ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 2, Issue 2, February 2013

Analysis of Depth of Penetration and Bead Width of Shielded Metal Arc Weld under Magnetic Field Applying Artificial Neural Networks

R. P. Singh[1], R. C. Gupta[2], S. C. Sarkar[3]

***Abstract*—Purpose of this research paper is to select optimal welding condition for depth of penetration and weld bead width for mild steel plates using shielded metal arc welding process. In this study, a variety of welding experiments were carried out to optimize the welding process. Welding current, welding speed, welding voltage and external magnetic field were chosen as input parameters, while depth of penetration and weld bead width as output parameters. The applications of magnetic field in welding processes have drawn much attention of researchers. However, the effect of external magnetic field on quality of weld is still lack of understanding. In this paper, the effect of a longitudinal magnetic field generated by bar magnets on the weld was experimentally investigated. Based on the results from welding experiments, optimal welding conditions were selected after analyzing correlation between input and output welding parameters. For this a back propagated feed forward artificial neural network model was trained to predict the output parameters. If four input process variables were fed to the trained model it provided the output variables having values very close to the experimental values.**

***Index Terms*—Artificial neural network, Back propagation, Bead geometry, External magnetic field, Input process parameters.**

I INTRODUCTION

Welding is used as an efficient and much economical method of joining similar or different metals. It has created significant impact on a large number of industries by increasing operational efficiency, productivity and service life of the plants and the equipments [1]. The shielded metal arc welding (SMAW) is the most commonly used method for joining metals in our daily life. The welding processes are required to be automated to obtain high production rate. Depth of penetration is the depth to which the base metal and filler material have melted and mixed during welding process. Weld bead width is the maximum width of the bead of the weld. These geometries depend on the weld process parameters used and can vary for different plate conditions. Establishing the required relationship between the process parameters and weld bead geometry is essential to predict and control the optimal weld bead quality [2]. These relationships can be developed by using artificial neural network method. The shielded metal arc welding process can be made semi-automatic by using the constant motion of cross slide of a lathe machine for speed of welding [3]. If external longitudinal magnetic field is applied, the weld bead becomes wider and some mechanical properties are improved [4]. The present paper has attempted to study the effect of input process parameters of welding like current, voltage, speed of welding and external magnetic field on depth of penetration and weld bead width. To obtain apparent results about main and interaction effects of variables, systematic experiments have been conducted. These results would be helpful in developing trained ANN models of welding variables effects [5]. Some weldment characteristics like depth of penetration and weld bead width are extremely important characteristics for structural integrity in case of welded joints. Several variables affecting the weld quality are unknown; also they may not be easily quantified. All these create difficulties for designing reliable welds and equipments used to produce them. In these circumstances the experience and knowledge of the human welder provides the last steps towards a reliable weld. The presented approach of neural networks methodologies would be an important aid to the weld designer and the welder in attaining the required weld specifications with minimal experimentation.

1R. P. Singh, Mechanical Engineering Department, G. L. A. University, Mathura, Mathura, India, Phone/ Mobile No:0945726122.
2R. C. Gupta, Mechanical engineering Department, Institute of Engineering and Technology, Lucknow. India, Phone/ Mobile No:093369906,
3S. C. Sarkar, Mechanical Engineering Department, Kumaon Engineering College, Dwarahat, India, Phone/ Mobile No: 09411574643,

