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A FUZZY LOGIC APPROACH TO PREDICT FATIGUE IN TIG MILD STEEL WELDS

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ABSTRACT

Welding defects influence the desired properties of welded joints giving Fabrication experts a common problem of not being able to produce weld structures with optimal strength and quality. In this present work, the fuzzy logic system was employed to predict welding fatigue. 30 sets of welding experiments was conducted and fatigue data was collected which was converted from crisp variable into fuzzy sets The result obtained showed that the fuzyy logic tool is a highly effective tool for predicting fatigue present in TIG mild steel weld having a coefficient of determination value of 99%

KEYWORDS: Fatigue, Predict, fuzzy, mild Steel, Tungsten Inert Gas, Welding.

1. INTRODUCTION

Manual metal arc welding was first invented in Russia in 1888.[1] It involved a bare metal rod with no flux coating to give a protective gas shield. welding was defined as an efficient and economical method for joining of metals. Welding has made significant impact on the large number of industry by raising their operational efficiency, productivity and service life the plant and relevant equipment.[2] Welding is one of the most common fabrication techniques which is extensively used to obtained good quality weld joints for various structural components. Welding is a joining process which involves intensive heating of the weldments, which causes an uneven temperature distribution and consequently local plastic strain in the weld and surrounding metal.[3] The mismatch of the plastic strains between the weld and the parent metal causes compressive stress, which can have adverse effects on the mechanical properties. Welding in steel structures design happens to be most the widely employed joining technology and it is well known to suffer challenges of corrosion and fatigue. Welding defects influence the desired properties of welded joints giving Fabrication experts a common problem of not being able to produce weld structures with optimal strength and quality. The reason TIG is becoming the most preferred technology is because it has the cleanest weld bead.[4] TIG welding is done in a controlled atmosphere using a tungsten electrode which serves to produce an arc to melt the metal. Direct current (DC) or Alternating Current of High Frequency (ACHF) is used to enable the resulting continuous and stable arc without touching the metal electrode.[4] The use of artificial intelligence to analyze welding parameters and develop mathematical models produce contour plots relating important input parameters such as penetration size and reinforcement height of the weld bead was highlighted.[5] several techniques connected to neural networks was explained and how they can be used to model TIG weld output parameters, the experimental data consisted of values for voltage, current, welding speed and wire feed speed and the corresponding bead width, penetration, reinforcement height and bead cross-sectional area.[6] The performance of neural networks for weld modelling was presented and evaluated using actual welding data. It was concluded that the accuracy of neural networks modelling is fully comparable with the accuracy achieved by more traditional modelling schemes.[6] Evaluation of Artificial Neural Network for monitoring and control of the plasma arc welding process was done.[7] The application of artificial intelligence concepts such as the ANN models to predict the mechanical properties of steels, It was found that the three ANN models successfully predicted the mechanical properties. it was also shown that ANNs could successfully predict multiple mechanical properties and the result of the sensitivity analysis were in agreement with both findings of the experimental investigation and reported results in the literature, Furthermore, it was mentioned that the use of ANNs resulted in large economic benefits for organisations through minimizing the need for expensive experimental investigation and/or inspection of steels used in various applications.[8] ANN model was developed for the analysis and simulation of the correlation between friction stir welding (FSW) parameters of aluminium plates and mechanical properties of the welded joint. The process parameters consist of weld speed and tool rotation speed verses the output mechanical properties of weld joint, namely: tensile strength, yield strength, elongation. Good performance of the ANN model was achieved and the model can be used to calculate mechanical properties of the welded plates.[9]

2. RESEARCH METHODOLOGY

2.1 Design of Experiment

Design of experiment is a scientific approach of combining process parameters optimally, it is a very important step taken for accurate data collection. The number of input parameters determines the type of experimental design. In this study three input parameters were considered, such as welding current, gas flow rate, and voltage making the central composite design the most suitable for this study. The experimental matrix was generated with the design expert software. This process followed the rules of repetition, randomization and local control so as to achieve an optimal experimental design. The input factors considered and their levels is shown in the table below

Table 2.1: process factors and their range.

