [17] studied the control of the welding process parameters on the weld ability of material (low carbon alloy steel (0.14% C)). The investigation was made to study the variation in the depth of penetration using welding current, welding voltage, welding speed, heat input rate are chosen as welding input parameters. The depth of penetrations was measured for each specimen after the welding operation on closed butt-joint.

Saadat Ali Rizviz et al., [18] made an attempt to know the effect on mechanical properties like tensile and yield strength for different welding process using steel material. From the study it was analyzed that shear strength of welded joints strongly dependent on the current, time and electrode in all types of welding process and they also analyzed that weld ability depends on crack sensitivity and welding temperature.

L Manihar et al., [19] Taguchi's technique had been implemented for obtaining parametric combinations to achieve desired weld bead geometry and dimensions related to HAZ. The authors carried experiments at two levels of input parameters such as current, voltage, welding velocity and electrode stick in submerged arc welding Weld bead width measured for each experiment. Finally an optimal parameter setting of weld bead width has been predicted. **G** Senthilkumar et al., [20] the authors focused on imperfections occurs in weld bead geometry by using imperfection of gases as one of the parameter. The intervals of imperfections was assumed by Gaussian distribution and processed through artificial neural network with back propagation. The fitness of curve was tested through chi- square test and found to be 96.25% overall accuracy is achieved.

Deepak Kumar et al., [21] The authors considered MIG for material 1018 steel to know cause of process parameters on output of welded joint by using taguchi technique And also they explained how each parameters effect on result of welded joint. They adopted design of experiment, of L9 orthogonal array and optimized level of current, welding voltage and gas flow rate for increased tensile strength. Vikas Chauhan et al., [22] the authors studied how to advance quality of weld bead by controlling input parameters. To improve in process a Taguchi technique was applied for optimization of tensile strength using three input process parameters such as welding current, welding voltage and speed considering higher –the- better- quality. The significant effect of each parameter was studied by using the Analysis of variance.

P Praveen et al., [23] The authors concentrated on effect of various welding parameters like welding current, base current, peak time and base time, effects on metal transfer mode to achieve good quality using pulse gas metal arc welding. The metal transfer mode study was based on the synchronization of welding signals and high speed camera to characterize and identify conditions under which different types of metal transfer modes are observed to achieve highest metal mode transfer. Further investigation involved to understand the effects of the pulsing parameters on different transition region involved in GMAW-P. Varinder singh et al., [24] the authors concentrated on the influence of FSW parameters of two dissimilar joint by using Al6061 andAl6082. The considered parameters are welding velocity, tool rotation velocity and tool pin profile on impact strength From ANOVA (analysis of variance) it was found that welding speed as greater influence on impact strength of dissimilar joint.

Y S Tarng and W H Yang [25] the author investigated on the welding process input parameters for obtaining an optimal weld bead geometry in ITG welding. The Taguchi technique is used to formulate the experimental layout, and also to analyze the cause of each welding process parameter and to predict the optimal setting for each welding process parameter. Farhad Kolahan and Mehdi Heidari [26] the author a carried set of experiments to collect a data which are used to assess the effect of GMAW process parameters in weld bead geometry. The process variables considered here are voltage (V); feed rate of wire (F); Angle of torch (A); welding velocity (S) and stand-off distance (D) along with output character include weld bead height, bead width and depth of penetration. The authors also stated that to establish the inter relationships between input and output parameters a Taguchi and regression modeling used. The competence of the model is evaluated using analysis of variance technique. In the further stage, the proposed model is embedded into a Simulated Annealing (SA) algorithm to optimize the GMAW process parameters. The objective is to determine a suitable set of process parameters that can produce desired bead geometry, considering the ranges of the process parameters. Computational results prove the effectiveness of the proposed model and optimization procedure.

Ajit Khatter et al., [27] The authors investigated to make a decision optimal setting of the welding process input parameters in TIG welding on tensile strength ,impact force and hardness. Authors made an investigation to model the weld bead geometry process for predicating the nature of various above mentioned properties. By using Taguchi and analysis of variance technique an optimal solution is find out, which provides us an optimal results of the varying condition. Hsuan-Liang Lin a & Chang-Pin [28] the author investigated parameters affect the quality of TIG welding process. And they apply three different type of design of experiments in integrated form like Taguchi technique, ANN and genetic algorithm to optimize the weld bead geometry. First step was considered for executing initial optimization via Taguchi method and to construct a database for the ANN. In second step, an ANN is used to provide the nonlinear relationship between factors and the response. Then, a GA is applied to obtain the optimal factor settings. The experimental results showed that the weld bead geometry of the optimal welding parameters via the proposed approach is slender than apply Taguchi method only.