II EXPERIMENTAL WORK

To investigate the weldment characteristics weld beads were obtained by welding two mild steel flat plates of 150 mm x 50 mm x 5 mm dimensions in butt position using AWS E 6013 rutile electrodes of 3.15 mm diameter. A manual welding machine was used to weld the plates. A lathe machine was used to provide uniform speed of welding to support electrode holder and bar magnet. The work piece was kept on cross slide with some arrangement. Work-piece moved with cross slide. Bar magnet was connected with tailstock with a wooden structure Since the weldment characteristics depend on welding current, welding voltage, speed of welding and magnetic field, we select different set of values of these inputs [6]. Welding currents were chosen as 90, 95,100, 105, and 110 A, arc voltages were chosen as 20, 21, 22,23, and 24V, the welding speeds were chosen as 40, 60, and 80 mm/min and external magnetic field strengths were used as 0, 20,40, 60, and 80 Gauss for the experiments. Current was measured with a clamp meter, voltage was measured with a multi meter and magnetic field was measured with a Gauss meter. To study the bead geometry, each bead was sectioned transversely at two points one near the start (leaving 2 cm from the start) and the other near the end (leaving 2 cm from the end). To get the microstructure, these sectioned beads were ground with emery belt grinder having 0, 2, and 3 grade emery papers then polished with a double disk polishing machine. Etching was done with a mixture of 2% nitric acid and 98% ethyl alcohol solution. To measure the bead height and bead width of each sample a digital slide caliper was used. The average values of bead height, bead width and depth of penetration were measured. Eighteen sets of values out of twenty five such sets obtained were used for training a network based on back propagation algorithm. Remaining seven sets of the values were used for prediction. These data sets are shown in table I. A program of back propagation neural network in C++ was used for training and prediction. In this program one input layer having four neurons, two hidden layers, both having five neurons and one output layer having two neurons, were used.

Fig. I, Grinding Weld Bead Surface

Table I, Data for Training and Prediction

	Serial Number	Current (A)	Voltage (V)	Welding Speed (mm/min)	Magnetic Field (Gauss)	Weld Width(mm)	Reinforcement eight (mm)	Depth of Penetration (mm)
Data for Training	1	90	24	40	0	6.95	1.13	0.79
	2	90	24	40	20	6.94	1.13	0.79
	3	90	24	40	40	6.96	1.14	0.80
	4	90	24	40	60	6.99	1.11	0.77
	5	90	24	40	80	7.03	1.09	0.76
	6	95	20	60	60	6.01	1.06	0.78
	7	95	21	60	60	6.08	1.07	0.76
	8	95	22	60	60	6.10	1.09	0.75
	9	95	23	60	60	6.15	1.11	0.74
	10	95	24	60	60	6.25	1.12	0.72
	11	100	22	40	40	5.94	1.17	0.83
	12	100	22	60	40	5.90	1.15	0.79
	13	100	22	80	40	5.86	1.11	0.76
	14	90	20	80	20	5.91	1.06	0.70
	15	95	20	80	20	5.92	1.09	0.71
	16	100	20	80	20	5.94	1.11	0.74
	17	105	20	80	20	5.95	1.13	0.77
	18	110	20	80	20	5.97	1.08	0.75
Data for Prediction	1	90	23	40	0	6.92	1.14	0.76
	2	95	22	60	40	6.05	1.11	0.72
	3	95	21	80	60	6.04	1.04	0.66
	4	100	24	40	40	6.99	1.16	0.78
	5	105	21	60	40	5.98	1.14	0.77
	6	105	22	60	20	5.96	1.13	073
	7	110	21	60	20	5.97	1.10	0.75

Table II, Measured and Predicted Values with percentage Error

S.N.	Current (A)	Voltage (V)	Welding Speed (mm/min)	Magnetic Field (Gauss)	Weld Wedth(mm) Measured	Weld Wedth(mm) Predicted	Error in Weld Wedth % age	Reinforcement Height (mm) Measured	Reinforcement Height (mm) Predicted	Error in Reinforcement Height (mm) % age	Wedth(mm)Weld Measured	Depth of Penetration (mm) Predicted	Error in Depth of penetration % age
1	90	23	40	0	6.92	6.54	-5.49	1.14	1.10	-3.51	0.76	0.74	-2.63
2	95	22	60	40	6.05	6.42	+6.12	1.11	1.08	-2.70	0.72	0.71	-1.39
3	95	21	80	60	6.04	6.44	+6.62	1.04	1.06	+1.92	0.66	0.70	+6.06
4	100	24	40	40	6.99	6.58	-5.87	1.16	1.14	-1.72	0.78	0.73	-6.41
5	105	21	60	40	5.98	6.41	+7.20	1.14	1.11	-2.63	0.77	0.74	-3.90
6	105	22	60	20	5.96	6.40	+7.38	1.13	1.09	-3.54	0.73	0.72	-1.37
7	110	21	60	20	5.97	6.39	+7.04	1.10	1.08	-1.82	0.75	0.74	-1.33

