INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

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

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Abstract:

The present study is concerned with the effect of welding current, welding voltage, welding speed and external magnetic field on impact 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. Impact strength or Toughness properties of the joints fabricated by E-6013 electrodes as filler metals were evaluated and the results were reported. From this investigation, it was found that the joints fabricated have increased impact strength if either speed of weld or external magnetic field was increased and the impact strength of weld decreased if either voltage or current was increased. An artificial neural network technique was used to predict the impact strength property of the weld for the given welding parameters after training the network.

Keywords: *Shielded metal arc welding, Back propagation, Impact toughness, Artificial neural network.*

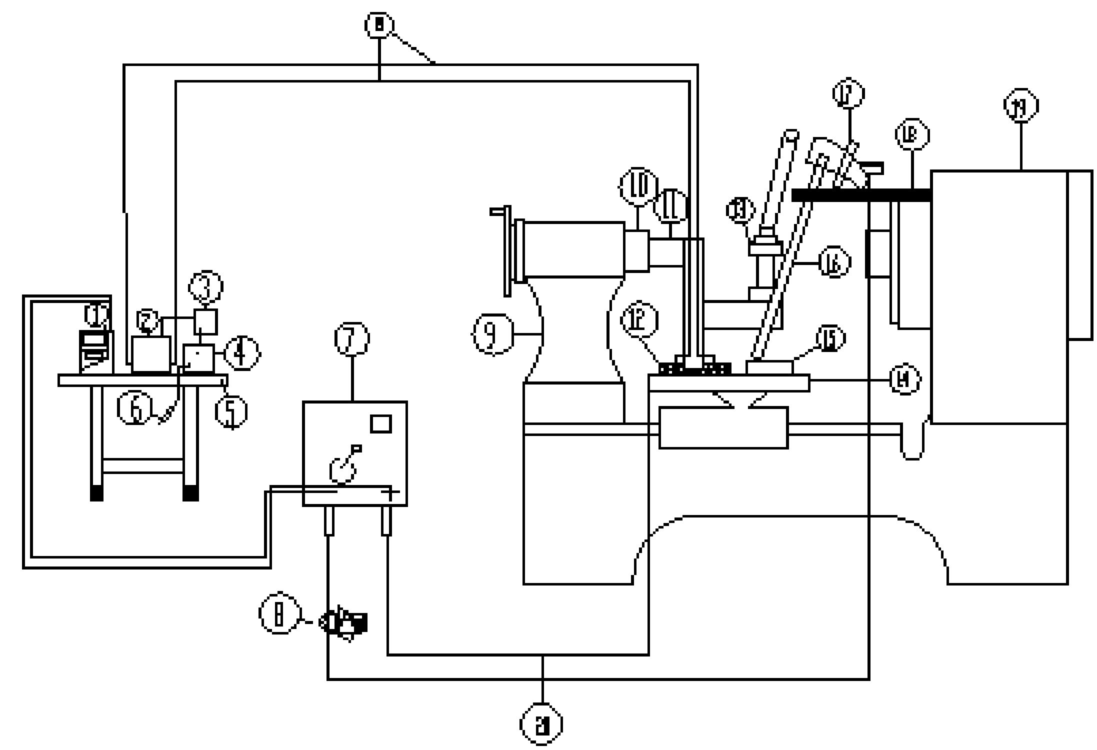
1.Introduction

Welding provides continuous strong joints, alleviates crevice and galvanic corrosion problems often associated with fasteners, and also offers enhanced aesthetics to the application. The SMAW process is used extensively in fabricating various structural components due to its ability to produce a good quality weld deposit and ease of application. One major drawback of the SMAW process is that the electrodes are changed while the work is incomplete and welding is going on. Shielded metal arc welding (SMAW) is a metal joining technique in which a joint is produced by heating the work piece with an electric arc set up between a flux coated electrode and the work piece. This is the simplest of the all the arc welding processes. The equipment is often small in size and can be easily shifted from one place to the other. Cost of the equipment is also low [1]. This process is applied in several applications because of the availability of a wide variety of electrodes which make it possible to weld a number of metals and their alloys. By SMAW process, welding of the joints may be carried out in any position with highest weld quality. Both alternating and direct current power sources are used effectively. Power sources for this type of welding can be used 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 [2]. Steels are still the most shielded metal arc welded materials; hence the present work was to weld mild steel plates by SMAW technique. Good weld design and selection of appropriate and optimum combinations of welding parameters are the most important facts for producing high quality weld joints with the desired strength, hardness and toughness. Improper welding practice which resulted in inadequate toughness, hardness and strength of the welded joints has been linked to several catastrophic service failures [3]. 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 impact 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 impact strength of this versatile structural steel [4]. Back propagation artificial neural network having one input layer, one output layer and two hidden layers, was used to predict the impact strength of weld. At first this network was trained with the help of 18 sets of data having four input welding parameters (current, voltage, speed of weld and external magnetic field) and one output mechanical property (impact 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 impact strength of weld for given sets of input welding parameters [5]. In this way the desired impact strength of the weld could be obtained by applying needed input welding parameters.

