ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 2, February 2019

Estimation of submerged arc Platesweldment properties using ANN and Regression Techniques

Yousif Younis Ashoor,A. AlkareemF.Hassan, Raad Jamal J.

MSc. Student, Mechanical Department, University of Basra College Of Engineering Basra, Iraq
Professor, Mechanical Department, University of Basra College Of Engineering Basra, Iraq
Lecture Mechanical Department, University of Basra College Of Engineering Basra, Iraq

ABSTRACT: The present work focus on ANN and regression analysis models based on experimental data to estimate the mechanical properties, and also comparison between them of submerged arc weldments. ASTM A36 low carbon steel plates 16mm thickness was welded according to orthogonal array. To establish the relationship between input parameters (welding current, Arc voltage and welding speed) and output parameters (ultimate tensile stress, yield stress, impact energy) by SAW process. ASTM A36 low carbon steel plates of dimensions (250 x 250x16 mm) were welded according to orthogonal array ($3^3 = 27$) welding process, to establish the relationship between input parameters (welding current (380-460 Amp), arc voltage (25-35 V) and welding speed (25-40 cm/min)) and output parameters (ultimate tensile stress, yield stress, impact energy. The relationship between input and output parameters for the welding process are conducted by three suitable mathematical models the first one based on ANN used multi-input-multi-output model. The second model based on regression analysis for the mechanical properties of the welded plates. It was found that ANN results are closer to the experimental results than regression results.
.

KEYWORDS: ANN, Regression analysis

I.INTRODUCTION

The American Welding Society (AWS) defined welding as," a localization coalescence (the fusion or growing together of the grain structure of the materials being welded) of metallic or non metallic material that produced by heating the material to the required welding temperature, with or without the application of pressure, or by the application of pressure alone with or without using of filler materials". There are two major classify of the welding process and also, defined by American Welding Society (AWS) . There are two major classify of the welding process and also, defined by American Welding Society (AWS) [1]:

1) Solid state welding: produce coalescence by welding process by application of pressure at a temperature lower than the temperature of the base and filler metal for this case.
2)Fusion welding: any welding process produce by fusion of the base metal in order to make the weld.

Arc Welding is e process create arc between the electrode and the workpiece into the joint by utilize power supply of electric this power converted into the heat through electric arc so that the metal is melted and the interface between the working pieces is reached and welding can be done. Electric arc welding is the most widely and plays an important role in industries, especially for steel and this process is inexpensive. It is used to pass the current through the welding electrode to the base metal to create suitable temperatures for the melting of the metal and the composition of the welding pool and then solidification of the weld metal. The use of arc welding in any place, such as the workshop or the sites of companies etc , needs staff and workers with high skill experiences [2].
The arc welding requires continuous power supply of either direct or alternating electrical current to generate an electric arc between a base material and the electrode to melt material at the welding point.

Arc welding processes can be divided into two classes based on the type of electrode used:
1) **The consumable electrode** dissolves and transferred across the gap to the workpiece and the weld metal is solidified.
2) **The non-consumable electrode** this type of non-molten electrodes does not dissolve and doesn't become part of the weld.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 2, February 2019

Submerged arc welding process is the current passes through the electrode to the workpiece, heat is generated and the welding is covered by flux (a layer of granulated mineral material). The flux covered the tip of the welding wire, arc, and workpiece [3], as show in fig.1.

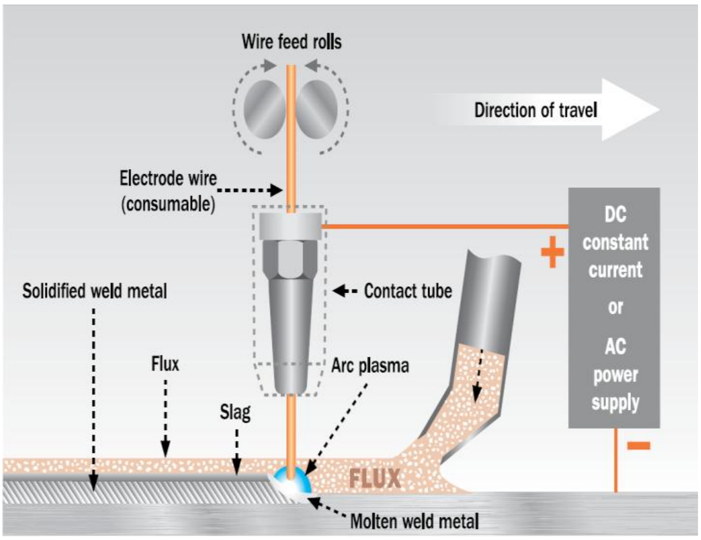

Fig.1: Submerged arc welding process (SAW) [4].

