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MAXIMIZATION OF COMPRESSIVE STRENGTH IN TIG WELDING OF MILD STEEL USING RESPONSE SURFACE METHODOLOGY

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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 study, 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 l 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 fatigue response with a P-value < 0.05

Keywords: Defects, fatigue, joints, maximize, model, steel, Tungsten Inert Gas,

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 obtain 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 produces 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 a randomized design of experiment for the selected input variables, namely current, voltage and gas flow rate using central composite design method prepare the mild steel coupons and produce the mild steel welded joints using tungsten inert gas (TIG) welding techniques, conduct the mechanical test on the welded samples in order to determine the post weld qualities, determine the optimum input parameters needed to achieve a specified value of weld process parameters using response surface methodology (RSM)

II. RESEARCH METHODOLOGY

2.1 Design of Experiment

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 1.

Table 1 :Process factors and their range

Parameters	Unit	symbol	Coded value Low (-1)	Coded value High(+1)
Current	Amp	A	180	240
Gas flow rate	Lit/min	F	18	24
Voltage	Volt	V	16	22

Table 2 : Experimental results of Compressive strength

Run	**Type**	**Current (A)**	**Voltage (V)**	**Gas Flow Rate (Lit/min)**	**Compressive Strength (Mpa)**
1	Center	200	42	7	450
2	Center	200	42	7	460
3	Center	200	42	7	440.5
4	Center	200	42	7	420.5
5	Center	200	42	7	436
6	Center	200	42	7	434
7	Fact	180	36	4	427
8	Fact	220	36	4	603.9
9	Fact	180	48	4	560.9
10	Fact	220	48	4	668.9
11	Fact	180	36	10	540.8
12	Fact	220	36	10	640.6
13	Fact	180	48	10	600.5
14	Fact	220	48	10	660.9
15	Axial	166.4	42	7	430.5
16	Axial	233.6	42	7	650.9
17	Axial	200	31.9	7	540.6
18	Axial	200	52.1	7	677.9
19	Axial	200	42	1.9	581.5
20	Axial	200	42	12.0	673.8

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 2mm 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