Impact test provides information about the impact strength and properties of the weld. Weld properties may behave in different way if a pre-existing fracture in the weld is exposed to a sudden impact, even more so at low or high temperatures. Keeping this in mind, designers must understand what effects unpredictable occurrences such as seismic activity, head-on collisions, or flying debris have on their structural designs. The fracture strength of a weld depends upon temperature, so it is very important for the design engineers to understand the weld's brittle-to-ductile transitional state. Drop-weight tear tests and Charpy V and U notch tests are common impact tests on metals.

2.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. A lathe machine was used to provide constant speed of welding[6]. and [7]. 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. The welded joints were sliced using power hacksaw and then machined to the required dimensions (55mm x 10mm) for impact test Impact test was conducted at room temperature using pendulum type impact testing machine with a maximum capacity of 300 Joule (J) and least count of 2 J. The amount of energy absorbed in fracture was recorded and the absorbed energy was defined as the impact toughness of the material.



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*		

Figure 1:Welding Set-up

	Serial Number	Current (A)	Voltage (V)	Welding Speed (mm/min)	Magnetic Field (Gauss)	Charpy Impact Strength. (J)
Data for Training	1	90	24	40	0	131
	2	90	24	40	20	131
	3	90	24	40	40	131
	4	90	24	40	60	136
	5	90	24	40	80	138
	6	95	20	60	60	138
	7	95	21	60	60	135
	8	95	22	60	60	133
	9	95	23	60	60	133
	10	95	24	60	60	130
	11	100	22	40	40	132
	12	100	22	60	40	134
	13	100	22	80	40	136
	14	90	20	80	20	134
	15	95	20	80	20	131
	16	100	20	80	20	130
	17	105	20	80	20	128
	18	110	20	80	20	126
Data for Prediction	1	90	23	40	0	132
	2	95	22	60	40	135
	3	95	21	80	60	137
	4	100	24	40	40	131
	5	105	21	60	40	128
	6	105	22	60	20	127
	7	110	21	60	20	126

Table 1:Data for Training and Prediction

S.N.	Current (A)	Voltage (V)	Welding Speed (mm/min)	Magnetic Field (Gauss)	Charpy Impact Strength (J) Measured	Charpy Impact Strength (J)) Predicted	Error in Charpy Impact Strength % age
1	90	23	40	0	132	131.8	-0.15
2	95	22	60	40	135	132.1	-2.15
3	95	21	80	60	137	132.3	-3.43
4	100	24	40	40	131	131.7	0.53
5	105	21	60	40	128	130.8	2.19
6	105	22	60	20	127	130.6	2.63
7	110	21	60	20	126	130.9	3.68

Table 2: Measured And Predicted Values With Percentage Error

3.Results

Charpy impact strength (toughness) values of all the joints were evaluated and they were presented in table 1[8]. The magnetic field had no effect on impact strength if it was changed in between 0 and 40 gauss, the impact strength remained constant at 131 J, and after this the impact strength increased if magnetic field was increased upto 80 gauss which was our investigation range. If the magnetic field was increased from 40 gauss to 60 gauss the impact strength increased from 131 J to 136 J and if it was increased from 60 gauss to 80 gauss the impact strength increased from 136 J to 138 J. If the speed of welding was increased from 40 mm/ min to 80 mm/min the impact strength continuously increased. Increment in voltage from 20 to 24V, decreased the impact strength from 138 J to 130 J., if the increment in current was from 90 A to 110 A, the impact strength of weld decreased from 134 J to 126 J. The variation of toughness (impact strength) properties with magnetic field, voltage, welding speed and current were shown clearly in figures 2, 3, 4, and 5 respectively.