SAW machine operation is used welding speed and high deposition rate of the SAW requires control of wire feeding motor, power supply system used in submerged arc welding operates to maintain a constant voltage and current [5].

A) Methods of analysis and prediction of welding process

1) Artificial Neural Networks (ANNs) are biologically inspired computational models that consist of processing elements called neurons with connections between them that constitute the network structure. They are essentially nonlinear function approximate that utilize process inputs to estimate process outputs. An important feature of the ANNs is the ability to adjust their connections through an adaptive learning process called Learning. Learning can be accomplished using a series of examples and patterns. Information obtained through learning is retained and represented by a set of connection weights within the neural network structure as shown fig.2 [8].

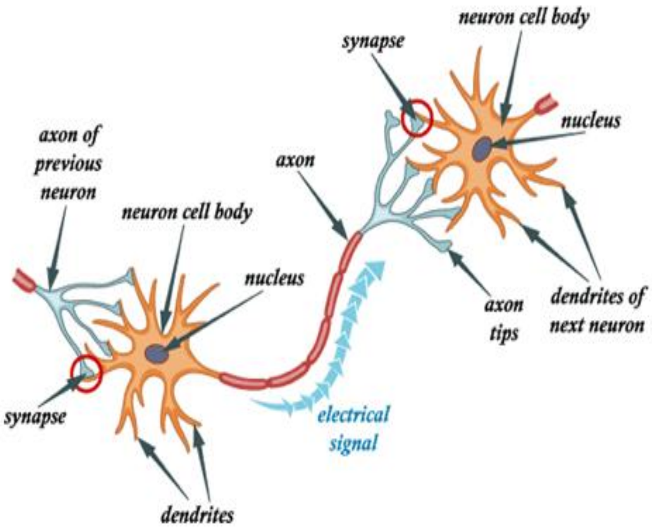

Fig.2: Biological neuron

The key components of neural signal processing are:
Step 1: External signal received by dendrites.
Step 2: External signal processed in the neuron cell body.
Step 3: Processed signal converted to an output signal and transmitted through the Axon.
Step 4: Output signal received by the dendrites of the next neuron through the synapse.

2) Regression analysis is basic model for econometric work is the linear regression model. It is an approach for modeling the relationship between a dependent variable and one or more explanatory variables. Linear regression can be used to fit a predictive model to a set of data values as well as a structural interpretation which allows for hypotheses testing. Structural interpretation means that we consider the covariates to influence the dependent variable, but not the other way round. the multiple regression analysis. This type of analysis is used for modeling and analyzing several variables[7]. The multiple regression analysis extends regression analysis by describing the relationship between a dependent variable and several independent variables.[8]

II. SIGNIFICANCE OF THE SYSTEM

The paper mainly focuses on The aim of the present study is to explore the possibilities improvement of carbon steel plate's weld joints (ASTM A36 Steel) by modifying the existing SAW process parameters namely welding current, arc voltage, welding speed. The Tools that will be used improve the SAW process can be summarized in the following objectives are developing neural network models for prediction of the welded plate's strength characteristics such as tensile strength, yield stress, impact energy and presenting regression models in explicit formula as mathematical function of ultimate tensile stress, yield stress, impact energy.
The study of literature survey is presented in section III, Methodology is explained in section IV, section V covers the experimental results of the study, and section VI discusses the future study and Conclusion.

III. LITERATURE SURVEY

Artificial neural network ANN is a branch in the field of artificial intelligence, which contains a hazy logic that have been created to model the human brain. Therefore it is called the artificial neural network because it is carried out in the computer. The neural network is biological neuron system to predict the automatic learning. There is an ability of predicting complex relationships in a relatively easier way than other computational methods. These networks were used to simulate human's brain methods [9].