Parameters	Unit	Symbol	Coded value Low(-1)	Coded value High(+1)
Current	Amp	A	180	220
Gas flow rate	Lit/min	F	36	42
Voltage	Volt	V	18	24

Table 2.2: Experimental Results of Fatigue.

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Notes for ADE DOE
- Design (Actual)
  - Summary
  - Graph Columns
  - Evaluation
- Analysis
  - Compressive Streng
  - Tensile Strength (Ar
  - Hardness (Analyze
  - Fatigue (Analyzed)
- Optimization
  - Numerical
  - Graphical
  - Point Prediction

Std	Run	Type	Factor 1 A:CURRENT Amp	Factor 2 B:VOLTAGE Volt	Factor 3 C:GAS FLOW RATE L/min	Response 1 Compressive Strength Mpa	Response 2 Tensile Strength Mpa	Response 3 Hardness Brinell	Response 4 Fatigue Mpa
16	1	Center	200.00	42.00	7.00	450	460.3	280.5	800
17	2	Center	200.00	42.00	7.00	460	430.5	270.8	805
20	3	Center	200.00	42.00	7.00	440.5	456.7	280.9	810
19	4	Center	200.00	42.00	7.00	420.5	440.3	268.9	820.5
15	5	Center	200.00	42.00	7.00	436	430.8	270.5	815.4
18	6	Center	200.00	42.00	7.00	434	460.5	240.7	822.8
1	7	Fact	180.00	36.00	4.00	427	360.8	210.9	680.9
2	8	Fact	220.00	36.00	4.00	603.9	450.3	234.5	690.7
3	9	Fact	180.00	48.00	4.00	560.9	460.7	210.8	800
4	10	Fact	220.00	48.00	4.00	668.97	470.8	190.8	850.7
5	11	Fact	180.00	36.00	10.00	540.8	320.4	194.5	1100
6	12	Fact	220.00	36.00	10.00	640.6	480.9	320.8	1200
7	13	Fact	180.00	48.00	10.00	600.5	380.9	178.9	980.5
8	14	Fact	220.00	48.00	10.00	660.9	477.52	267.8	1100.5
9	15	Axial	166.36	42.00	7.00	430.5	321.4	183.2	860.7
10	16	Axial	233.64	42.00	7.00	650.9	475.6	280.9	970.9
11	17	Axial	200.00	31.91	7.00	540.6	405.8	260.4	950.5
12	18	Axial	200.00	52.09	7.00	677.9	480.9	200.4	1005
13	19	Axial	200.00	42.00	1.95	581.54	464.9	203.4	600.7
14	20	Axial	200.00	42.00	12.05	673.79	450.6	250.6	1170.5

2.2. Experimental procedure

Power Hacksaw was used for cutting the mild steel plate to size measuring 60 x 40 x 10mm. The grinding machine was used for preparing the groove on the double transverse side of the plates of Mild Steel Subsequently single ‘V’ groove angles (30 degree) were cut in the plates with 2 mm root faces for a total of 60 degree inclined angle between After the V-groove preparation, the Mild Steel were ready for the welding. The mild steel plates were tightly clamped during welding. The root gap of 2 mm is provided between the two plates while performed for the welding. The V-groove butt welding is performed during TIG welding process. The tungsten non consumable electrode having diameter 3 mm was used in experiment. The argon gas is used as a shielding gas. The pressure regulator was used to adjust the gas flow rate during operation. The filler metal ER309L having 2 mm diameter was used for the welding. The direct current Electrode positive (reverse polarity) was used for the welding.

2.3 Materials used for the experiment

Mild Steel is one of the most common of all metals and one of the least expensive steels used. It is found in almost every product created from metal. It is easily weldable, very durable. Having less than 2 % carbon, it will magnetize well and being relatively inexpensive can be used in most projects requiring a lot of steel.



