Electrical Current Optimization of Spot TIG Welding on the Tensile Strength of Material Mild Steel SPCG 250 using ANFIS

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Abstract*—This research describes the optimization of electric current of Spot TIG welding on the tensile strength of SPCG 250 mild steel using fuzzy Sugeno ANFIS type. By using ANFIS method, the error value is 11.8712. The validation process is carried out by matching the ANFIS output results and the real data with the mechanical properties of the material, namely 320 MPa, so that the optimization value of 80 A current and 10 holding time with a value of 342.92 MPa determine the optimization of the effect of electric current parameters on the results. Tensile strength test, decision making system can be done using the ANFIS method.

Keywords—spot TIG welding, current, holding time, ANFIS, MATLAB.

I. INTRODUCTION

One of the products produced by the Astra Manufacturing Polytechnic is Toolbox. Toolbox is a type of equipment used as storage for machine tools. Toolbox consists of several box components made of mild steel material with a thickness of 0.8 mm. One indicator of the quality of toolbox is that the quality of the assemblies between components must be tight when closed and strong in the welding process of mild steel material. Because the mild steel material used is 0.8 mm thick, it is able to produce good and strong welding strength. The welding process is carried out with spot TIG welding. In the process of spot TIG welding, welding parameters are needed including electrical current, holding time and gas flow rate. To be able to find the best combination of parameters to optimize the variable of electric current, the holding time of the SPSCG 250 mild steel material in the TIG spot welding was processed without trial and error to speed up the process and save material costs.

The toolbox product and the area that will be welded can be seen in Fig. 1 and Fig. 2.

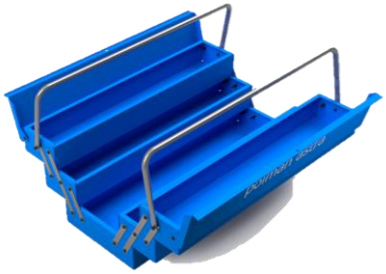

Fig. 1. Product toolbox

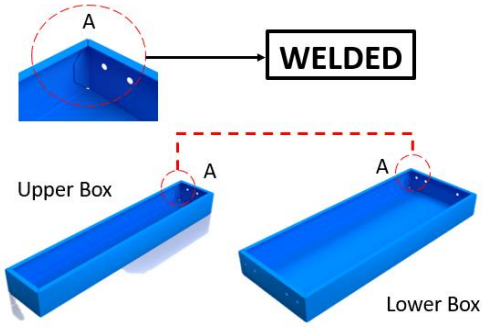

Fig. 2. Welded toolbox area

In this study, the ANFIS method will be used to optimize the variable of electric current. The holding time of the SPSCG 250 mild steel material in the TIG p spot welding is processed by developing an adaptive membership function which is closely related to the welding process.

From the background described above, the problem formulations that can be studied are:

1. To develop the ANFIS model based on variations in the electric current of spot TIG welding, with holding time, constant gas flow rate, and tensile strength in SPCG 250 mild steel material.
2. To validate and evaluate the optimized parameters by comparing the spot TIG welding before and after the system is optimized.

II. LITERATURE REVIEW AND RESEARCH METHODOLOGY

A. *Spot TIG Welding*

Spot TIG welding is a welding process adapted from resistance spot welding where the process is almost similar. In addition, the spot TIG welding method allows two sheets of material to be welded together from one side of the material only (from the top side only) while the welding process in resistance spot welding usually requires two electrodes or both sides of the material surface (from the top side) [1]. The surface of the nuggets resulting from spot TIG welding is smoother when compared to resistance spot welding. Nugget in spot TIG welding is produced because of a jump in electric current from an electric arc or tungsten spot gun electrode through the top sheet of material and then the bottom sheet of material then melted to the top resulting in the metal to melt and then forms a weld bead or is called a nugget [2].

B. *Welding Parameter*

There are several welding parameters that can affect the result of the joint in the spot TIG welding process, including welding current, holding time, and the flow rate of the protective gas.

