Weld Quality Prediction of Mild Steel Pipe Joint during Shielded Metal Arc Welding through fuzzy Logic

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Abstract* —The present paper describes fuzzy logic simulation of shielded metal arc welding (SMAW) process to predict the Quality of weld joint. It describe the quality of weld joint & effect of welding current, voltage and welding speed on tensile strength of shielded metal arc pipe welded mild steel joints. An ERW Mild steel pipe I S 1239 of 6 mm thickness and 150 mm diameter were used as the base material for preparing root & final pass butt welded joints. Speed of weld was provided by welder in 6G position. Tensile strength of the joint fabricated by A 5.1 E-6013 electrodes as filler metals was evaluated and the results were reported. Report is used in fuzzy logic simulation to predict the tensile strength of weld for the given welding parameters. A series of 19 experiments were carried out for collecting the data. Out of which 9 experimental data were then used for building a fuzzy logic model to predict the effects of control factors on the responses. The model was also tested from 10 set of data to establish it's adequacy. The Fuzzy logic predictions shows to be an excellent agreement with experimental results and the prediction error find are minimal.

Keywords- *Shielded Metal Arc* Welding, Tensile Strength, Fuzzy logic

All plant now a day's uses Pipelines for transport of water, and petroleum products these pipelines play an important role for sustaining vital functions such as power generation, heating supply and transportation If the pipeline carrying these chemicals burst/leaks it results huge loss of money & time. Failure of these pipelines is due lack of strength, lack of penetration, gas porosities, and cracks etc. Pipeline welding under field conditions has always faced severe demands with regard to quality and cost.

Manual metal arc welding also called shielded metal arc welding (SMAW), is the most extensively used manual welding process, which is done with stick (coated) electrodes. Though in USA, its use is decreasing in comparison to the other arc welding processes. This process is highly versatile and can be used extensively for both simple as well as sophisticated jobs. Further, the equipment is less expensive than those used in most of the other arc welding processes. Welds by this process can be made in any position [1].

Quality is a very important factor in the field of welding. The quality of a weld mainly depends on mechanical properties of the weld metal which in turn depends on metallurgical characteristics and chemical composition of the weld. The mechanical feature of weld depends directly on welding

process parameters [2].SMAW input process parameters like welding current, welding speed; open circuit voltage and external magnetic field are highly influencing the quality of weld joints. [3].Selection of process parameters like welding current, welding speed and voltage has great influence on the quality of a welded connection. The selection of the process variables and control of weld bead shape has become important because mechanical strength of weld is depend on it. The high weld quality can be achieved by meeting quality requirements such as bead geometry which is highly influenced by various process parameters involved in the process. Poor weld bead dimensions will contribute to failure of the welded structure [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[5] Also SMAW is slower than other methods of welding and is more depend on the operator skill for high weld quality[6]. We are using ANN in this paper as it can easily represent non-linear relationships between input data and output data. Even if the data is incomplete, neural networks are able to correctly classify the different data classes captured from the network or other sources [8]. ANN modeling has been chosen by its capability to solve complex and difficult problems. Kim et al. used multiple regression analysis and back propagation neural network in modeling bead height in metal arc welding [9].

The Prediction of bead geometry in pulsed GMA welding is done by using back propagation neural network, with the use of ANN. The back propagation neural network model is developed for the prediction of weld bead geometry in pulsed gas metal arc welding process. The model is based on experimental data. The thickness of the plate, pulse frequency, wire feed rate, wire feed rate/travel speed ratio, and peak current have been considered as the input parameters and the bead penetration depth and the convexity index of the bead as output parameters to develop the model. The developed model is then compared with experimental results and it is found that the results obtained from neural network model are accurate in predicting the weld bead geometry [10]. The Prediction of gas metal arc welding parameters based on artificial neural is done. A novel technique based on artificial neural networks (ANNs) for prediction of gas metal arc welding parameters. Input parameters of the model consist of gas mixtures, whereas, outputs of the ANN model include mechanical properties such as tensile strength, impact strength, elongation and weld metal hardness, respectively. ANN controller was trained with the extended delta bar delta learning algorithm. The measured and calculated data were simulated by a computer program. The results showed that the outcomes of the calculation were in good agreement with the measured data, indicating that the novel technique presented in this work shows the good performance of the ANN model [11].

