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Minimization of Fatigue in TIG Welding Of Mild Steel Using Artificial Intelligence

Oyinbade .A.A [1] Achebo .J.I [2] and Ozigagun A. [3]

[1] *Department of Production Engineering,Faculty of Engineering, University of Benin, P.M.B 1154, Benin City, Edo State,*

[2] *Department of Production Engineering,Faculty of Engineering, University of Benin, P.M.B 1154, Benin City, Edo State,*

[3] *Department of Production Engineering,Faculty of Engineering, University of Benin, P.M.B 1154, Benin City, Edo State, Nigeria*

Abstract-*Welding defects influence the desired properties of welded joints giving Fabrication expertsa common problem of not being able to produce weld structures with optimal strength and quality.In this present work, fatigue was minimized using artificial intelligence such as the Response Surface Methodology.An optimal design of experiment was developed which was used as a guiding plan to conduct the experiment., thereafter a second order polynomial model was developed which was used to minimize the fatigue with very significant statistical results. The result shows that the quadratic model was the most suitable for minimizing the fatigueresponse with a P-value < 0.05*

Keywords: Fatigue, Minimize, Steel, Response Surface Methodology, Tungsten Inert Gas, Welding

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I. 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]. severaltechniques 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 modellingschemes[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].

II. RESEARCH METHODOLOGY

2.1 Design of Experiment

Design of experiment is a very important step taken to accurately apply artificial intelligent methods to either minimize or maximize a targeted manufacturing response. The experimental design considers the following factors such as welding current, gas flow rate, and voltage as input . The experimental matrix was generated with the design expert software ,the central composite design was the most suitable for this experiment. 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

Table2.1: process factors and their range

Parameters	Unit	Symbol	Coded value	Coded value
			Low(-1)	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

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 atotal 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

III. RESULTS AND DISCUSSION

In assessing the strength of the quadratic model towards maximizing the percentage dilution one way analysis of variance (ANOVA) table was generated which is presented in table 3.1

Table 3.1: ANOVA table for minimizing the weldfatigue

Response 4 Fatigue

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	5.081E+005	9	56456.29	614.38	< 0.0001	significant
A-CURRENT	15889.52	1	15889.52	172.92	< 0.0001	
B-VOLTAGE	1686.36	1	1686.36	18.35	0.0016	
C-GAS FLOW RATE	3.931E+005	1	3.931E+005	4277.81	< 0.0001	
AB	463.60	1	463.60	5.05	0.0485	
AC	3180.03	1	3180.03	34.61	0.0002	
BC	31012.95	1	31012.95	337.50	< 0.0001	
A^2	17586.54	1	17586.54	191.38	< 0.0001	
B^2	46553.02	1	46553.02	506.61	< 0.0001	
C^2	8478.88	1	8478.88	92.27	< 0.0001	
Residual	918.91	10	91.89			
Lack of Fit	521.94	5	104.39	1.31	0.3856	not significant
Pure Error	396.97	5	79.39			
Cor Total	5.090E+005	19				

To validate the adequacy of the quadratic model based on its ability to minimizefatigue the goodness of fit statistics is presented in table 3.2

Table 3.2: goodness of fit statistics for fatigue

Std. Dev.	9.59	R-Squared	0.9982
Mean	891.76	Adj R-Squared	0.9966
C.V. %	1.07	Pred R-Squared	0.9909
PRESS	4612.24	Adeq Precision	88.516

The "Pred R-Squared" of 0.9909 is in reasonable agreement with the "Adj R-Squared" of 0.9966.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 88.516 indicates an adequate signal. This model can be used to navigate the design space.