III METHODOLOGY OF ARTIFICIAL NEURAL NETWORK MODELING

Generally the industrial processes are non-linear, complex and many input variables are involved in processes. The mathematical models are unable to describe the behavior of the processes. ANNs are easy to understand, cost effective and have the capability to learn from examples and have found in many industrial application [7]. The arrangement of neurons into layer and the connection pattern within and between the layers are called as network architecture. The architecture is consisted of three parts: Input layer receives the welding parameters, Hidden layers considered as black boxes and Output layer obtaining the values of bead geometry. The performance of the neural networks depends upon, the number of hidden layers and number of neurons in the hidden layers. Hence, optimum structure is obtained by changing number of hidden layers and neurons by making many attempts. The appropriate neural networks structure was chosen by the trial and error method. Feed forward artificial neural network structure was established by keeping four neurons in the input layer, two hidden layers each having five neurons and three neurons in output layer using C++. It was trained with help of feed forward back propagation (BP) algorithm. The designed neural networks structure was 4-5-5-2 (3 neurons in input layer, 5 neurons in both hidden layers and 2 neurons in output layer). Proposed feed forward neural network architecture is shown in fig. II. Non-linearity and input-output mapping are the useful complement in artificial neural networks. Hence, it has been adapted to model the input-output relation of non-linearity and interconnected system [8], [9].

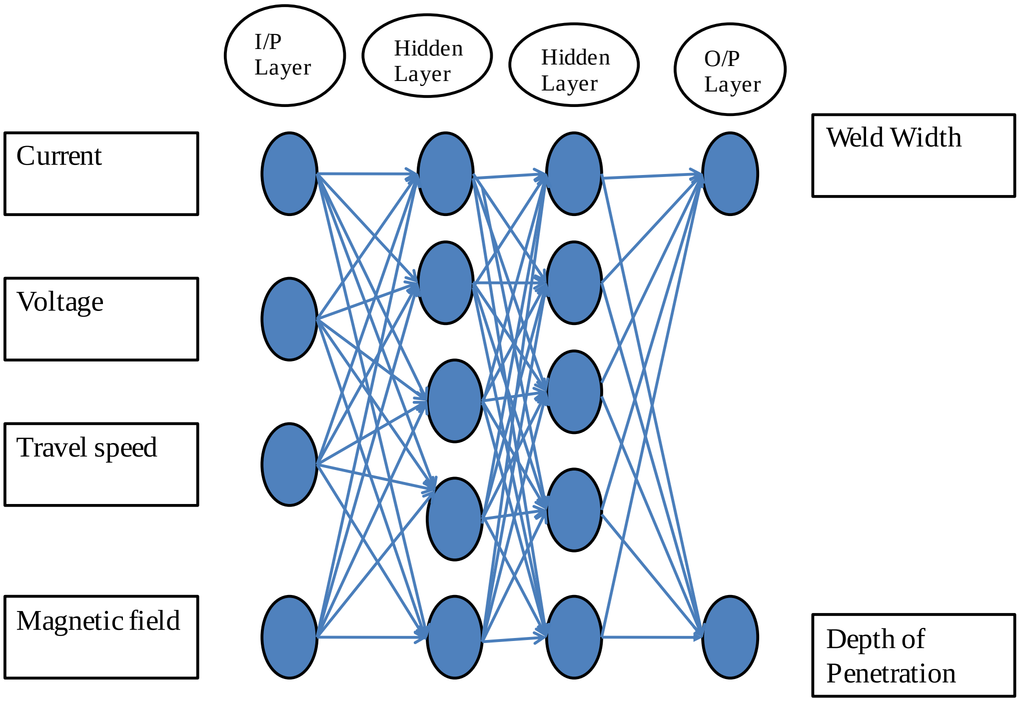

Fig. II, Feed-forward neural network (4-5-5-2) architecture

IV RESULTS AND DISCUSSION

Table II provides, the measured weld bead width, reinforcement height and depth of penetration from the experiment and predicted output values of depth of penetration and bead width using artificial neural feed forward network. The measured and predicted output values are close to each other which show the strong possibility of the use of neural network to predict the weld bead geometry.