Kim et al., used a neural network as well as multiple regression methods (linear and curvilinear equations) in the prediction of process parameters on bead height for robotic multi-pass in butt gas metal arc welding. process and to select suitable model that provided the weld find configuration and properties as output and employed the process parameters as input. The process parameters included three levels of pass number (2, 3 and 4), three levels of arc current (170, 220, and 270 Amp.), three levels of welding voltage (23, 26, 28 V) and 12 to 50 cm/ min of welding speed that depends on weld quality. The results showed that process parameters influence bead height for gas metal arc welding. process. Also, the results showed that neural network models are capable of making bead height prediction of the experimental values with reasonable accuracy and could be better than the empirical models (linear and curvilinear equations).

Kumanan et. al.,presented the application of Taguchi technique and regression analysis to determine the optimal process parameters for semiautomatic submerged arc welding (SAW). Multiple regression analysis was conducted using statistical package for social science (SPSS) to construct the relationship between the dependent variables of bead width, weld reinforcement, depth of penetration and weld bead hardness with welding current, arc voltage, welding speed and electrode stick out. The results indicated that welding current and arc voltage are the significant welding process parameters that affect the bead width and the results showed that the mathematical model could be used to predict the bead geometry for any given welding conditions.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 2, February 2019

Dutta et al., determined the relationship between the input and output in tungsten inert gas (TIG) welding process. They used two neural network-based approaches (back propagation algorithm and genetic neural system)and conventional regression based on full factorial design of experimental (DOE). namely , speed of welding , rate of wire feed %, cleaning , gap rate, current of welding) include parameters for input and (front, back height , front and back width) output process parameters of TIG welding process .

S. Datta, et.al., developed nonlinear mathematical models in order to reveal the direct and interactive effects of process parameters on mechanical properties of butt weldments by Submerged Arc Welding (SAW). Based on factorial design without replication, experiments were conducted with different levels of process parameters (welding current, electrode stick-out and voltage on mild steel plates) to obtain butt welds. Various bead quality and performance parameters like hardness, toughness, yield strength and ultimate tensile strength were measured for each of the butt welds made in the experimental runs. Multiple linear regression method was used to calculate the coefficients of the models. The significance of the coefficients for each of the factors in the models was calculated by Analysis of Variance (ANOVA) Method. The predictions as given by the models have been represented graphically to show the influence of the process control parameters on bead quality in terms of mechanical properties associated with the weldments.

Mohammad W. Dewan et al., used FSW with welding parameters including welding speed (V), spindle speed (N), plunge force (Fz) in order to determination the ultimate tensile strength(UTS). The 2219-T87aluminum alloy was used in this work. The total data 73 included welded and tensile properties by using optimized ANFIS model. It is predicting (UTS) for FSW and the input (V, N, Fz, EFI: Empirical Force Index) utilizing a matlab platform. By comparing between ANFIS and ANN predicted results that optimized ANFIS better than ANN. The resulted lowest from ANFIS model RMSE and MPE value of 29.7 Mpa and 7.7% respectively and the corrected is non-linearly with the parameters (V, N, Fz). The input variable for ANN (V, N and EFI) resulted in (min) RMSE (36.7Mpa) and MAPE (10.09%).

IV. METHODOLOGY

In this chapter the experimental work of submerged arc welding process is described and presented. Three parameters of the (SAW) process will be used in this study: welding speed, current and voltage. Carbon steel samples werewelded and then tested byusing radiograph (RT), i.e. X-ray, tensile and impact and hardness tests. The flow chart of the experimental procedures illustrates as shown in the figure (3.1).

In this work, the base metal low carbon steel plates (ASTM A36) with thickness of 16mm (5/8 in) is used as a base metal for the experimental work. It is widely used in steel structure, i.e (pressure tanks ,building structures ,vessels and pipeline for petroleum industries). These plates are cut to dimensions of (125 x 250x16 mm). Both surfaces are cleaned to remove oxides, dirt and rust before welding. The chemical composition of the carbon steel shown in the table1 and the mechanical properties to ASTM A36 as shown in Table2.

