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Application of Artificial Neural Network to Analyze and Predict the Tensile Strength of Shielded Metal Arc Welded Joints under the Influence of External Magnetic Field

[1]R.P. Singh, [2]R.C. Gupta and [3]S.C. Sarkar
[1] Mechanical Engineering Department, I.E.T., G.L.A. University Mathura, (U.P.)
[2]Mechanical Engineering Department, I.E.T., Lucknow, (U.P)
[3] Mechanical Engineering Departments, Kumaon Engineering College, Dwarahat, (Uttarakhand)

Abstract - *The present study is concerned with the effect of welding current, voltage, welding speed and external magnetic field on tensile strength of shielded metal arc welded mild steel joints. Mild steel plates of 6 mm thickness were used as the base material for preparing single pass butt welded joints. Speed of weld was provided by cross slide of a lathe, external magnetic field was obtained by bar magnets. Tensile strength of the joint fabricated by E-6013 electrodes as filler metals was evaluated and the results were reported. From this investigation, it was found that the joints fabricated have increased tensile strength if either speed of weld or external magnetic field was increased and this mechanical property decreased if either voltage or current was increased. An artificial neural network technique was used to predict the tensile strength of weld for the given welding parameters after training the network.*

Keywords - *Shielded metal arc welding, tensile properties, back propagation, artificial neural network.*

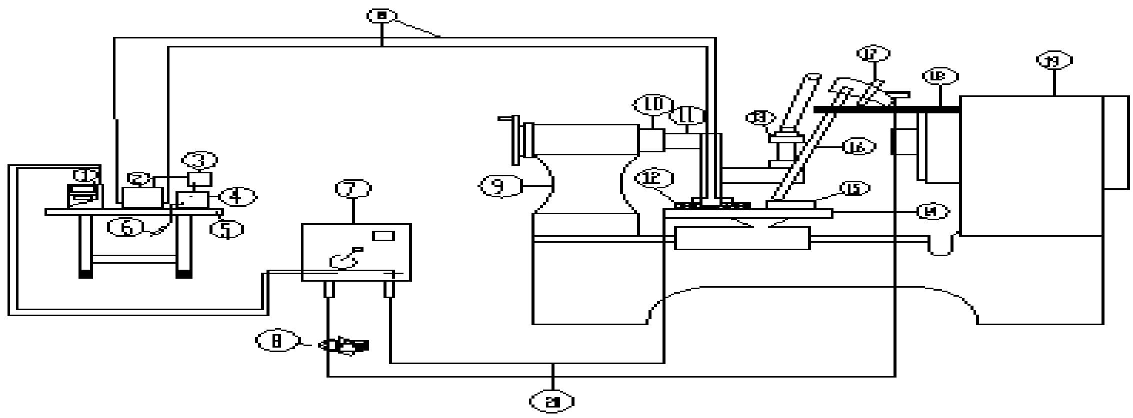
I. INTRODUCTION

Welding is one of the most important and versatile means of fabrication available for industries. It is used to join thousands of different commercial alloys in many different required shapes and sizes. In fact, many products could not even be made without the use of welding, for example, guided missiles, nuclear power plants, jet aircraft, pressure vessels, chemical processing equipment, transportation vehicle etc. Many of the problems which are inherent to welding can be avoided by proper consideration of the particular characteristics and requirements of the process. Correct design of the joint is critical. Selection of the particular process requires an understanding of the large number of available options, the variety of possible joint configurations, and the numerous variables that must be specified for each operation. If the potential benefits of welding are to be achieved and harmful side effects are to be avoided, proper consideration should be given to the selection of the process and the design of the joint. The quality of a weld joint is strongly influenced by different process parameters during the welding process. In order to achieve high quality welds a good selection of the process variables should be utilized, which in turn results in optimizing the bead geometry. In this study an attempt is made to investigate the effect of welding parameters on tensile strength of the welded joint. With this objective, several test specimens were welded with varying welding speed, current, voltage and external magnetic field [1]. Shielded metal arc welding (SMAW) is a metal joining technique in which the joint is produced by heating the work piece with an electric arc set up between a flux coated electrode and the work piece. The advantages of this method are that it is the simplest of the all arc welding processes. The equipment is often small in size and can be easily shifted from one place to the other [2]. Cost of the equipment is also low. This process is used for numerous applications because of the availability of a wide variety of electrodes which makes it possible to weld a number of metals and their alloys. The welding of the joints may be carried out in any position with highest weld quality by this process. Both alternating and direct current power sources could be used effectively. Power sources for this type of welding could be plugged into domestic single phase electric supply, which makes it popular with fabrications of smaller sizes. However, non equilibrium heating and cooling of the weld pool can produce micro structural changes which may greatly affect mechanical properties of weld metal [3]. Mild steel is perhaps the most popular steel used in the fabrication industry for constructing several daily used items due to its good strength, hardness and moderate to low temperature notch toughness characteristics. In these applications, it is important to form strong joints that allow efficient load transfer between the different components and welding is, generally, the preferred joining method [4]. Good weld design and selection of appropriate and optimum combinations of welding parameters are imperative for producing high quality weld joints with the desired tensile strength. Understanding the correlation between the process parameters and mechanical properties is a precondition for obtaining high productivity and reliability of the welded joints.