The optimal equation which show the individual effects, and the combine interactions of the selected input variables, namely; current, voltage and gas flow rateagainst the mesured fatigue is presented based on actual factors in Tables 3.3

Table 3.3:Optimal equation in terms of actual factors for minimizing fatigue

Final Equation in Terms of Actual Factors:

Fatigue	=
+6389.25679	
-38.21816	* CURRENT
-119.23929	* VOLTAGE
+97.64185	* GAS FLOW RATE
+0.063438	* CURRENT * VOLTAGE
+0.33229	* CURRENT * GAS FLOW RATE
-3.45903	* VOLTAGE * GAS FLOW RATE
+0.087333	* CURRENT^2
+1.57877	* VOLTAGE^2
+2.69510	* GAS FLOW RATE^2

To asses the accuracy of prediction and established the suitability of response surface methodology using the quadratic model, a reliability plot of the observed and predicted values of the fatigue response was obtained as presented in Figures 3.1

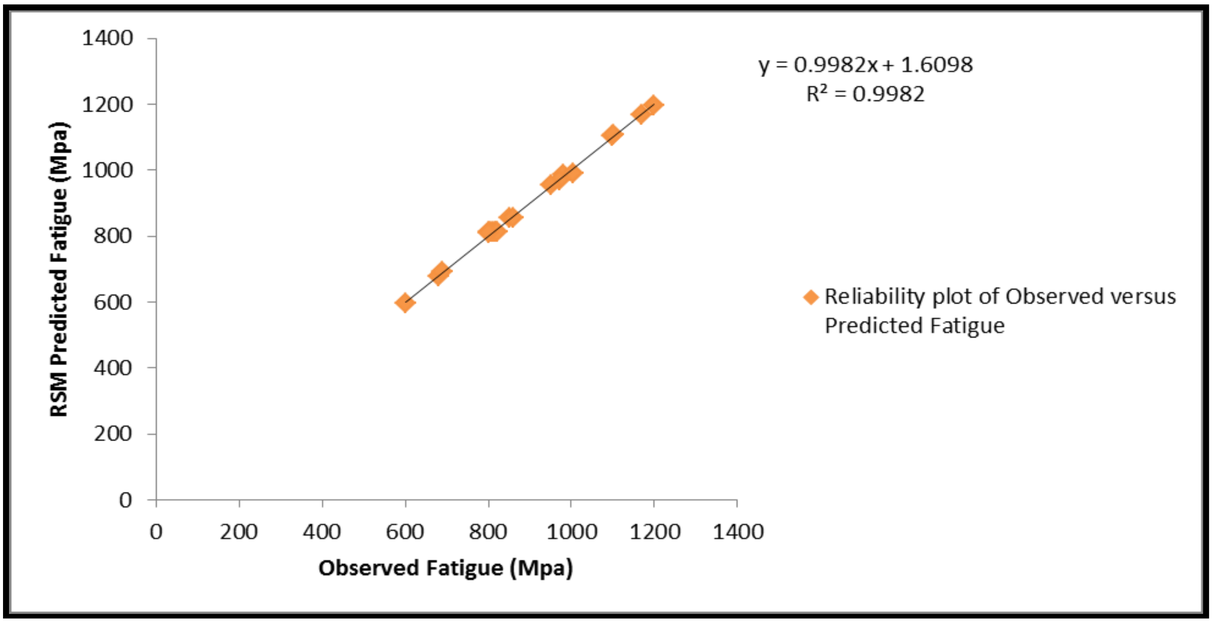


Figure 3.1: Reliability plot of observed versus predicted fatigue

To study the effects of combine input variables on fatigue eeach response variable), 3D surface plots presented in Figure 3.2