Table1. The chemical composition of ASTM A36 of carbon steel

Composition	Standard %	Test %
Carbon, C	0.26 %	0.19-0.21%
Iron, Fe	99.0 %	98.6-98.7%
Manganese, Mn	0.75 %	0.53-0.54%
Phosphorous, P	≤ 0.040 %	0.050%
Sulfur, S	≤ 0.050 %	0.030-0.043%

Table2 .The mechanical properties of ASTM A 36 of steel carbon

Ultimate tensile stress(MPa) Min		Yield stress (MPa)Min	
Standard	Test	Standard	Test
400-550	405	250	261

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 2, February 2019

Preparation of the specimens twenty seven pairs of carbon steel plates have been prepared before the weld and machined to the required dimensions (250 x250x16 mm) , V-groove partial penetration- butt joint with 8 mm face root and angle of 60° with 2mm opening (gap between two specimens) was prepared to fabricate SAW joints as shown fig.3. The preparation of all specimens' joint edges (bevels) was done by grinding machine and (disc polishing).
The range of parameters is welding speed, arc voltage and current can be shown in table3.

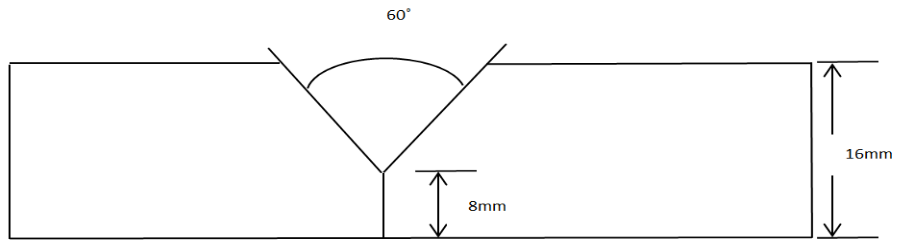

Fig.3-V-groove partial penetration- butt joint

.

Table3. Input parameters and their levels of SAW process

Input process Parameters	Notation	Unit	Max. value +1	Medium Value 0	Min. value -1
Welding speed	WS	cm/min	40	30	25
Arc voltage	AV	V	35	30	25
Welding Current	WC	A	460	420	380

In the present study, selection of orthogonal array standard for many experiments was performed .The parameters chosen for the experiment was: welding current, welding voltage and welding speed. for each parameter was assigned three levels, which are as shows in table4. The experiments were performed according to the 27 (3^3). In the orthogonal array, the first column was assigned to welding current , second column was assigned to welding voltage and the third column was assigned to welding speed.

Table4. Orthogonal array of experimental results

Sample No.	Current A	Voltage V	Welding speed Cm/min
1	-1	-1	-1
2	-1	-1	0
3	-1	-1	+1
4	-1	0	-1
5	-1	0	0
6	-1	0	+1

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 2, February 2019

7	-1	+1	-1
8	-1	+1	0
9	-1	+1	+1
10	0	-1	-1
11	0	-1	0
12	0	-1	+1
13	0	0	-1
14	0	0	0
15	0	0	+1
16	0	+1	-1
17	0	+1	0
18	0	+1	+1
19	+1	-1	-1
20	+1	-1	0
21	+1	-1	+1
22	+1	0	-1
23	+1	0	0
24	+1	0	+1
25	+1	+1	-1
26	+1	+1	0
27	+1	+1	+1

.

A) Mechanical Tests

1) Tensile Test

Tensile testing is one of the most common destructive tests. This test computes the tensile stress and yield stress of a sample that has special dimensions as shown in fig.4 . The sample was prepared according to [ASME IX-2017(QW-151.2) and API-STANDARD-1104(5.6.3) and the samples were made as a vertical piece on the welding direction**.**