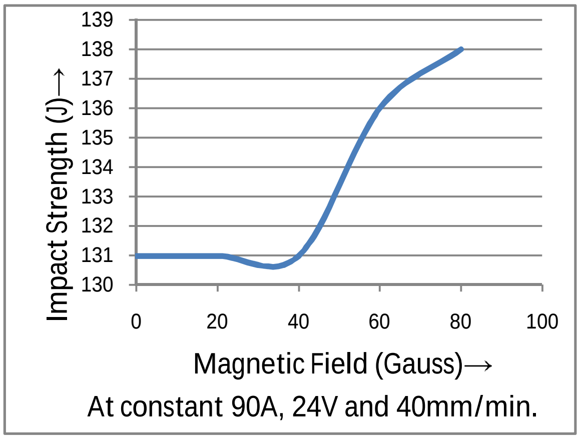


Figure 2:Magnetic field vs Impact Strengt

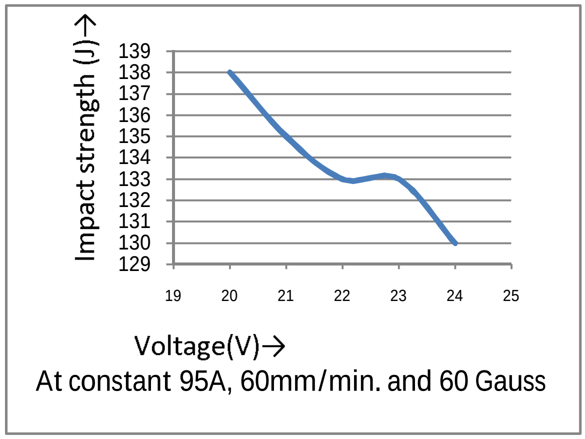


Figure 3:Voltage vs Impact Strength

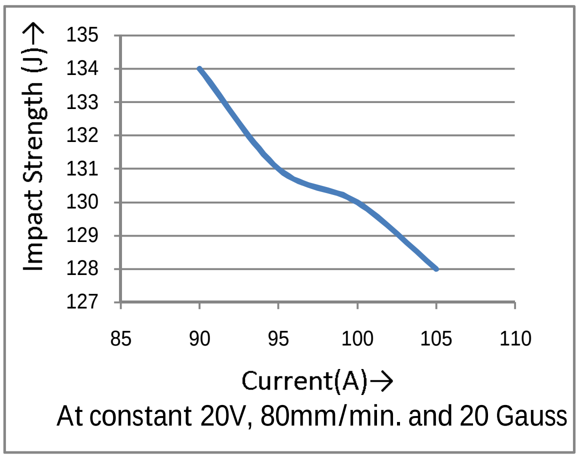


Figure 4: Current vs Impact Strength

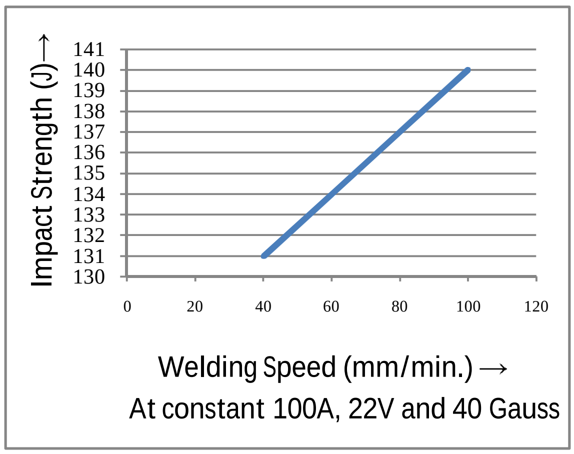


Figure 5:Welding Speed vs Impact Strength

3.1.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 of the impact strength are 3.68 and 3.43 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.

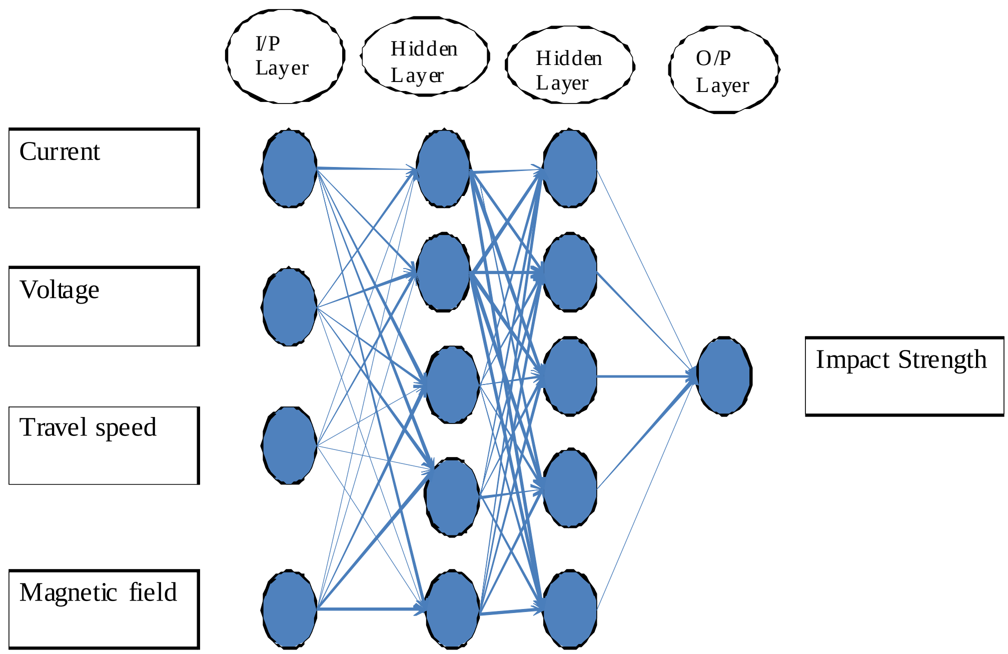


Figure-6, 4-5-5-1 ANN Diagram

4.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 impact 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. 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.

5.Conclusion

Based on the experiment performed and the artificial neural networks following conclusions are drawn:

- A strong joint of mild steel is produced by using the SMAW technique.
- If the current is increased, impact strength of weld, generally decreases.
- If welding voltage is increased, impact strength of weld, generally decreases.
- If travel speed of welding is increased, impact strength of weld, generally increases.
- If external magnetic field strength is increased, impact strength of weld, generally increases.
- Artificial neural networks based approaches can be used successfully for predicting the impact strength of weld as shown in table 2. However the error is rather high as in some cases in predicting impact strength it is more than 3 percent. Increasing the number of hidden layers and iterations can minimize this error.

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