From above literature survey it can be concluded that the incline in welding velocity or using cold wire improves depth of penetration for optimum level and further increase in speed may decrease in weld bead properties. It was also said that rotating electrode improves weld bead geometry and appropriate selection of input parameters influence over Heat affected zone (HAZ) and using of alternative shielding gas doesn't have effect over weld bead geometries. From survey it can be concluded that input parameters in welding process causes effect over weld bead geometry. In the present work an investigation has been done to a develop model in order to predict weld bead geometry. Since measure advantage of neural networks which includes extreme computation, powerful memory and rapid learning. It has been reported that the implementation of neural network could minimize the time and cost consumption during process. In the present work, an attempt has been made to develop a neural network model in order to predict accurately the weld bead geometry in the MIG welding process.

NEURAL NETWORKS

Artificial neural network (ANN) is widely used in the artificial intelligence tool for development of model which establishes an interrelationship between input data and output data in non linear form of function. Neural networks exhibits like biological neurons in the function of human brain. A neural network model which follows the central nervous system is part of theoretical neuroscience and computational neuroscience. The measure advantage of ANN is that it provides changes in output for the impact of increased or decreased dataset of input, helps in knowing where the model fits and also it explains where model works better in environment. In the present work five input parameters are considered like angle of torch, wire feed rate, standoff distance, welding speed and Welding current and the responses are Back height and width, Front height and width, and also depth of penetration. The following Figure 1 represents a neural network established for predicating weld bead geometry in MIG welding and Figure 2 gives sectional view of weld bead geometry. In this view analysis of ANN is carried out in two phases. In the first phase, network model is trained while in the second phase, testing data is passed through trained network to validate developed model.

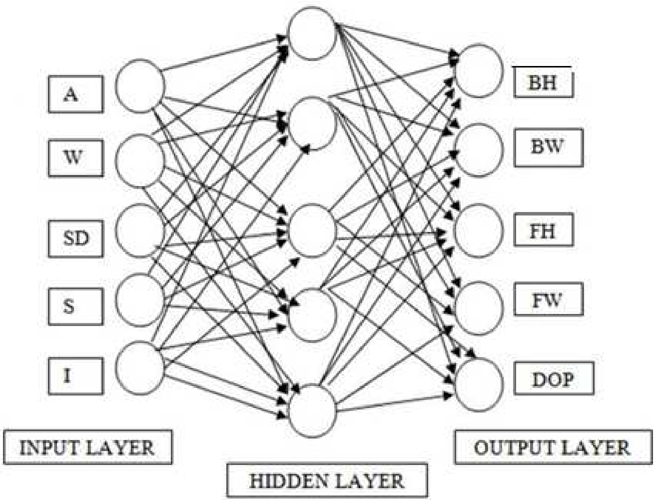

Figure 1: Neural Network of Weld Bead Geometry.

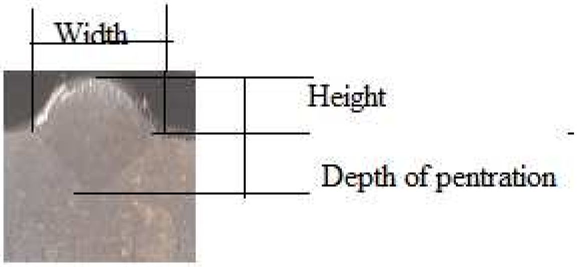

Figure 2: Weld Bead Geometry.

RESULTS AND DISCUSSIONS

The choosing optimal network is a challenging step in ANN. Since it has three layers like input layer, hidden layer and output layer. As there are five inputs and five outputs, the numbers of neurons in the input and output layer are 5 and 5, respectively with back propagation neural network. In order to find an optimal structure of ANN, different numbers of neurons in the hidden layer were adopted and output values are predicated, since back propagation neural network works on the fault feedback correction rule. Therefore, the operation of the neural network model is divided into two steps like neural network forward computing and backward learning.

Forward computing in ANN: In forward computing, the input layers along with input neurons are mentioned and each neuron in the hidden layer determines an input value based on all its input relations. The nodes are connected to each other so that the value of one node will affect the value of another. The relationship between input layer and hidden neurons are specified by weight. And the net input is calculated by the summation of input values multiplied by their corresponding weight. The weight on the connection from the i^{th} neuron in the forward layer on the j^{th} neuron is indicated as Wij. The following equation gives relationship between weights and hidden neuron.

$$net_j = \sum_{i=0}^{n} W_{ij} X_j + X_0$$

$$Y_j = f_{act}(net_j)$$

Where net_j=linear combination of each of x_i values multiplied by w_{ij},x_0 constant

n=Number of inputs to the j^{th} neuron

f_{act}= activation of neuron j

Backward computing: In backward computing, the output generated is compared with necessary output and error is computed for each output neuron.