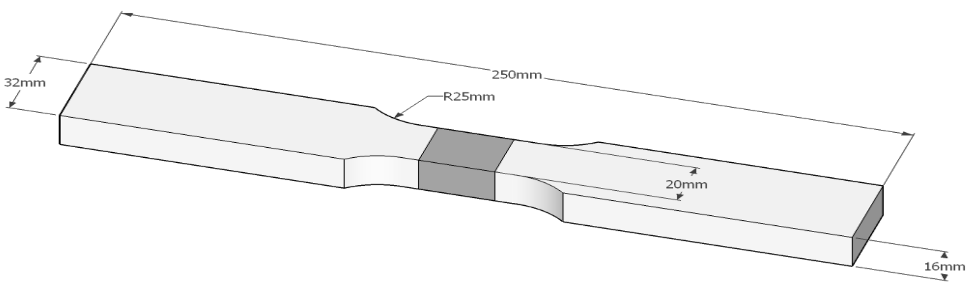

Fig.4.Dimensions of tensile testing specimen

2) Impact Test

The test is a measure the absorbed energy of material. Absorbed energy measured from the sample depending on the amount of energy absorbed from the broken sample and the sample is perpendicularon the direction of the weld. The sample contains a chisel (V) at 45 angle, 2 mm depth, dimensions according to ASME (QW-463.1(f)) as shown in fig.5 and fig.6 after impact test.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 2, February 2019

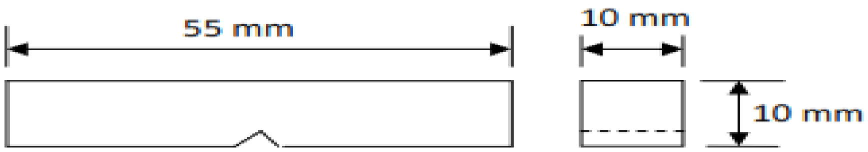

Fig.5. Dimensions of impact test specimen

Fig.6.After impact test

V. EXPERIMENTAL AND THEORETICAL RESULTS

Table5: result of experimental test

No.SP.	Current A	Voltage V	WS (Cm/ min)	UTS MPa	Yield stress MPa	Impact (J)
1	380	25	25	435	308	200
2	380	25	30	442	313	206
3	380	25	40	446	318	213
4	380	30	25	434	301	155
5	380	30	30	436	308	200
6	380	30	40	441	317	204
7	380	35	25	432	300	152
8	380	35	30	434	303	163
9	380	35	40	440	309	176
10	420	25	25	429	302	162
11	420	25	30	440	307	166
12	420	25	40	444	312	175
13	420	30	25	435	297	141
14	420	30	30	437	300	153
15	420	30	40	439	314	167
16	420	35	25	432	299	155
17	420	35	30	435	303	151
18	420	35	40	436	308	168
19	460	25	25	439	298	155
20	460	25	30	430	301	158
21	460	25	40	434	304	169
22	460	30	25	424	296	138

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 2, February 2019

23	460	30	30	428	299	149
24	460	30	40	435	300	152
25	460	35	25	431	296	150
26	460	35	30	433	299	158
27	460	35	40	435	304	168

A) ANN RESULT

Table6. Comparison between the experimental and the predicted multi ANN model results welded mechanical properties and geometry for testing samples. Five values of the experimental results were used and compared with the corresponding values of ANN. The maximum percentage error in the ultimate tensile stress, yield stress, impact energy, hardness number, width and height of the welding bead are 1.9115%, 2.0515%,7.5536%, 2.7755%, 8.9423%,144.3814% respectively.

Table 6: Comparison between the experimental and the predicted multi ANN model results Welded mechanical properties and geometry for testing samples

UTS (MPa)			YS (MPa)			Impact energy (J)		
EXP	ANN model	Error %	EXP	ANN Model	Error %	EXP.	ANN model	Error %
435	435.1231	0.0283	303	304.3286	0.4385	151	162.406	7.5536
435	432.6702	0.5356	300	306.1545	2.0515	152	160.4722	5.5738
444	442.0682	0.4351	312	313.4312	0.4587	175	181.8463	3.9122
434	431.4071	0.5974	304	302.2313	0.5818	169	164.5282	2.6461
428	428.0057	0.0013	299	297.2668	0.5797	149	155.403	4.2973
424	432.1049	1.9115	296	295.1593	0.2840	138	141.2092	2.3255
Mean error %		0.5849	Mean error %		0.7324	Mean error %		4.4385
Correction coefficient		0.99971						