Figure 2.1: welded sample. Figure 2.2: TIG shielding gas cylinder. Figure 2.3: TIG welding machine

3 RESULTS AND DISCUSSION

3.1 Defining the linguistic variables and terms

Consider a fuzzy logic model aimed at predicting fatigue. Let the weld factors, namely; current (c), voltage (v) and gas flow rate (gfr) be termed the linguistic variables. To qualify the current, voltage and gas flow rate, terms such as (very low, low, moderate, high and very high) are used in real life. These are the linguistic values of the current, voltage and gas flow rate. Therefore, C (c) = {very low, low, moderate, high and very high}V (v) = {very low, low, moderate, high and very high}GFR (gfr) = {very low, low, moderate, high and very high}In the same way, the output variable (fatigue) can be qualified in real term as: (FG) = {very low, low, moderate, high and very high}.

The terms in bracket represent the set of decompositions for the linguistic variable current, voltage, gas flow rate and fatigue. Each member of this decomposition is called a linguistic term. For this problem, the linguistic variables and their range of values include:

- Current; this range from 180 to 220 amps
- Voltage; this range from 36 to 48 volts
- Gas flow rate; this range from 4 to 10 L/min
- Fatigue; this range from 600.70 to 1200.00 Mpa

The fuzzy logic tool box that defines the input and output variables is presented in Figure 3.1

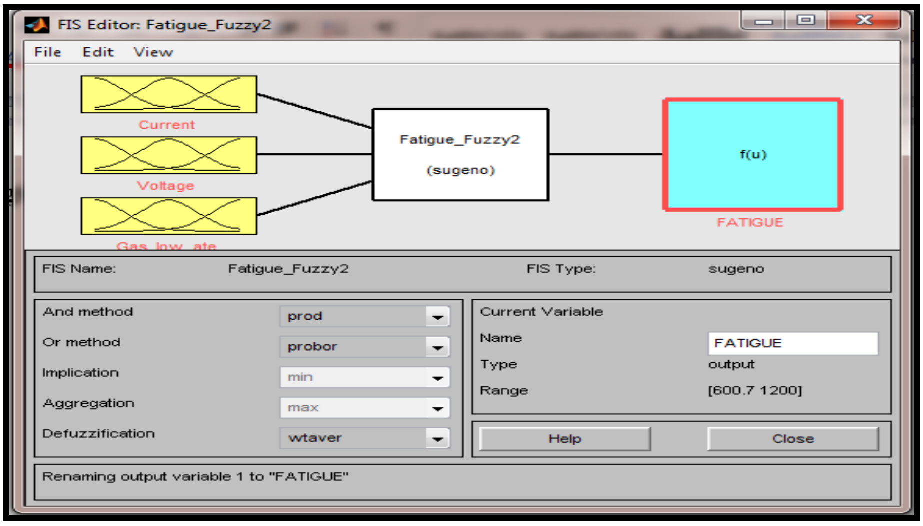

Figure 3.1: Fuzzy logic tool box containing the input and output variables.

3.2 Converting the crisp variables into fuzzy sets

To convert the crisp variables (actual experimental data) into fuzzy sets (fuzzification), adaptive neuro fuzzy inference system (Anfis) was employed to generate a fuzzy inference system (FIS For this problem, the fuzzification step was done using anfis as presented in Figure 3.2.