A Weld Width

The weld width of the welded joints was almost unaffected if the magnetic field was changed from 0 to 20 gauss or from 20 to 40 gauss. If the field was increased from 40 gauss to 60 gauss, the weld width increased from 6.97 mm to 6.99 mm. and if it was increased from 60 gauss to 80 gauss, the weld width increased from 6.99 mm to 7.03 mm. If the speed of welding was increased from 40 mm/min to 60 mm/min, the weld width decreased from 5.94 mm to 5.90 mm, and if it was increased from 60 mm/min to 80 mm/min, the weld width of the weld decreased from 5.90 mm to 5.86 mm. The effect of voltage was positive for weld width i.e. if voltage was increased from 20 V to 24 V, the weld width increased from 6.01 mm to 6.25 mm. The increment in current, increased the weld width for all the investigated values. If the current was increased from 90 A to 110 A the weld width increased from 5.91 mm to 5.97 mm. The variation of weld width with magnetic field, voltage, welding speed and current were shown in figures III, IV, V, and VI respectively.

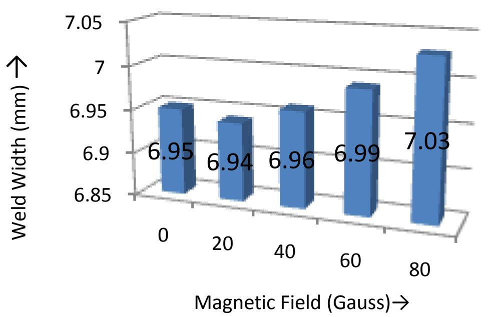

Fig. III, Magnetic Field vs Weld Width
At 90 A, 24 V, and 40 mm/min

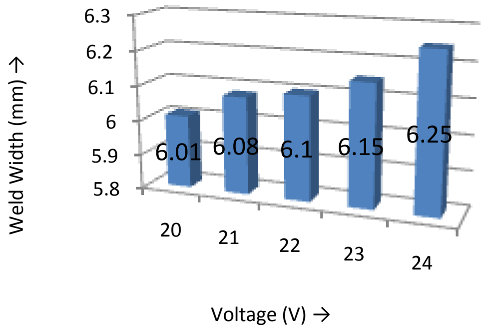

Fig. IV, Voltage vs Weld Width
At 95 A, 60 mm/min, and 60 Gauss

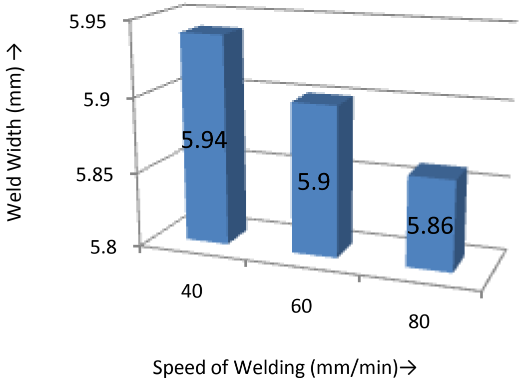

Fig. V, Speed of Welding vs Weld Width
At 100 A, 22 V, and 40 Gauss

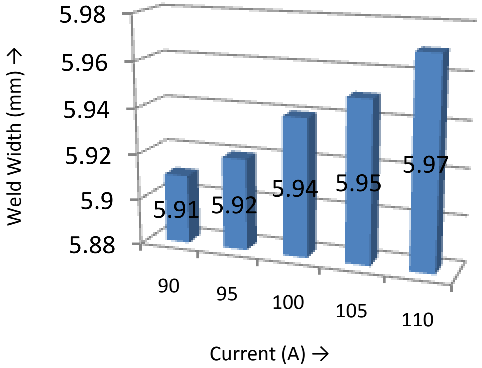

Fig. VI, Current vs Weld width
At 20 V, 80 mm/min, and 20 Gauss

B Depth of Penetration

The depth of penetration of the weld cross-section was measured and the results were displayed in table 1. There was generally no effect of magnetic field on depth of penetration if the strength of the field was less than 40 gauss and if it was increased from 40 gauss to 80 gauss the depth of penetration decreased from 0.80 mm to 0.76 mm. If the speed of welding was increased from 40 mm /min to 80 mm/ min the depth of penetration decreased from 0.83 mm to 0.76 mm. If the voltage was increased from 20 V to 24 V the depth of penetration decreased from 0.78 mm to 0.72 mm. If the current was increased from 90 V to 110 V, the depth of penetration increased from 0.70 mm to 0.75 mm. The variation of depth of penetration with magnetic field, voltage, welding speed and current were shown in figures VII, VIII, IX, and X respectively.