B. Direct effect of SAW parameters on properties of welded plates

1. Effect welding current on plate's welded and geometry

As the current increased from 380 to 460A, the ultimate tensile stress decreased and the yield stress decreased as shown in Fig.7. When the current is increased welding heat input increases, which means that (the heat input is directly proportional to the current value). Therefore any reduction in the UTS and yield stress is because of the increase of heat input and temperature.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 2, February 2019

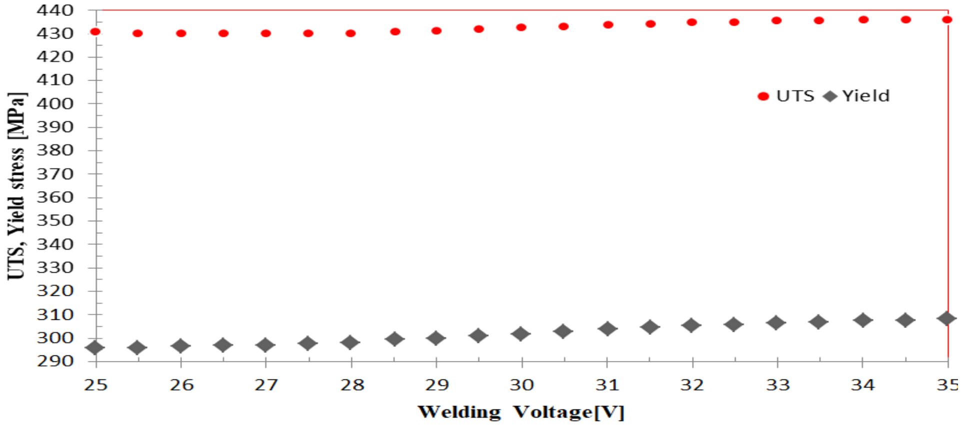

Fig.7: effect current on the tensile strength and Yield strength.

The effect of voltage on ultimate tensile stress and yield strength for the welded are shown in fig.8, However increase in welding voltage from 25 to 35V will increase the ultimate tensile stress and the yield stress . This increase is because of the heat input inversely proportional to voltage. Then the ultimate tensile stress and yield stress increase with welding voltage increase.

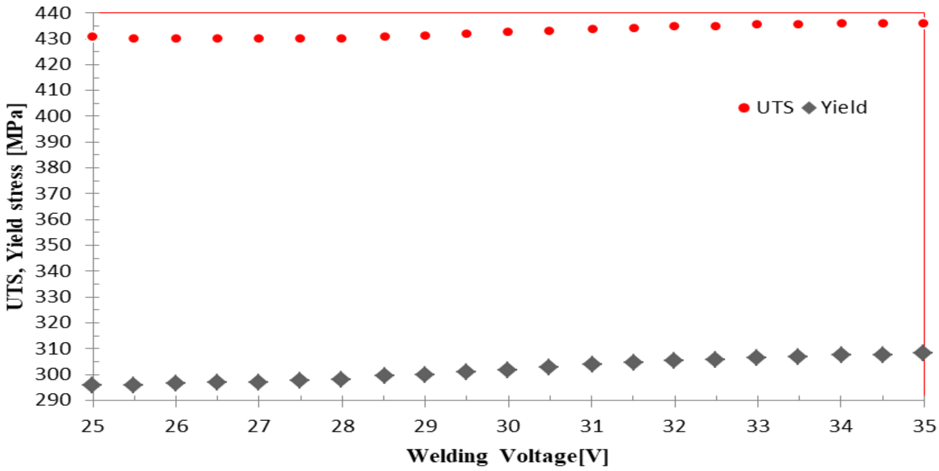

Fig.8: effect voltage on the UTS and yield stress.

Increase in welding speed from (25 to 40) cm/min decreases the ultimate tensile stress and yield stress respectively. The range of welding speed increase the UTS and yield stress will decrease as shown in fig.9.