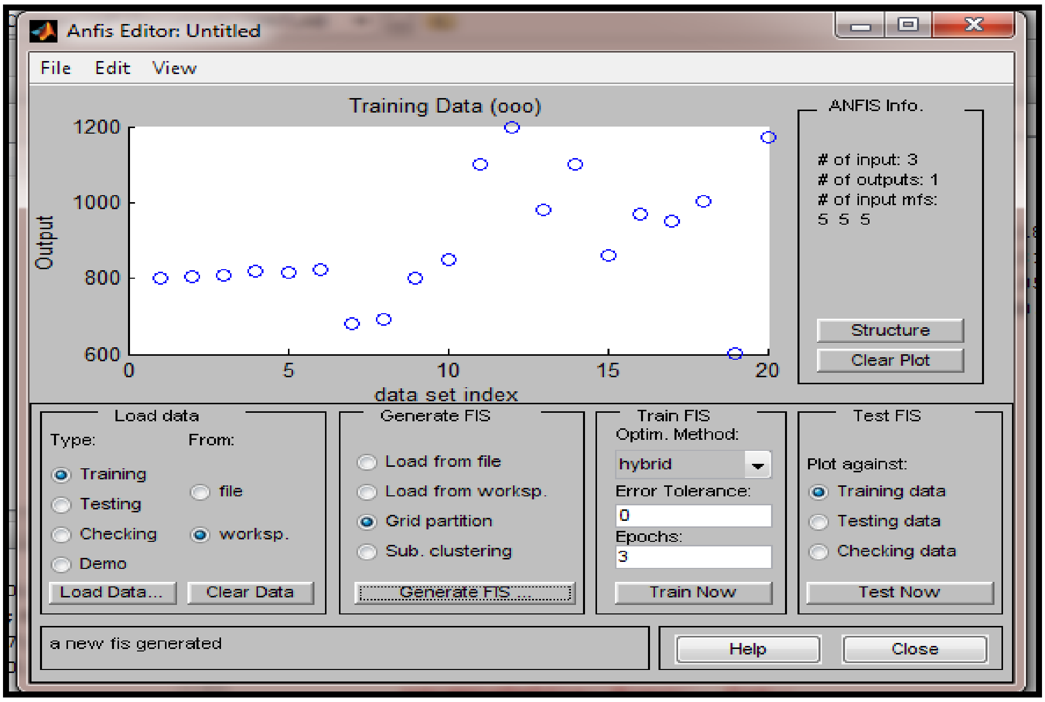

Figure 3.2 Defining the inputs and output Membership Function.

Membership functions are used in the fuzzification and defuzzification steps of a Fuzzy Logic Systems (FLS), to map the non-fuzzy input values to fuzzy linguistic terms and vice versa. A membership function is used in most cases to quantify a linguistic term.

3.3: Definition of membership function for current

Figures 3.3 shows the definition of the membership function for current.