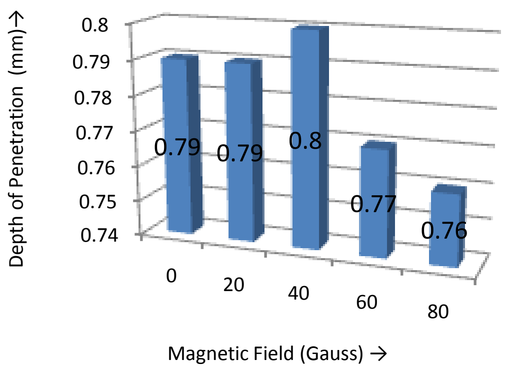

Fig. VII, Magnetic Field vs Depth of Penetration
At 90 A, 24 V, and 40 mm/min.

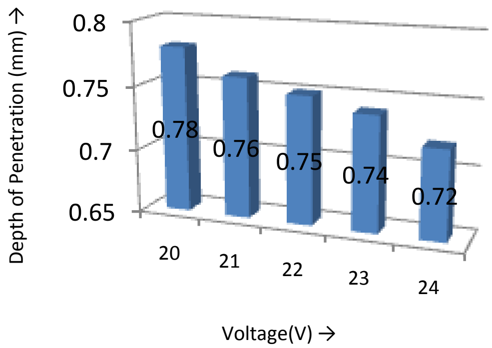

Fig. VIII, Voltage vs Depth of Penetration
At 95 A, 60 mm/min, and 60 Gauss

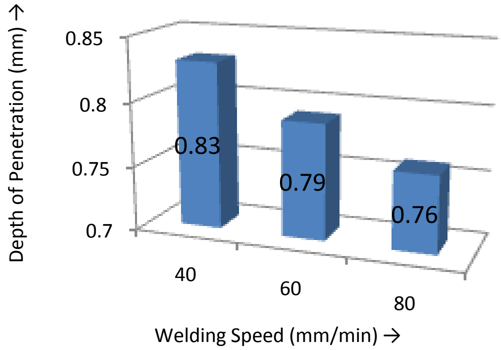

Fig.IX, Welding Speed vs Depth of Penetration
At 100 A, 22 V, and 40 Gauss

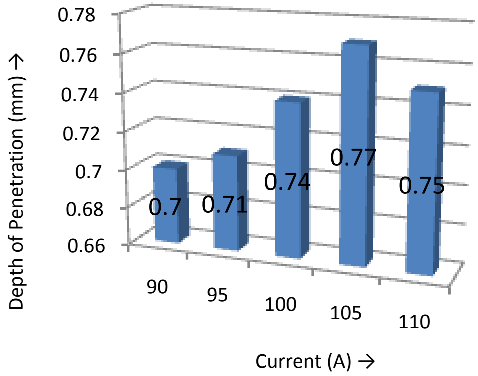

Fig. X, Current vs Depth of Penetration
at 20 V, 80 mm/min, and 20 Gauss

C Prediction of Depth of Penetration and Bead Width using Artificial Neural Networks

The developed neural network architecture was trained with help of back propagation algorithm using 18 data sets. The developed network was tested out of 7 datasets. The training data sets and testing data sets are shown in table I, the testing data were not used for training the network. The % error was calculated between the experimental and predicted values as shown in table II. The % error is ranging between -6.41 to 7.38. The other predictions are in between the above ranges and hence are very close to the practical values, which indicate the super predicting capacity of the artificial neural network model.

V DISCUSSION

In this investigation, an attempt was made to find out the best set of values of current, voltage, speed of welding and external magnetic field to produce the best quality of weld in respect of weld width and depth of penetration. Shielded metal arc welding is a universally used process for joining several metals. Generally in this process speed of welding and feed rate of electrode both are controlled manually but in the present work the speed of welding was controlled with the help of cross slide of a lathe machine hence only feed rate of electrode was controlled manually which ensures better weld quality. In the present work external magnetic field was utilized to distribute the electrode metal and heat produced to larger area of weld which improves several mechanical properties of the weld. The welding process is a very complicated process in which no mathematical accurate relationship among different parameters can be developed. In present work back, propagation artificial neural network was used efficiently in which random weights were assigned to co-relate different parameters which were rectified during several iterations of training. Finally the improved weights were used for prediction which provided the results very near to the experimental values.