Use of ANN with Marquardt feed forward back-propagation (LMBP) and 3-20-1 configuration for predicting tensile strength during shielded metal arc welding of mild steel pipe joints is very much accurate. Most of the predicted data fall within actual measured values. The Error obtain with this technique is very low**.** This technique was extended to the prediction of the quality of pipe weld joint Results revealed that an artificial neural network with feed forward back propagation is one of the alternatives methods to predict the weld quality in termsof tensile strength.[12]

As different to conventional approach of modeling the welding process, the fuzzy logic modeling technique provides a good solution. Although significant achievements have been made in this area, direct, accurate, reliable and real-time techniques for predicting the SMAW weld strength is more promising due to the specific limitations associated with each individual method. This investigation presents a basis to predict the effect of a variety of process parameters (welding speed,welding current, and Voltage) on the weld Strength.

I. EXPERIMENT CONDUCTED

The experiments were conducted in a power plant for during welder qualification test. The experiment is conducted according to Welding Procedure Specification followed by the plant during the welder qualification test i.e. 5.1 ASME Sec IX QW. The following machines and consumables were used for the purpose of conducting the experiments:

1. A mild steel pipe of 6mm thickness and 150 mm diameter.
2. Electrode E 6010 and E 6013(both 2.5mm and 3.15mm were used).
3. Welding machine.
4. Universal Testing Machine (UTM).

A. Preparation of Specimen

A mild steel pipe was cut into two small pieces each of length approx 5 inch and the edge preparation was carried out by creating a groove of 30^0 to 35^0 each end of the pipe in order to get a 60^0 to 70^0 total groove angles according to ASME section IX, QW-402 [7]. In order to achieve a very strong weld, the joints were properly cleaned with a grinder and sand paper. fit up preparation, a gap of 2 to 3mm was used to prepare before tacking of pipe The preparation of welder test for 6G position is made at angle 45^0 according to QW-461.4. 6G position for pipe only, both pipes are inclined to axis at angle 45^0. The pipe cannot be turned or rolled. The Chemical composition of base metal is shown in table 1.

TABLE 1 The Chemical composition of base metal.

C	Si	Mn	Cu	Ni	Cr	Mo
0.08	0.2	0.5	0.01	0.01	0.01	0.01

All the parameter welding current, voltage and welding speed were recorded as per PQR format according to ASME section IX. All weld sections should be clean and remove the slag and fluxes from the joint. Repeating this method for several times.

B. Mechanical Testing

After processing the visual inspection, the tested weld joint is cut according to ASME section IX Qw-462.1 if the joint fail to pass visual test then the joint is rejected for tensile test and weld joint is declared as failed joint. The tensile specimens were prepared to evaluate transverse tensile properties of the joints such as tensile strength. The specimen was mounted on both ends of the universal testing machine. The Tensile test was conducted with a controlled universal testing machine. Typically, the testing involved taking a small sample (to ASME section IX Qw-462.1) with a fixed cross-sectional area and then pulling it with a controlled, gradually increasing force until the sample changed shape and eventually fractured. Figure 1 shows UTM with test specimen during testing .The data of tensile strength in universal testing machine for each welder sample were noted in MPa..

Different result are obtained by conducting the experiments, tensile strength results were read directly from the Universal Testing Machine (UTM) and the input parameter reading of joint were recorded. Fig 1 shows the tensile test of specimen in UTM.About 19 specimens were tested and recoded the different reading of welding current, voltage, welding speed and tensile strength during shielded metal arc welding of mild steel pipe joints.