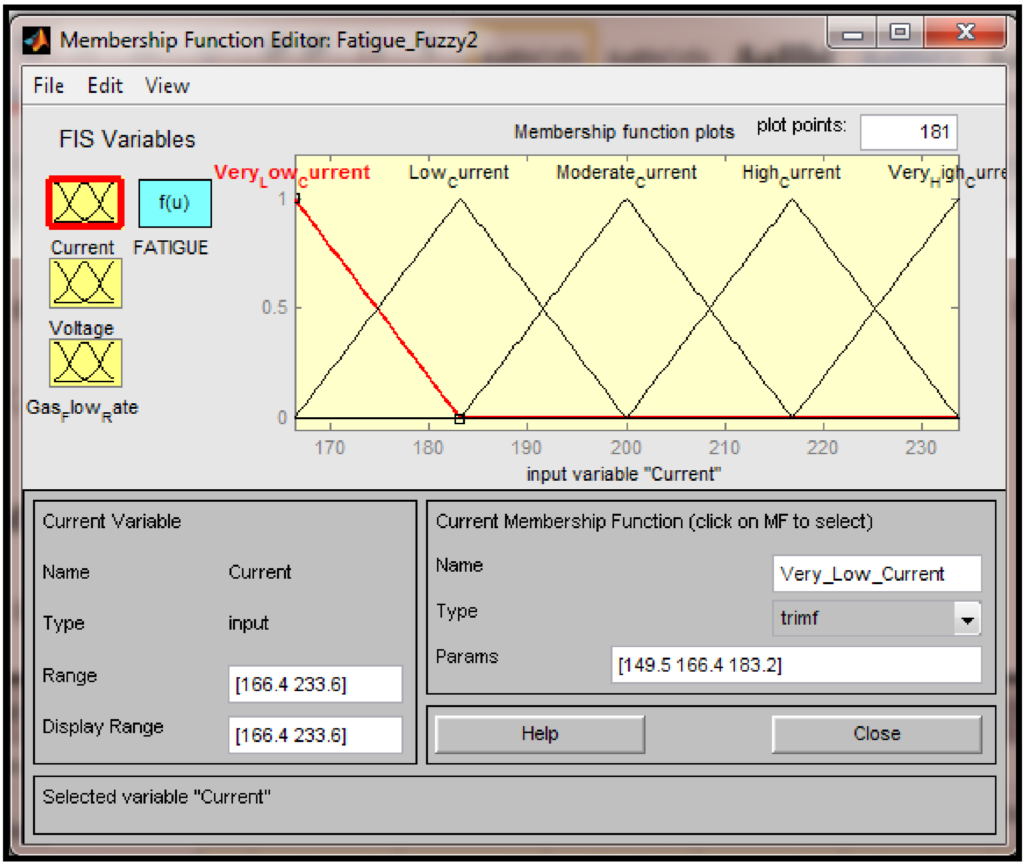

Figure 3.3: Definition of membership function for current (very low current).

Figure 3.3 shows the membership function for current. The current range is specified as [166.4 233.6] while the membership set that defines very low current is given as [149.5 166.4 183.2]. The membership function type is the triangular membership function.

3.4 Definition of membership function for voltage

Figures 3.4 shows the definition of the membership function for voltage.