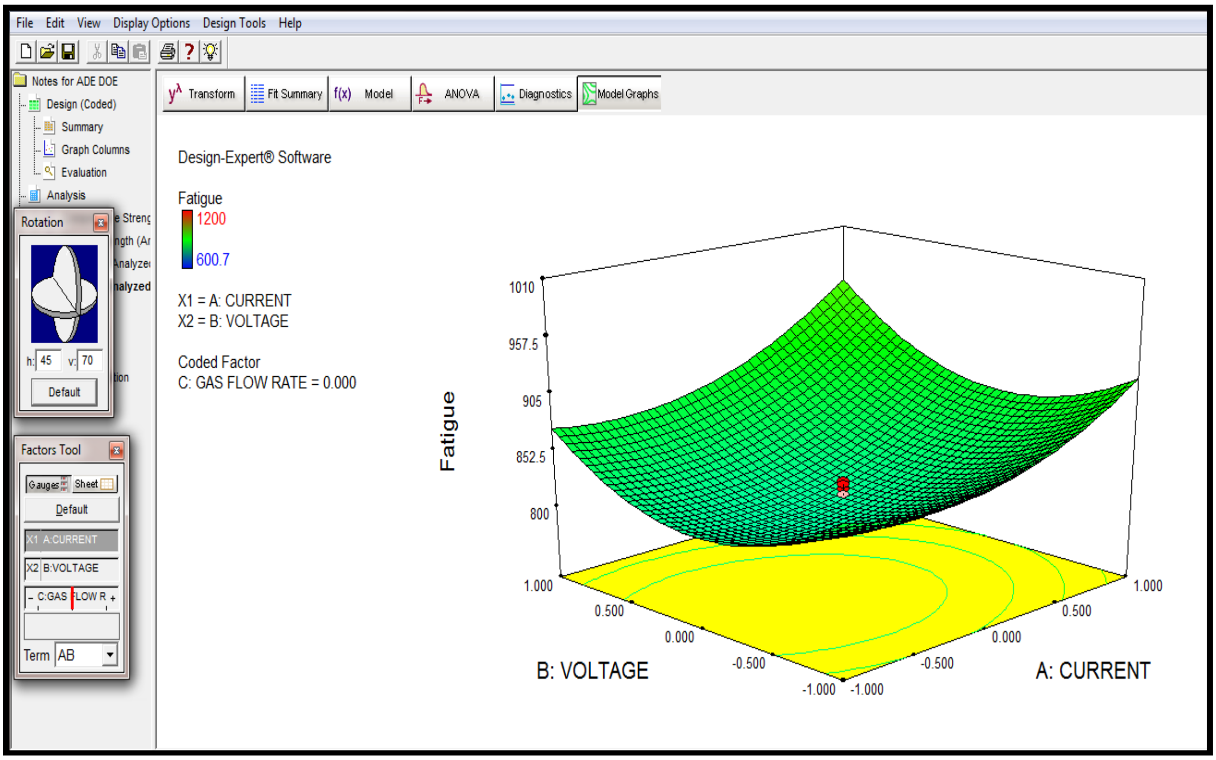
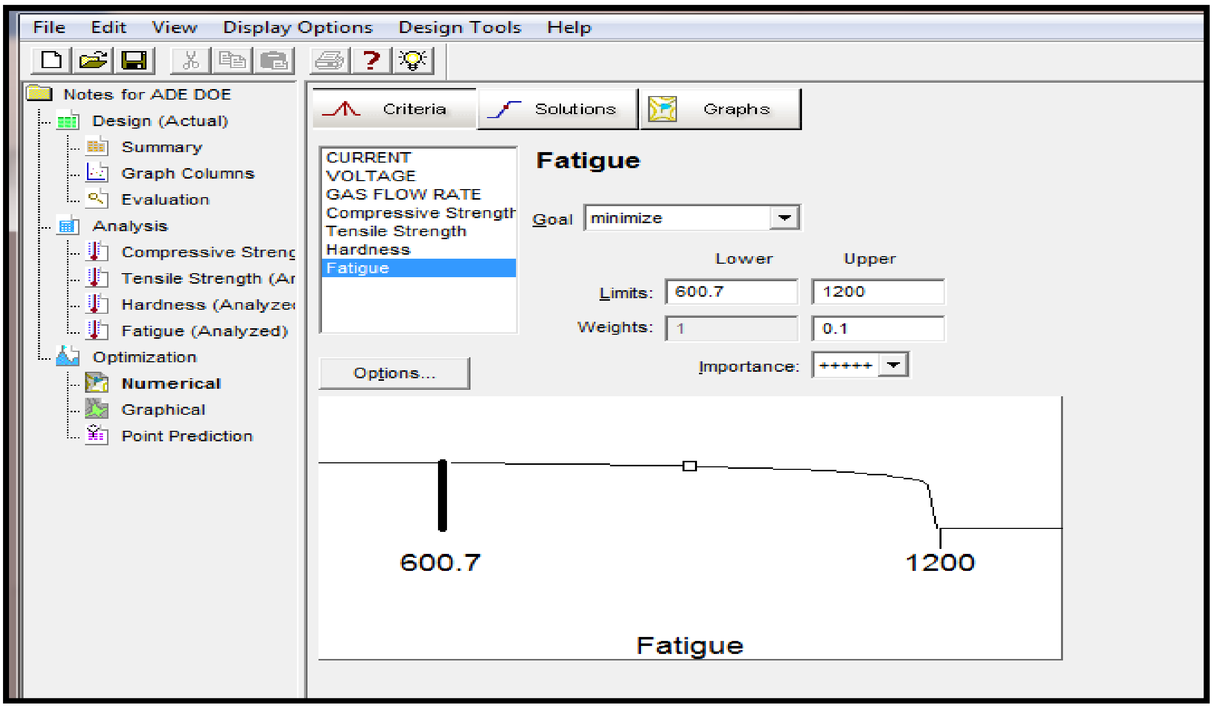