Figure 1. UTM with test specimen

II. FUZZY MODEL CONSTRUCTION.

The SMAW welding is dependent on several parameters which can be varying over a wide range. Initially, feasibility study was carried out to predict the weld strength. Fuzzy logic is a highly flexible and non linear modeling technique with an ability to learn the relationship between inputs variables and output features. The most successful applications of fuzzy set theory is observed in modeling the experimental data involving certain uncertainties between the relationships of input process variables and responses [13]. Its major features are the use of linguistic variables rather than numerical variables.

Fuzzy sets are characterized by fuzzification, membership functions, a fuzzy rule, an inference system and a defuzzification inference. The structure of three inputs, one outputs fuzzy logic controller developed for this present research is shown in Fig. 3. The inputs values to the model were given in linguistic form and after fuzzification, the outputs were obtained in crisp form.

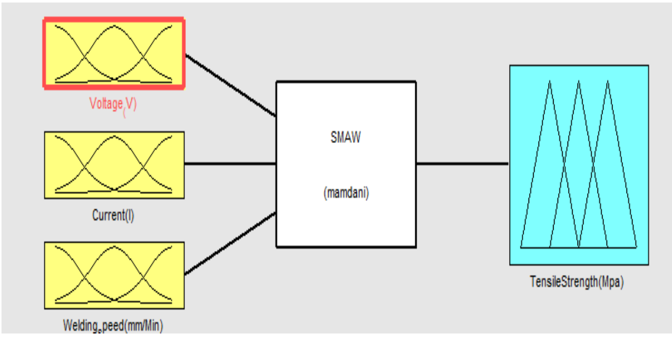

Figure 3. Input-output parameters of Fuzzy logic control model

A fuzzy logic controller is based on a collection of control rules. The execution of these rules is governed by nine set of experimental data. In this study the triangular membership functions were used for the input process parameters such as Voltage, welding current and welding speed to predict the tensile strength.