Although mild steel is widely used in the industry for many applications requiring good strength, hardness and toughness, there is not much information in the open literature about variations in its tensile, hardness and impact properties with changing heat input or other performance-altering welding parameters. The purpose of this work was to determine the effect of travel speed, welding voltage, current and external magnetic field on the tensile strength of mild steel welded joints prepared using the SMAW process. This study will improve the current understanding of the effect of heat input, speed of welding and external magnetic field on the tensile strength of this versatile structural steel [5]. Back propagation artificial neural network having one input layer, one output layer and two hidden layers was used to predict the tensile strength of weld. At first this network was trained with the help of 18 sets of data having input welding parameters (current, voltage, speed of weld and external magnetic field) and output mechanical property (tensile strength) of the weld, which were obtained with the help of corresponding welding and different tests. After this the trained artificial neural network could be used to predict the tensile strength of weld for given sets of input welding parameters [6]. In this way the desired mechanical properties of the weld could be obtained by applying needed input welding parameters.

II. EXPERIMENTATION

The mild steel plates of 6 mm thickness were cut into the required dimension (150 mm×50 mm) by oxy-fuel cutting and grinding. The initial joint configuration was obtained by securing the plates in position using tack welding. Single 'V' butt joint configuration was used to fabricate the joints using shielded metal arc welding process. All the necessary cares were taken to avoid the joint distortion and the joints were made with applying clamping fixtures. The specimens for testing were sectioned to the required size from the joint comprising weld metal, heat affected zone (HAZ) and base metal regions and were polished using different grades of emery papers. Final polishing was done using the diamond compound (1μm particle size) in the disc polishing machine. The specimens were etched with 5 ml hydrochloric acid, 1 g picric acid and 100 ml methanol applied for 10–15 s. The welded joints were sliced using power hacksaw and then machined to the required dimensions (100 mm x 10mm) for preparing tensile tests. The un-notched smooth tensile specimens were prepared to evaluate transverse tensile properties of the joints such as yield strength and tensile strength. The gripping of tensile specimens on universal testing machine was made easy by welding the both ends of specimens with circular rods. Tensile test was conducted with a 40 ton electro-mechanical controlled universal testing machine. Since the plate thickness was small, sub-size specimens were prepared [7].



1. Multi-meter
2. Battery Eliminator
3. Electric Board
4. Gauss Meter
5. Table
6. Measuring Prob
7. Transformer Welding Set
8. Clamp meter
9. Tail Stock
10. Sleeve
11. Link (Wood)
12. Solenoid
13. Tool post
14. Iron sheet
15. Workpiece
16. Electrode
17. Electrode Holder
18. Metal Strip Connected with head stock
19. Head stock
20. Connecting Wires

Fig. No. 1 Welding Set-up (Line Diagram)