Figure 3.2: A surface plot of voltage and current on fatigue

The objective of this study was to determine the optimum current (Amp), voltage (volts) and gas flow rate (L/min) that will minimize fatigue.The interphase of the numerical optimization showing the objective function is presented in Figures 3.3



The design expert software was used to produce the best optimal solution of that will minimize the fatigue present in the welds,the optimal solutions is shown in table

Table 3.4: The numerical optimal solution showing minimized fatigue response

Number	CURRENT	VOLTAGE	GAS FLOW RAT	Compressive	Tensile Streng	Hardness	Fatigue	Desirability	
1	220.00	36.00	5.13	575.668	455.074	262.399	772.286	0.962	Selected
2	220.00	36.00	5.17	574.956	455.295	263.218	775.206	0.962	
3	220.00	36.00	5.09	576.461	454.835	261.471	768.984	0.962	
4	220.00	36.00	5.23	573.857	455.648	264.514	779.871	0.962	
5	220.00	36.00	5.26	573.45	455.785	265.014	781.694	0.962	
6	219.97	36.00	5.02	577.5	454.449	260.116	764.119	0.962	
7	220.00	36.00	5.44	570.683	456.81	268.645	795.238	0.962	
8	220.00	36.00	4.84	581.634	453.469	256.146	750.843	0.962	
9	220.00	36.07	5.29	572.011	456.111	265.608	782.985	0.962	
10	219.85	36.00	5.10	575.161	454.804	261.793	769.414	0.962	
11	220.00	36.15	5.05	575.283	454.973	260.7	764.658	0.962	
12	219.86	36.04	5.26	571.844	455.793	265.09	780.787	0.962	
13	220.00	36.00	5.68	567.703	458.231	273.39	813.892	0.962	
14	220.00	36.22	5.09	573.499	455.396	261.726	767.516	0.962	
15	219.90	36.00	4.69	584.378	452.617	252.894	739.686	0.962	
16	220.00	36.00	4.44	591.614	451.376	247.262	722.684	0.962	
17	220.00	36.00	6.06	564.724	460.489	280.333	843.347	0.962	
18	220.00	36.04	4.23	597.31	450.409	242.327	707.693	0.961	
19	220.00	36.00	6.85	565.012	465.471	293.323	907.522	0.961	
20	218.42	36.00	4.88	569.109	452.614	257.5	747.491	0.960	

IV. CONCLUSION

In this paper the fatigue response of TIG welding process has been minimized so as to increases the strength of the weldments.this study has systematically applied the response surface methodology (RSM) to minimize fatigue of Tungsten inert gas mild steel weld. The results obtainedshows that the fatigue of TIG mild steel weld are strongly influenced by input variables such as current, and gas flow rate. The surface plot shows that current and voltage were observed to have the highest significant effect on the fatigueof TIG mild steel weld. The result shows that a current of 220 amp, voltage of 36volt, and gas flow rate of 15.13 L/min will result in a welding process with minimumfatigue of 772.This solution was selected by design expert as the optimal solution with a desirability value of 96%.

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