Training development model: The performance of the artificial neural network mainly depends on the number of hidden layers, and the number of neurons in the hidden layers. Therefore many several trainings were conducted to find an optimal structure of the neural network for each output predication of weld bead geometry in MIG welding. In the present work, 5 input layers such as angle of torch, wire feed rate, standoff distance, welding velocity and welding current and 5 output layer such as Back width, Back height, Front width, Front height and depth of penetration were considered.

The current structure of ANN includes (5 neurons in the input layer,6 hidden layer,5 output layer and 5neuron in the output layer). The five input neurons are A,W,SD,S and I ,and the output neurons are BH,BW,FH,FW and DOP. When the network is executed, all the neurons of any layer process in parallel and they provide their outputs to all the neurons of the successive layer. The process continues in the same way until the results are obtained from the neurons of the output layer. The ANN was modeled using MATLAB. The algorithm used for training of network was Levenberg-Marquardt (trainlm). This algorithm typically takes huge memory but with less time. Training automatically stops when generalization stops improving, as indicated by an increase in the mean square error of the validation samples. The transfer functions used in all hidden layers were logarithmic sigmoidal

Table 1: Performance of ANN Structure in Taguchi Method

Experiment No	ANN Structure	Training Function	Transfer Function (Logarithmic Sigmoidal)	R Correlations Coefficients
Run-1	5-2-5-5	Trainlm	LS	0.94362
Run-2	5-4-5-5	Trainlm	LS	0.97934
Run-3	5-6-5-5	Trainlm	LS	0.98142
Run-4	5-8-5-5	Trainlm	LS	0.96540
Run-5	5-10-5-5	Trainlm	LS	0.97206
Run-6	5-12-5-5	Trainlm	LS	0.96410
Run -7	5-14-5-5	Trainlm	LS	0.94880

Table 2: Weld Bead Responses and Error

W. N	Back width		Back height		Front width		Front height		DOP	
	Predicated in mm	% Error	Predicated in mm	% Error	Predicated in mm	% Error	Predicated in mm	% Error	Predicated in mm	% Error
1	7.52	-0.14	8.96	0.02	7.63	0.29	9.53	0.25	1.49	0.03
7	5.63	0.05	9.3	0.11	5.42	-0.12	9.47	0	2.5	0.07
12	8.15	0.05	9.31	0.11	7.83	0.39	9.33	0.09	3.24	0.5
28	8.46	-0.43	9.47	0.12	8.63	-0.72	9.17	-0.04	3.99	-0.24
29	8.11	0.64	9.83	-0.17	6.82	1.29	9.38	-0.33	4.5	-0.97

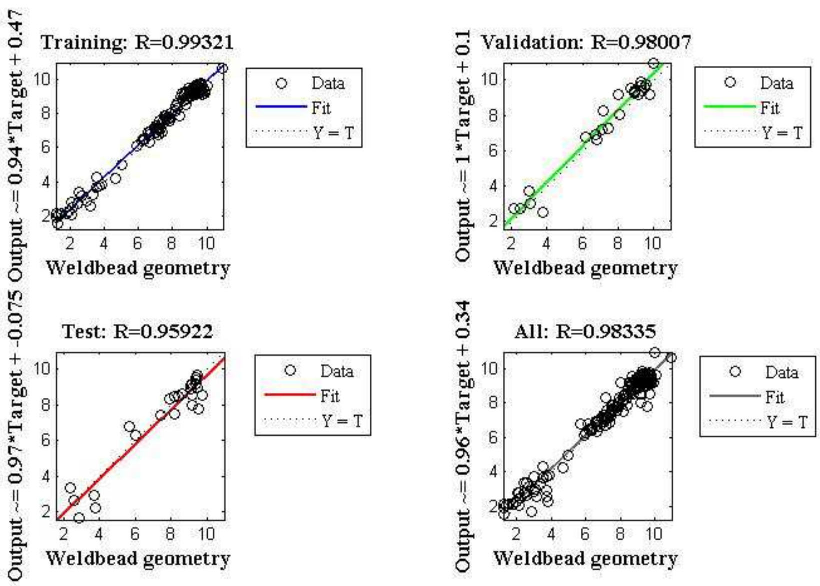

Figure 3: Regression Plot of Weld Bead Geometry.