Table 1: Data for Training and Prediction

	Serial Number	Current (A)	Voltage (V)	Welding Speed (mm/min)	Magnetic Field (Gauss)	Tens. Strength. (MPa)
Data for Training	1	90	24	40	0	266
	2	90	24	40	20	266
	3	90	24	40	40	266
	4	90	24	40	60	268
	5	90	24	40	80	272
	6	95	20	60	60	284
	7	95	21	60	60	282
	8	95	22	60	60	280
	9	95	23	60	60	278
	10	95	24	60	60	276
	11	100	22	40	40	254
	12	100	22	60	40	258
	13	100	22	80	40	262
	14	90	20	80	20	282
	15	95	20	80	20	280
	16	100	20	80	20	278
	17	105	20	80	20	274
	18	110	20	80	20	272
Data for Prediction	1	90	23	40	0	268
	2	95	22	60	40	278
	3	95	21	80	60	284
	4	100	24	40	40	252
	5	105	21	60	40	272
	6	105	22	60	20	270
	7	110	21	60	20	270

Table 2: Measured and Predicted Values with percentage Error

S.N.	*Current (A)*	*Voltage (V)*	*Welding Speed (mm/min)*	*Magnetic Field (Gauss)*	*Tensile Strength (MPa) Measured*	*Tensile Strength (MPa)) Predicted*	*Error in Tensile Strength % age*
1	90	23	40	0	268	274.5	2.43
2	95	22	60	40	278	275.2	-1.01
3	95	21	80	60	284	276.1	-2.78
4	100	24	40	40	252	273.3	8.45
5	105	21	60	40	272	274.1	0.77
6	105	22	60	20	270	273.3	1.22
7	110	21	60	20	270	273.6	1.33

III. RESULTS

A. *Tensile property*

Transverse tensile property of the joints was evaluated. The specimens were tested, and the results were presented in table 1. The yield strength and tensile strength of unwelded base metal were measured as 359 and 524 M Pa, respectively. But the yield strength and tensile strength of mild steel (fabricated using E-6013, rutile electrode filler metal) joints were reduced by about 50% in both the cases. The tensile strength of the welded joints was 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 tensile strength increased from 266 M Pa to 268 M Pa. and if it was increased from 60 gauss to 80 gauss, the tensile strength increased from 268 M Pa to 272 M Pa. If the speed of welding was increased from 40 mm/min to 60 mm/ min, the tensile strength increased from 254 M Pa to 258 M Pa and if it was increased from 60 mm/min to 80 mm/min, the tensile strength of the weld increased from 258 M Pa to 262 M Pa. The effect of voltage was adverse for tensile strength i.e. if voltage was increased from 20 V to 24 V, the tensile strength decreased continuously from 284 M Pa to 276 M Pa. The increment in current also decreased the tensile strength for all the investigated values. If the current was increased from 90 A to 110 A the tensile strength decreased from 282 M Pa to 272 M Pa. The variation of tensile properties with magnetic field, voltage, welding speed and current were shown in figures 2, 3, 4 and 5 respectively.