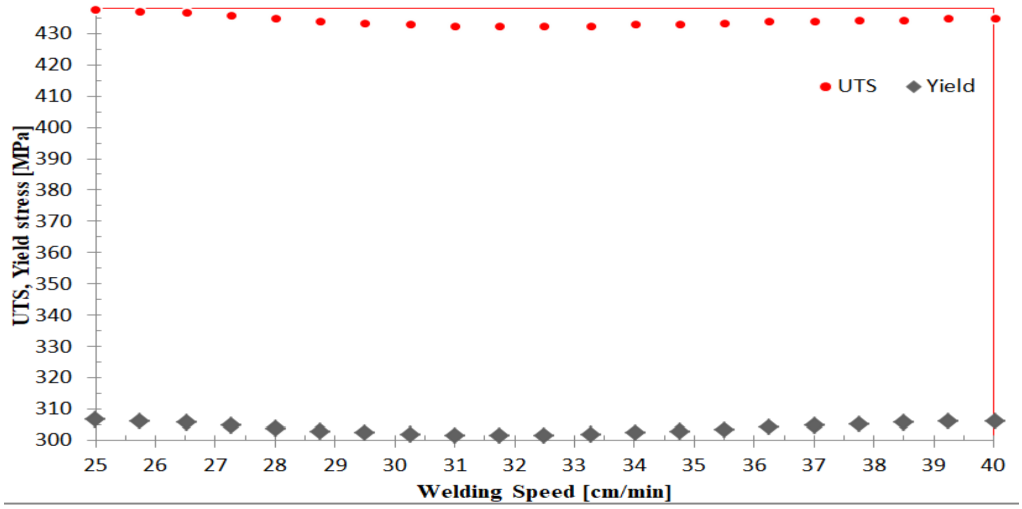

Fig.9: effect welding speed on the UTS and yield stress.

C. REGRESSION MODEL

Regression procedure is used to develop the required mathematical model for estimate the ultimate tensile stress, yield stress, impact energy, hardness. The response function representing the strength of welded plates by $Y = f(WC, AV, WS)$. Equation .1 shows the 2nd order polynomial (surface factor k').[15]

$$Y = b_o + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x_{ii}^2 + \sum_{i<j} b_{ij} x_i x_j \quad (1)$$

Where
b_o is the free term of the regression equation.
b_1, b_2, b_3 and b_4 are coefficients linear terms.
$b_{11}, b_{22}, b_{33}, b_{44}$ and b_{55} are quadratic terms the coefficients.
$b_{12}, b_{13}, b_{14}, b_{15}, b_{55}, b_{23}, b_{24}, b_{25}, b_{34}, b_{35}$ and b_{45} are coefficients interaction terms.
k is number of trails.
IBM SPSS Statistical 24 was used to calculate the values of these coefficients. The mathematical models that calculate by the above analysis are represented below:

$$\text{Ultimate tensile stress} = (-0.274 * WC - 0.109 * AV + 0.339 * WS - 0.135 * WC^2 - 0.182 * WS^2 + 0.189 * WC * AV - 0.065 * WC * WS - 0.117 * AV * WS) * 11 + 438.157 \quad (2)$$

$$\text{Yield stress} = (-0.577 * WC - 0.182 * AV + 0.551 * WS - 0.226 * WC^2 + 0.104 * AV^2 - 0.057 * WS^2 + 0.223 * WC * AV - 0.026 * WC * WS - 0.022 * AV * WS) * 11 + 305.02 \quad (3)$$

$$\text{Impact energy} = (-0.366 * WC - 0.211 * AV + 0.25 * WS - 0.331 * WC^2 - 0.152 * AV^2 - 0.14 * WS^2 + 0.315 * WC * AV - 0.114 * WC * WS - 0.008 * AV * WS) * 37.5 + 160.688 \quad (4)$$

The maximum and minimum error between the experimental and regression results of the ultimate tensile stress are 2.937% and 0.044% , and the yield stress are 2.878% and 1.124 % respectively as shows in table 7 The same above procedure for impact energy.