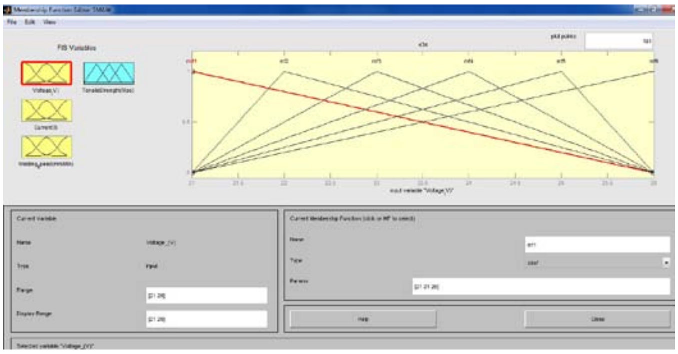

Figure 3. Membership functions for inputs process parameter of Voltage

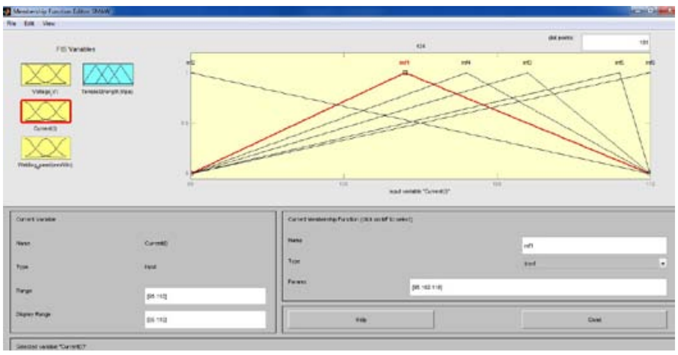

Figure 3. Membership functions for inputs process parameter of current

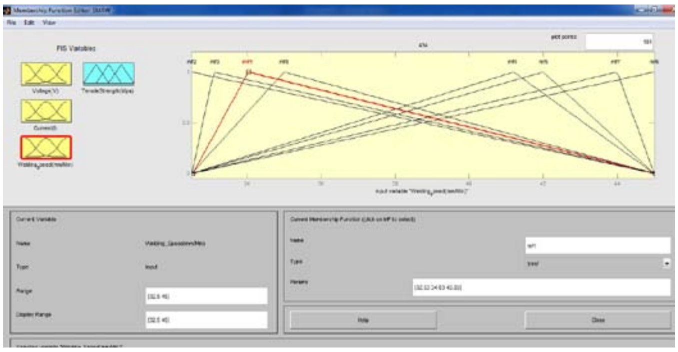

Figure 3. Membership functions for inputs process parameter of welding speed

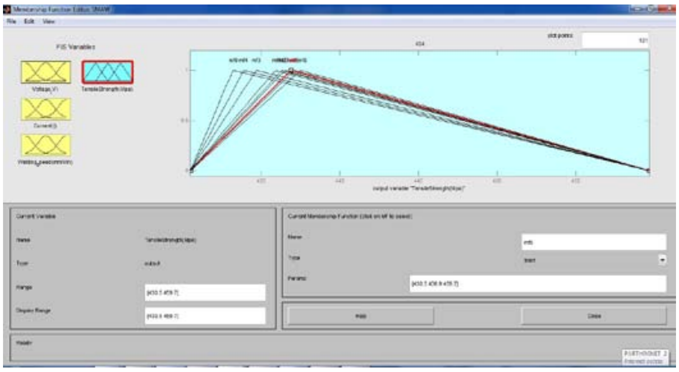

Figure 3. Membership functions for output parameter of tensile strength.

The fuzzy logic controller was Mamdani type and rule based on output data are feed on it, total nine rule are feed. The rules based on knowledge to predict tensile strength are shown in fig 4.

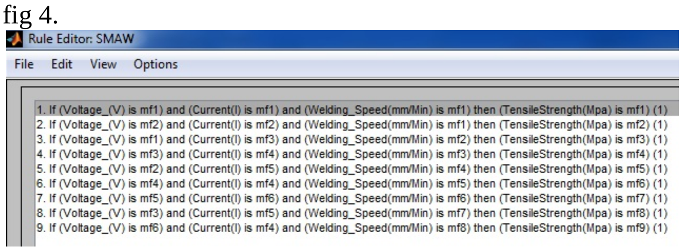

Figure 3. Fuzzy rule

The fuzzy input and output parameters are shown in Fig. 6 and Fig. 7 respectively.

III. SIMULATION OF FUZZY LOGIC MODEL.

In this study, the fuzzy model has been developed based on nine experiments of SMAW process parameters. The fuzzy model was simulated for test cases which has been done within the range of the fuzzy set. The experiments was conduct of process parameters such as current, **voltage** and welding speed. The purpose of the simulation was to minimize the error of outputs for test case experiments A MATLAB Simulink model was developed to predict the tensile strength of welding. To confirm the adequacy of fuzzy logic model, test case inputs were used to predict the outputs from the model. The measured and predicted values of SMAW characteristics are given in Table 4 and the percentage relative error of fuzzy modeling analysis is presented in Table 5 for the test cases.