- Electrical Current

The welding current is the weld meter which directly affects the penetration of the material being welded and the melting rate of the parent metal. The amount of welding current required depends on the electrode diameter, the thickness of the material being welded, the type of electrode used, the electrode core diameter, and the welding position. The higher the welding current, the greater the penetration and the melting speed are. The amount of current in welding affects the results of the weld, if the welding current is too low, the displacement of fluid from the tip of the electrode used is very difficult and the electric arc occurred is unstable [1].

- Holding Time

The holding time or the so-called pressing time in spot TIG welding is also one of the parameters determining the heat input used to melt the parent material to be welded. Short or fast holding time will reduce the quality of the tensile strength of the resulting joint; this is because the resulting nuggets are small so that it can indicate that the welding is not perfect. The determination of the holding time must be precise, so that it can produce a connection with good tensile strength [1].

- Flow Rate Gas

The function of the protective gas in the spot TIG welding process is to protect the electric arc and the welding material from outside air contamination. The protective gas used in the spot TIG welding process is the noble gas of the argon type, this gas was chosen because it has properties that do not readily react with other elements [3]. When compared to the protective argon gas with other protective gases, in this case, helium gas, this argon gas still has more protective capabilities, but the penetration of the welded material is shallow. Increasing the volume of gas flow is one solution that can be done to deepen the penetration of the welding material. For the welding process on very thin materials (material thickness below 1 mm), pure argon gas can be applied in the spot TIG welding process [4].

C. *Low Carbon Steel*

Low carbon steel is an alloy steel between 0.05-0.25 % carbon content. Since it is comparatively cheap, this low carbon steel is the most common type of steel but has suitable material properties for many applications. These low carbon steels have comparatively low tensile strength. But by carburizing, the surface stiffness can be improved by being low-cost and easy to mold. This low carbon alloy steel is commonly used for sheet metal shaping processes, structures of the vehicle chassis, pipelines, and etc. This low carbon steels also have good weldability and can be strengthened by the "Cold Working" method.

The chemical composition of low carbon steel SPCG 250 [5] and mechanical properties material can be seen in Table 1 and 2 below.

TABLE I
CHEMICAL COMPOSITION MATERIAL SPCG 250

No	Element Name	Symbol	Percentage (%)
1	Carbon	C	0,06
2	Mangan	Mn	0,4
3	Phosphor	P	0,02
4	Sulphur	Sl	0,02

TABLE II
MECHANICAL PROPERTIES MATERIAL SPCG 250

YS (MPa)	TS (MPa)	Elongation (%)
250 min.	320 min.	25 min.

Variations in electrical current parameters are 40, 50, 60, 70, 80 Ampere and holding times of 5 and 10 seconds. For other parameters, this study uses a 2% thoriated tungsten electrode with ANSI/AWS A5.12M-98 specifications, 99.9% pure argon gas, and without filler or autogenous. In this study, specimens in the form of plates were cut with each size of 120 mm x 20 mm and thickness of 0.8 mm. The plates that have been cut are then arranged overlap according to ASTM E8 standard. The size of the specimen of the material to be welded is illustrated in Fig. 3.

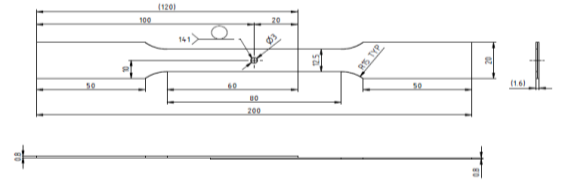

Fig. 3. Test specimens on spot TIG welding

D. Adaptive Neuro Fuzzy Inference System (ANFIS)

Mapping a given set of inputs to an output space using fuzzy logic is the process used in the fuzzy inference system. (1) Fuzzy sets and membership functions, (2) fuzzy implication operator, and (3) linguistic if-then laws are used in the FIS. A membership function is a curve that determines a membership value between 0 and 1, which is called the degree of membership of each point in the input space (l). There are several types of roles for membership, i.e. In the current work, triangular, trapezoidal, Gaussian, generalized bell, sigmoidal, etc., in which triangular, Gaussian, and generalized bell are taken into account and their relative utility is contrasted [6].