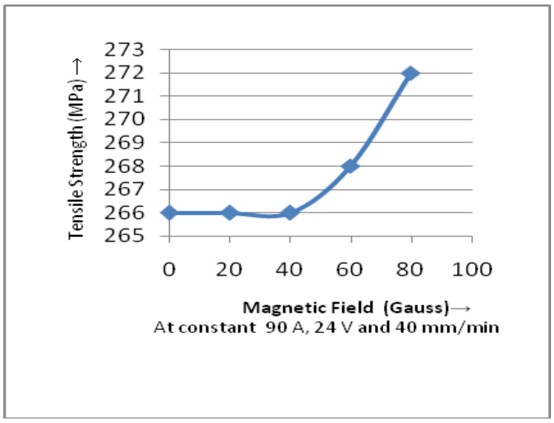


Fig. No. 2 Tensile Strength vs Magnetic Field

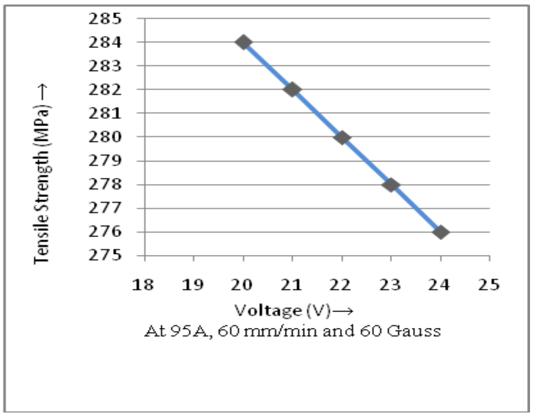


Fig. No. 3 Tensile Strength vs Voltage

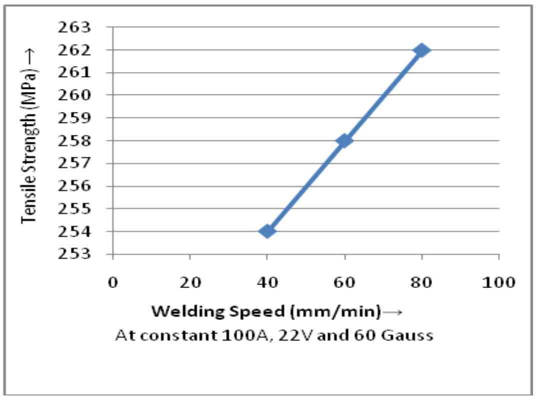


Fig. No. 4 Tensile Strength vs Welding Speed

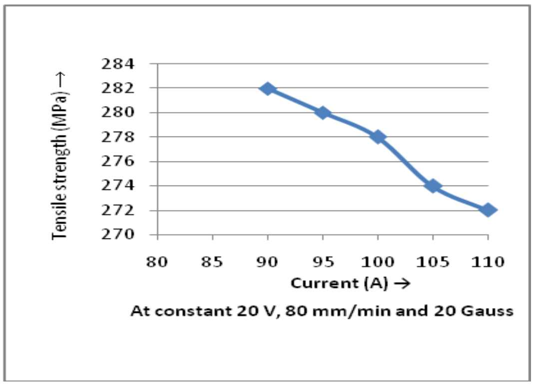


Fig. No. 5 Tensile Strength vs Current

B. PREDICTION MADE BY ARTIFICIAL NEURAL NETWORK

From the table 2, it is clear that the prediction made by artificial neural network is almost the real value. The maximum positive and negative percentage errors in prediction tensile strength values are 8.45 and 2.78 respectively. 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.

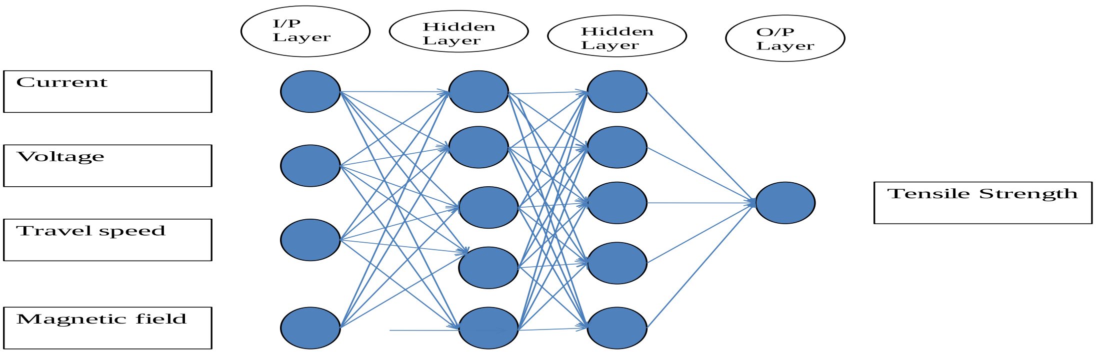


Fig. No. 6, 4-5-5-1 ANN Diagram

IV. 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 tensile strength. 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 [8]. 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 [9]. Finally the improved weights were used for prediction which provided the results very near to the experimental values.

V. CONCLUSIONS

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, tensile strength of weld generally decreases.

(3) If voltage of the arc is increased, tensile strength of weld decreases.

(4) If travel speed is increased, tensile strength of weld generally increases.

(5) If magnetic field is increased, tensile strength of weld generally increases.

(6) Artificial neural networks based approaches can be used successfully for predicting the output parameters like tensile strength of weld as shown in table 2. However the error is rather high as in some cases in predicting hardness and tensile strength it is more than 8 percent. Increasing the number of hidden layers and iterations can minimize this error.

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