VI CONCLUSION

The experimental analysis confirms that, artificial neural networks are power tools for analysis and modeling. Results revealed that an artificial neural network is one of the alternatives methods to predict the weldbead geometry. Hence it can be proposed for real time work environment. Based on the experimental work and the neural network modeling the following conclusions are drawn:

(1) A strong joint of mild steel is found to be produced in this work by using the SMAW technique.

(2) If amperage is increased, weld width and depth of penetration, both generally increase.

(3) If voltage of the arc is increased, weld width generally increases but depth of penetration decreases.

(4) If travel speed is increased, weld width and depth of penetration of weld, both generally decrease.

(5) If magnetic field is increased, weld width, increases but depth of penetration of weld, decreases.

(6) Artificial neural networks based approaches can be used successfully for predicting the output parameters like weld width and depth of penetration of weld as shown in table 2. However the error is rather high as in some cases in predicting reinforcement height it is more than 7 percent. Increasing the number of hidden layers and iterations can minimize this error.

ACKNOWLEDGMENT

We express our gratitude to the GLA University Mathura, for giving us the opportunity to work on the

Research Paper during our busy schedule of teaching work. Our special thanks to the faculties of Mechanical Engineering Department of the University for their Invaluable Guidance throughout our work and endeavor period have provided us with the requisite motivation to complete our Research paper successfully. We are also grateful to our lab assistants Mr. Rajendra Singh, Mr. Rakesh Singh, Mr. Khaim Chandra Sharma and Pandit Ji without whom the work could not be completed.

REFERENCES

[1] S. V. Nadkarni, "Modern Arc Welding Technology", New Delhi, India: IBH Publication, pp. 1, 1988.

[2] R. S. Parmar, "Welding Processes and Technology", Khanna Publishing Company, New Delhi, pp.4, 1997.

[3] M. I. Khan and A. K. Gupta, "A study of Hard Facing under Magnetic Field", ASME Conference, I.I.T. Delhi, pp. 174-176, 1989.

[4] R. P. Singh, R. C. Gupta and S. C. Sarkar, "The Effect of Process Parameters on Penetration in Shielded Metal Arc Welding under Magnetic Field using Artificial Neural Networks", International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 1, Issue 4, pp. 12-17, December 2012.

[5] L. S. Kim, S. H Lee, and P. K. D. V Yarlagadda, "Comparison of multiple regression and back propagation neural network approaches in modeling top bead height of multipass gas metal arc welds". Sci. & Tech.of welding and joining, 8(5), pp. 347-352, 2003.

[6] Md. Ibrahim Khan, "Welding Science and Technology" New Age International (P) Limited Publishers, 2007.

[7] Y. K. Yousif , K. M. Daws and B. I. Kazem, "Prediction of Friction Stir Welding Characteristic Using Neural Network",Jourdan J,Mech & Indus. Engg. 2, pp. 151-155, 2008.

[8] Jeng- Ywan Jeng, Tzuoh- Fei Mau, and Shyeu-Ming Leu, "Prediction of laser butt joint welding using back propagation and learning vector quantization networks", J Mater. Procs. Tech, pp. 207-218, 2000.

[9] R. P. Singh, R. C. Gupta and S. C. Sarkar, "Application of Artificial Neural Network to Analyze and Predict the Mechanical Properties of Shielded Metal Arc Welded Joints under the Influence of External Magnetic Field", International Journal of Engineering Research & Technology (IJERT), Vol. 8, Issue 1, October, 2012, pp. 1-12.

Author

Rudra pratap Singh received the B.E. degree in Mechanical Engineering from MMMEC Gorakhpur in 1992 and the M.Tech. degree in mechanical Engineering in 2009 from UPTU Lucknow. During 1992 to 1999 he worked in Jindal Group as a quality control engineer, from 1999 to till date he is working in GLA group (now GLA University) Mathura as a faculty in Mechanical Engineering Department. He is pursuing Ph. D. (Registered in, March, 2010) from Uttarakhand Technical University, Dehradun. He has published ten papers in international journals and three papers in national conferences.