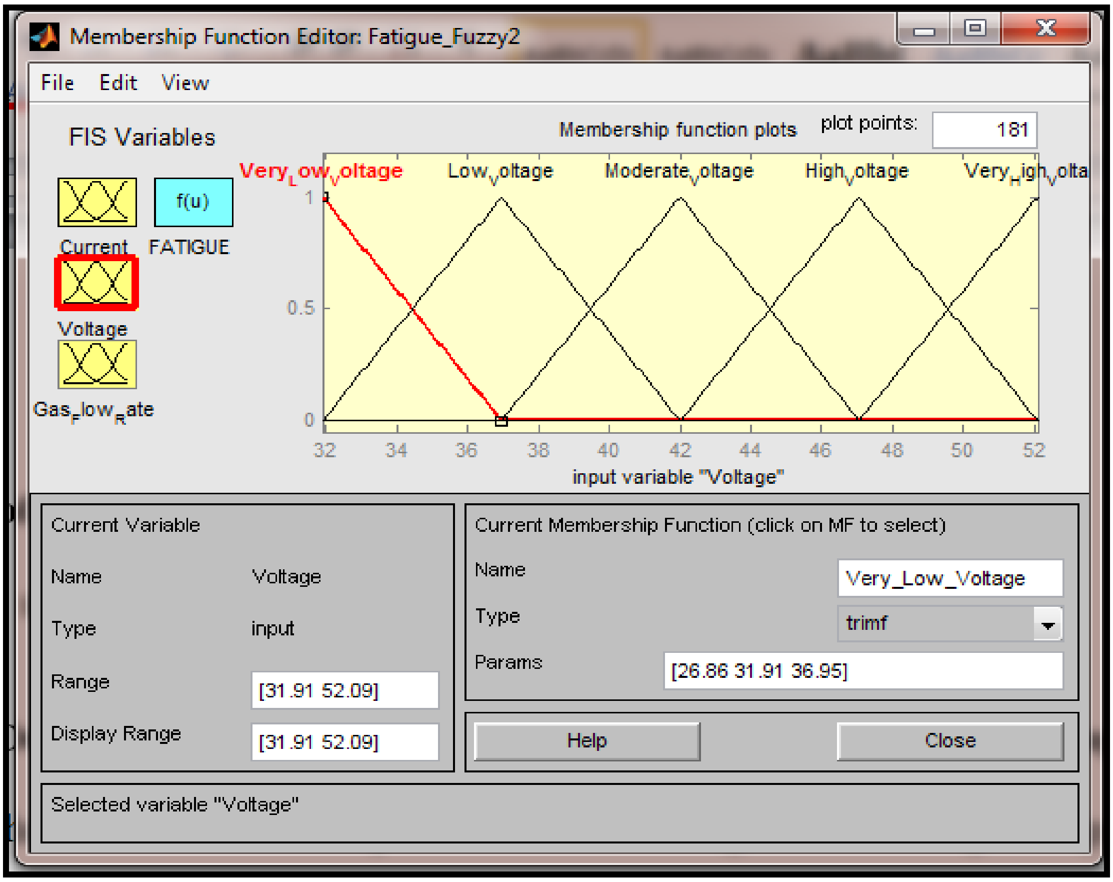

Figure 3.4: Definition of membership function for voltage (very low voltage).

Figure 3.4 shows the membership function for voltage. The voltage range is specified as [31.91 52.09] while the membership set that defines very low voltage is given as [26.86 31.91 36.95]. The membership function type is the triangular membership function.

3.5 Definition of membership function for Fatigue

Figures 3.5 show the definition of the membership function for fatigue.

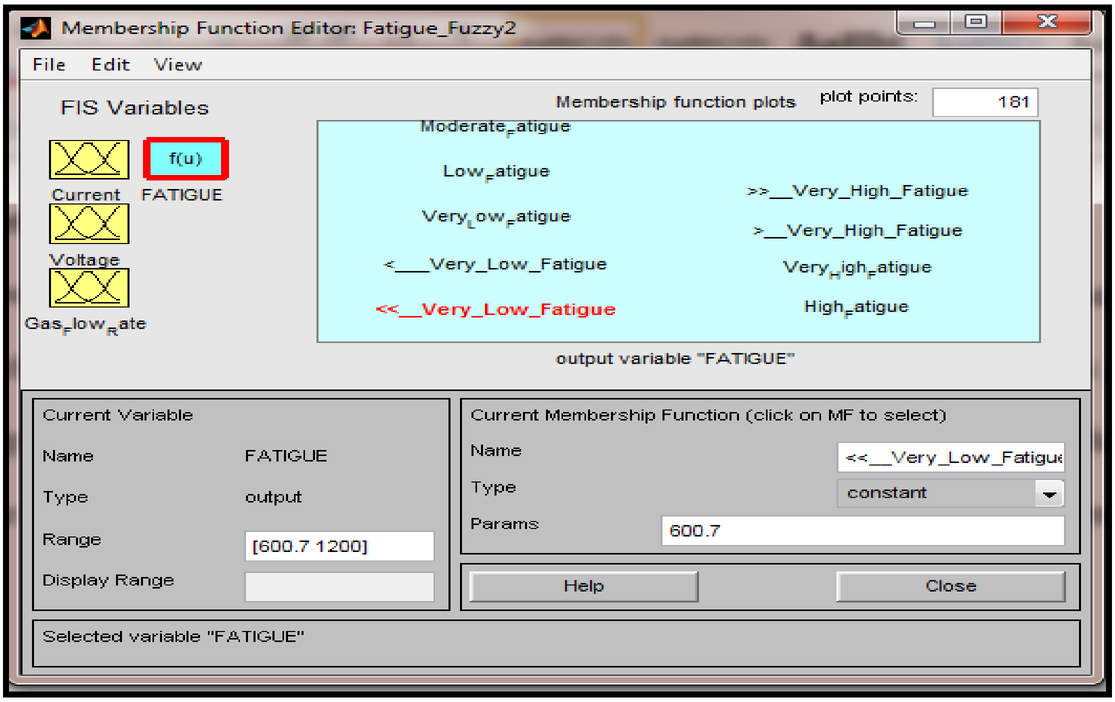

Figure 3.5: Definition of membership function for fatigue.

Figure 3.5 shows the membership function for fatigue. The range for fatigue is specified as [600.70 1200] while the membership set that defines (<< very low fatigue (least fatigue)) is given as [600.70]. The membership function type is the constant membership function.