Compared to conventional methods, the fuzzy logic (FL) method offers two very important advantages in the data analysis process. The first is to reduce the level of difficulty that may occur in modeling and analyzing very complex data. The second is the place to include the qualitative aspects of human experience to comply with the rules of mapping. Artificial neural networks (ANN) have also been widely used in identifying very complex models of systems. For the same purpose, artificial neural network (ANN) and fuzzy logic (FL) are combined, which can be referred to as ANFIS [7]. The combination of the two will be able to complement the advantages and disadvantages of each system [8]. And based on historical data entered, it can function and can forecast future events based on those data. So that ANFIS has the strength of both [9].There are five layers in the framework of the ANFIS process, namely the fuzzification layer, the rule layer, the normalization layer, the defuzzification layer, and a single neuro result [10]. The ANFIS structure is as shown in Fig. 4.

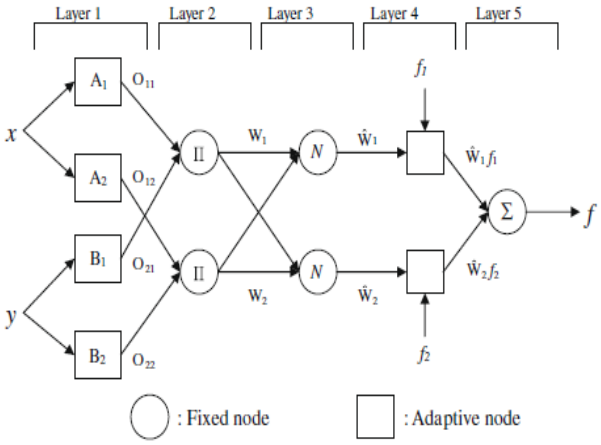

Fig. 4. Structure ANFIS

E. Data Analysis

This study used 10 samples in each experiment as shown in Table 3. Each sample uses different electrical currents and holding times. The number of samples used was 100 samples. The following Table 3 is the results of the tensile strength test of 100 samples which then take the average of each electrical current and holding time.

TABLE III
SAMPLE DATA AVERAGE

No	Current (Ampere)	Holding time (second)	Strength
1	40	5	140
2	50	5	179
3	60	5	233
4	70	5	260
5	80	5	292
6	40	10	183
7	50	10	237
8	60	10	323
9	70	10	335
10	80	10	344

F. Research Methodology

The research design is one of the guidelines used in the research process in determining data collection instruments, determining samples, collecting data, and analyzing data as shown in Fig. 5. By choosing the right research design, researchers will be able to carry out research properly. Without a good design, a researcher will not be able to do research properly because he does

not have clear research guidelines. The research design carried out is as follows:

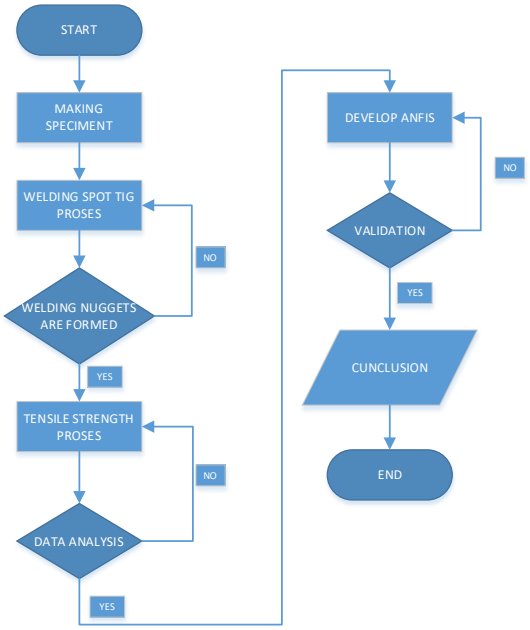

Fig. 5. Research flow process

III. RESULTS

There are 100 data sets used to test the FIS. ANFIS model was developed separately to predict optimization of the tensile strength test results of mild steel SPCG 250 with spot TIG welding process.

A. *ANFIS Tuning*

This test is conducted to determine the fuzzy error value that has been made with 100 samples and to obtain 9 rules using ANFIS, because ANFIS can create input-output mapping in the form of fuzzy if-then rules with the appropriate membership function. The only type of rule that can be presented is the Sugeno type. Mamdani type cannot be applied to ANFIS [7]. From this process, the system error value is 11.8712 as shown in Fig. 6.