From the above graph Figure 3 it is clear that the R value in all cases are above 93% which indicates that predicated values are correct and fits the model for all values of weld bead geometry. In all models of curve fit indicates that the output values are nearer to slope line, which elaborates fit curve.

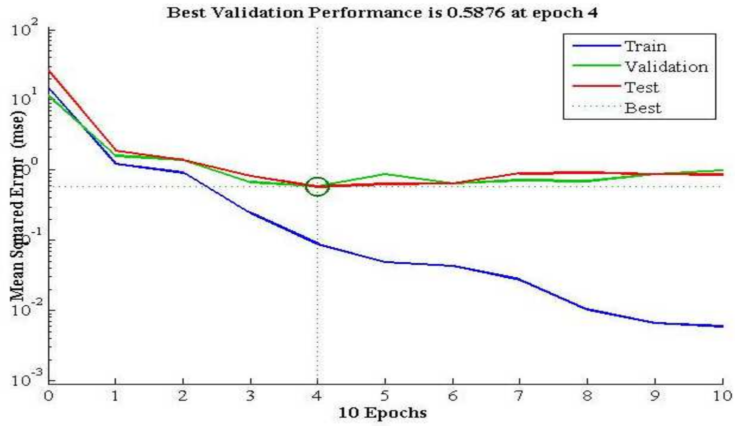

Figure 4: Plot Fit Model in ANN of TT.

From Figure 4 it shows that training stopped when the validation error increased for 4 iterations, which occurred at iteration 10. The final mean-square error is small. The test set and validation have similar characteristics and training data curve diverged to some extent later goes parallel with test data with some mean square error. No significant over fitting has occurred by iteration 10 (where the best validation performance occurs).

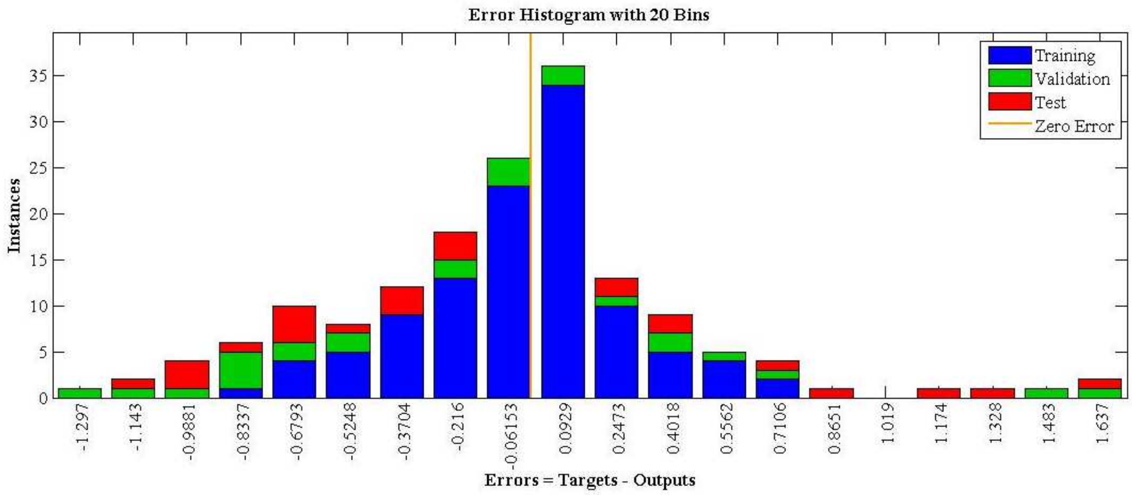

Figure 5: Error Histogram Graph in ANN of TT.

Figure 5 show that the performances of network in terms of mean square error. The blue color bar indicates training data, green bar indicates validation data and red bar indicates testing data. From histogram it is clearly observed that errors fall in between 0.8651 to 1.143. The training terminates with error of -1.297 towards left and error of 1.637 towards right. Also from histogram it is clearly visible that the errors start decreases on both sides after training for some time reduce to zero on both sides.

CONCLUSIONS

The conclusions from above discussion are

- Artificial neural network can be applied for predication weld bead geometry with accuracy in the results.
- The actual values of weld bead geometry fits for 98%, indicating weld bead geometries fits along the fit curve.
- It can be applied for any application of mechanical process to predict output responses.

- The Taguchi and Response surface methodology design of experiments have been found to be effective to learn weld bead input parameters interaction on responses of weld bead.

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