UTS (MPa)			YS (MPa)			Impact energy (J)		
EXP	Regression model	Error %	EXP	Regression model	Error %	EXP	Regression model	Error %
428	432.4309	1.025	299	294.002	1.700	149	157.0917	5.151
433	433.7399	0.171	299	295.6773	1.124	158	166.5917	5.157
424	428.642	1.083	296	289.213	2.347	138	149.025	7.398
430	431.1219	0.260	301	294.614	2.168	158	158.9917	0.624
439	426.475	2.937	298	289.664	2.878	155	151.125	2.564
431	430.809	0.044	296	291.05	1.701	150	158.325	5.258
Mean error %		0.9200	Mean error %		1.9863	Mean error %		0.3587
correlation coefficient squared		0.864	correlation coefficient squared		0.923	correlation coefficient squared		0.876

VI. CONCLUSION AND FUTURE WORK

In this work the submerged arc welding process was successfully modeled using three methods are ANN and regression analysis, and the best method which is closest to the experimental results is ANN. The ultimate tensile stress, yield stress, and impact energy decreased, as the welding current increased, The ultimate tensile stress, yield stress, impact energy increase with increasing arc voltage . The ultimate tensile stress, yield stress, impact energy, increases with increasing welding speed. In future Study the effect of thickness and flux of workpiece on these properties obtained from the welding process. Study of effect of workpiece thickness on the welding penetration. This process is applied to other types of welding methods for the purpose of obtaining one mathematical model representing all welding methods.

REFERENCES

[1]] Prakash Mohan., "Study the effects of welding parameters on TIG welding of aluminum plate", National Institute of Technology Rourkela -769 008 (India), 2014

[2] QianHancheng, Xia Bocaib, Li Shangzheng, Wang Fagen." Fuzzy neural network modeling of material properties" Journal of Materials Processing Technology, vol. 122, 2002, pp.196–200.

[3] Welding Guideline, June 2000.

[4] Submerged Arc Welding Equipment Catalog "Miller" .

[5]Ajay Nair A/L Ravindran Nair., "The investigation of influence of filler welding materials on the microstructure and hardness of the GTA Welding in dual phase steel. Faculty Mechanical Engineering, University Teknikal Malaysia Melaka, June 2012.

[6]Simon Haykin, "Neural Networks and Learning Machines", Prentice Hall, 3 rd edition, 2008.]

[7]Alexander Gustafsson, Sebastian Wogenius, Modelling Apartment Prices With The Multiple Linear Regression Model", Stockholm, Sweden 2014.

[8] TuróczyZsuzsanna, Liviu Marian, "Multiple regression analysis of performance indicators in the ceramic industry" , Procedia Economics and Finance.Vol-3,2012, 509 – 514.

[9] Praveen Kumar Edara. " Mode Choice Modeling Using Artificial Neural Networks" MSc Civil Engineering, faculty of the Virginia Polytechnic Institute and State University,2003.

[10]] I.S. Kim, J.S. Son, C. E. Park, C.W. Lee, " A study on prediction of bead height in robotic arc welding using a neural network", Journal of Materials processing technology, vol. 130-131, 2002, pp. 229-234.

[11] S. Kumanan, J. Edwin Raja Dhas, K. Gowthaman," Determination of submerged arc welding process parameters using Taguchi method and regression analysis", Indian Journal of engineering & Materials Sciences", vol. 14, 2007, pp. 177-183.

[12] ParikshitDutta, Dilip Kumar Pratihar, "Modeling of TIG welding process using conventional regression analysis and neural- based approaches", Journal of Materials processing technology, vol. 184, 2007, pp. 56-68.

[13] S. Datta , M. Sundar , A. Bandyopadhyay , G. Nandi , P.K. Pal , S.C. Roy , Effect of process parameters on mechanical properties of submerged arc butt-welding experiments and statistical modeling, *Int. J. of Microstructure and Materials Properties* , Volume 2, pp. 339-360, 2007.

[14] Mohammad W. Dewan, Daniel J. Huggett, T. Warren Liao, Muhammad A. Wahab, Ayman M. Okeil.'' Prediction of tensile strength of friction stir weld joints with adaptive neuro-fuzzy inference system (ANFIS) and neural network" Materials and Design, vol. 92 ,2016,pp. 288 –299.

[15] Falah Mustafa Al-Saraireh."The effect of current and voltage on mechanical properties of low carbon steel products" Faculty of Engineering Mutah University, Al-Karak, Jordan. Vol.9,2018, pp. 134–142.