3.6 Predicting fatigue using Fuzzy Logic

Figures 3.6 shows the predictions that were made using fuzzy logic systems

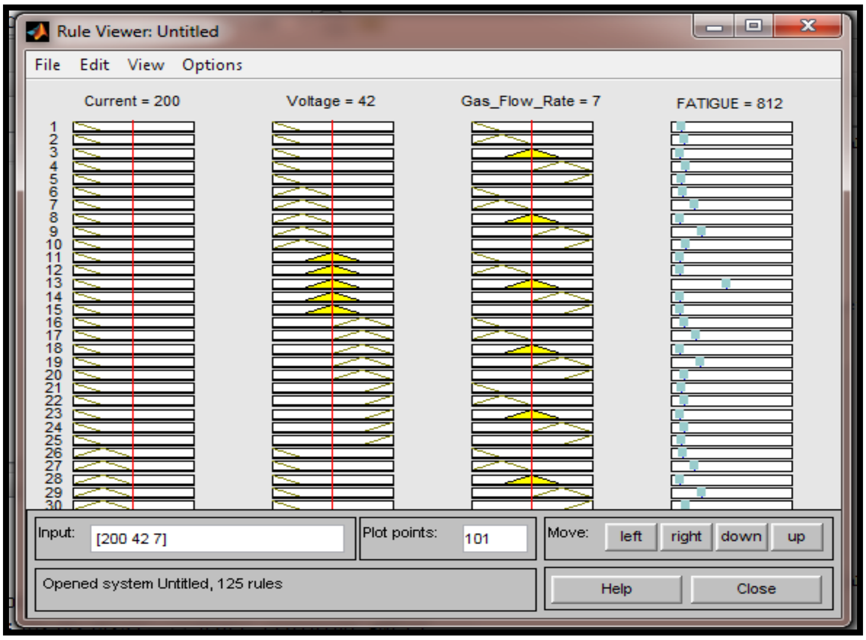

Figure 3.6: Prediction of fatigue using fuzzy logic.

From the result of Figure 3.6, it was observed that; for a current of 200Amp, voltage of 42volt, and gas flow rate of 7.0L/min, the predicted fatigue was 812.0Mpa.a comparison between the experimental and the fuzzy logic predicted results for fatigue response is presented in table 3.1.

Table 3.1: Experimental and fuzzy logic predicted results for fatigue.

Run No.	Current (A)	Voltage (V)	Gas Flow Rate (L/min)	Fatigue (Mpa) Experimental Values	Fatigue (Mpa) FL Predicted Values
1	200	42	7	800	812
2	200	42	7	805	812
3	200	42	7	810	812
4	200	42	7	820.5	812
5	200	42	7	815.4	812
6	200	42	7	822.8	812
7	180	36	4	680.9	681
8	220	36	4	690.7	691
9	180	48	4	800	800
10	220	48	4	850.7	851
11	180	36	10	1100	1100
12	220	36	10	1200	1200
13	180	48	10	980.5	980
14	220	48	10	1100.5	1100
15	166.3641	42	7	860.7	861
16	233.6359	42	7	970.9	971
17	200	31.90924	7	950.5	950
18	200	52.09076	7	1005	1005
19	200	42	1.954622	600.7	600
20	200	42	12.04538	1170.5	1170

4. CONCLUSION

In this paper the fatigue response of TIG welding process has been minimized so as to increases the strength of the weldments. The fuzzy logic system has been employed to predict values of fatigue in TIG mild steel weldments. It was observed that the fatigue of TIG mild steel weld are strongly influenced by input variables such as current, and gas flow rate. The result obtained from the fuzzy logic system showed that the fuzzy logic tool is a highly effective tool for predicting fatigue present in TIG mild steel weld having a coefficient of determination value of 99%surface findings from the investigation showed that the fatigue response in TIG process affects the strength and quality of the weld structure produced. Hence we conclude that minimizing the fatigue in the weld metal will control the hardness quality of the weldment which is a less desired quality. The weld metal possessed an appreciable amount of tensile strength with minimum fatigue of which the tensile strength which is a key promoter of the integrity and strength of the welded structure.

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