Fig. 6. Test result ANFIS

B. *Generate the FIS Model Structure*

Select the Gaussian membership function (gaussmf) and the degree of membership is assigned to three representative linguistic variables such as low, medium, and high [11]. The membership function parameters are set initially by ANFIS. Then, a new FIS created apply the Grid partition technique, namely clustering all data sets and creating rules accordingly. Some basic rules in predicting depth of penetration models are as follows:

If (current is Low) and (HT is Low) then (Strength is out1mf1)
If (current is Low) and (HT is Medium) then (Strength is out1mf2)
If (current is Low) and (HT is High) then (Strength is out1mf3)
If (current is Medium) and (HT is Low) then (Strength is out1mf4)
If (current is Medium) and (HT is Medium) then (Strength is out1mf5).....

C. *Train ANFIS Using Optimization Methods*

The independently developed Gaussian membership function model can predict the optimization of Electrical Current of the Spot TIG welding on the Tensile Strength of Material Mild Steel SPCG 250. For example, the parametric tuning membership function is observed before and after FIS training for prediction of Electrical Current optimization of Spot TIG Welding on the Tensile Strength of Material Mild Steel SPCG 250 using a gaussian membership function as shown in Fig. 7 and Fig. 8.

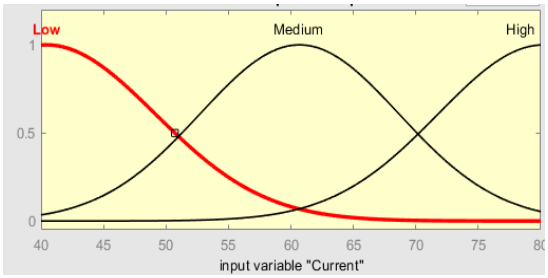

Fig. 7. Gaussian membership function for the input variable current

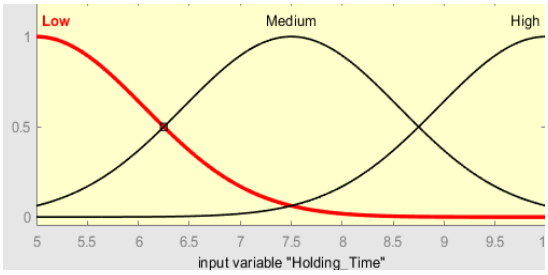

Fig. 8. Gaussian membership function for the input variable holding time.

D. Validations

In determining the validation results, standard data from SPCG 250 mild steel is needed, which is 320 MPa (see Table 2 of the material SPCG 250 mechanical properties) which can be used as a reference to ensure whether the ANFIS results are standard or not. The ANFIS output can be seen in the following in the Table 4.

TABLE IV
OUTPUT ANFIS

No	Current (Ampere)	Holding time (second)	Output ANFIS
1	40	5	140.42
2	50	5	179.10
3	60	5	231.09
4	70	5	263.30
5	80	5	290.31
6	40	10	180.34
7	50	10	241.61
8	60	10	320.13
9	70	10	336.47
10	80	10	342.93

From the data in Table 2 above, the standard value of Tensile Strength is at least 320 MPa, so it can be seen from the data of the fuzzy output results that there are 3 optimization values that are above the standard tensile strength value, which can be seen in the following Table 5.

TABLE V
OPTIMIZATION DATA

No	Current (Ampere)	Holding time (second)	Output ANFIS
1	60	10	320.13
2	70	10	336.47
3	80	10	342.93

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

Based on the results of the tests and analysis that have been carried out in this study, it can be concluded that the optimization of the electrical current of the Spot TIG Welding on the Tensile Strength of Material Mild Steel SPCG 250 using ANFIS occurred at a welding current of 80 amperes and a holding time of 10 seconds. In this parameter, the value of the greatest tensile strength test results is 342.93 MPa.

B. Recommendations

Research on optimization of electrical current of the spot TIG welding on the tensile strength of mild steel material SPCG 250 using ANFIS requires continuous research; the aim is to get more optimal results than it was done before. One that has an important role in parameter optimization is by adding variations in electrical current, holding time and gas flow rate.

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