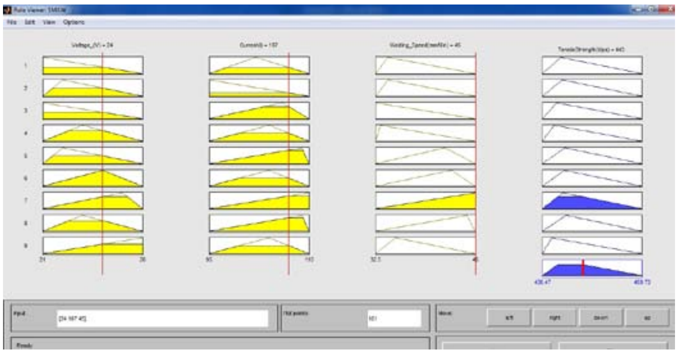

TABLE 2 Comparison of predicted and actual tensile strength with error

S No.	V	I	Weld Speed	Actual tensile strength (MPa)	Predicted tensile strength (MPa)	Error	% Error
1	23	105	45	448.58	443	0.012596	1.259594
2	24	101	44	459.73	444	0.035428	3.542793
3	24	101	39	445.09	442	0.006991	0.699095
4	22	104	34	443.51	442	0.003416	0.341629
5	26	110	32	436.39	445	-0.01935	-1.93483
6	21	97	44	440.81	445	-0.00942	-0.94157
7	24	102	33	430.47	442	-0.02609	-2.6086
8	23	105	37	438.53	442	-0.00785	-0.78507
9	22	110	39	445.165	444	0.002624	0.262387
10	24	107	45	444.34	443	0.0030	0.3024

						25	83

The experimentally observed and predicted values of fuzzy outputs were used for graphical representation of the tensile strength. The results from fuzzy logic simulation indicated that the predicted values and experimental values closely agreed. In some cases the predicted values and experimental values are observed to be little deviated. That might be due to some experimental error. It can be observed that there is good agreement between the experimental and predicted values.

On the basis of Table 2 the graph is plotted as shown in fig 4 the graph shows the result variation in actual and predicted value of tensile strength with maximum and minimum difference of 15.73 MPa and -3.74 MPa

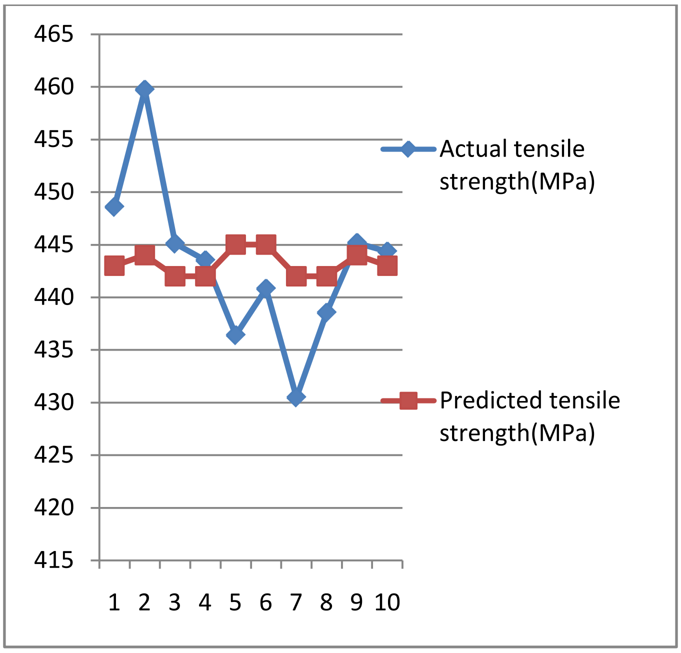

Table 2 the relative error is plotted for predict tensile strength 10 sample it shows the largest and smallest relative errors were 3.542793% and -1.93483%, respectively which can be considered as good and acceptable The constructed fuzzy logic model exhibited good prediction performance.

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The model was able to fit most of the tensile strength close to the target value Some of the test data did not fit very well, and this might be due to several reasons including the limited data set and other welding parameters which were not tested.

IV. CONCLUSION.

This study reveals the successful use of ANN with Marquardt feed forward back-propagation (LMBP) and 3-20-1 configuration for predicting tensile strength during shielded metal arc welding of mild steel pipe joints is very much accurate.Most of the predicted data fall within actual measured values. The Error obtain with this technique is very low**.** This technique was extended to the prediction of the quality of pipe weld jointResults revealed that an artificial neural network with feed forward back propagation is one of the alternatives methods to predict the weld quality in terms of tensile strength. This method provides a effective way to better predict mechanical properties of welded joints with different input parameters, and can provide theoretical optimal designs of parameters in the welding procedure test Hence it can be proposed for real work during welder test and in field welding.

ACKNOWLEDGMENT *(HEADING 5)*

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression, "One of us (R. B. G.) thanks . . ." Instead, try "R. B. G. thanks". Put sponsor acknowledgments in the unnumbered footnote on the first page.

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