Figure 1: weld samples

Figure 2: TIG shielding gas cylinder

Figure 3: TIG equipment

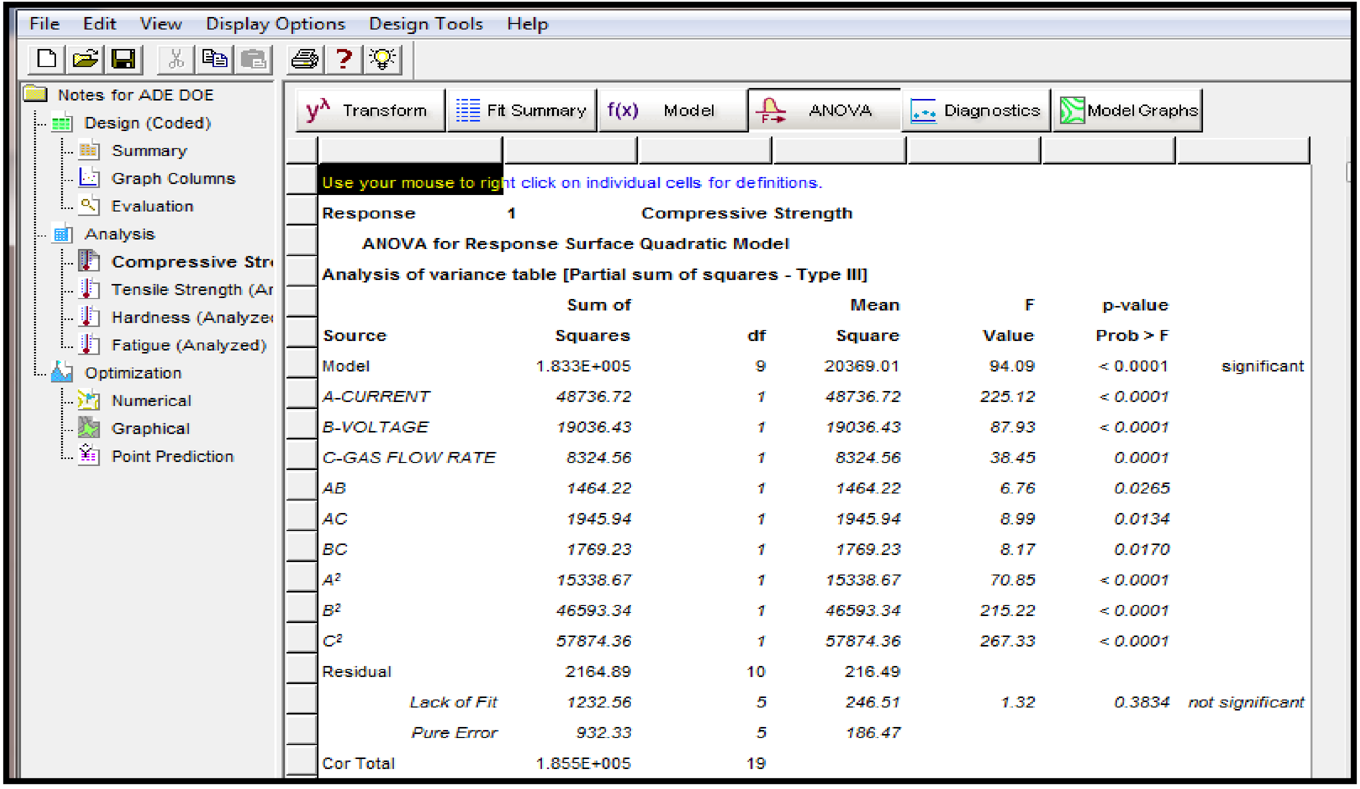
2.3 Materials used for the experiment

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 weld able, 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.

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 as presented
table 3

Table 3: ANOVA table for maximizing compressive strength



Use your mouse to right click on individual cells for definitions.

Response 1 Compressive Strength

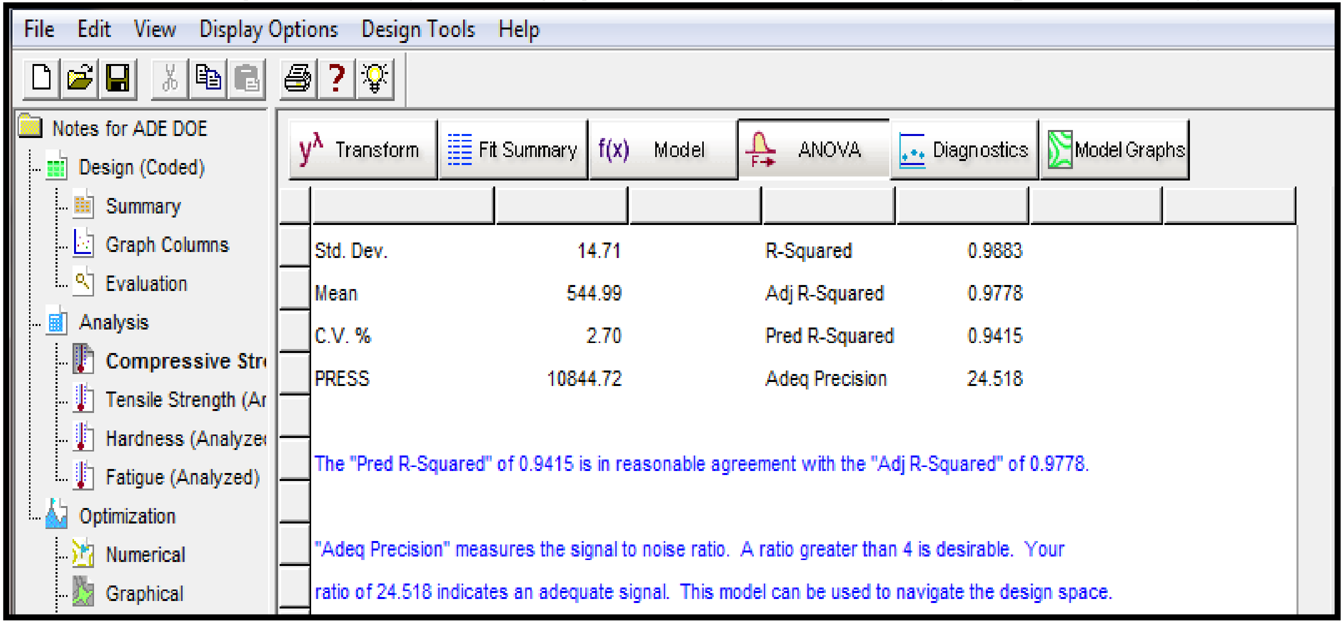
ANOVA for Response Surface Quadratic Model

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

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	1.833E+005	9	20369.01	94.09	< 0.0001	significant
A-CURRENT	48736.72	1	48736.72	225.12	< 0.0001	
B-VOLTAGE	19036.43	1	19036.43	87.93	< 0.0001	
C-GAS FLOW RATE	8324.56	1	8324.56	38.45	0.0001	
AB	1464.22	1	1464.22	6.76	0.0265	
AC	1945.94	1	1945.94	8.99	0.0134	
BC	1769.23	1	1769.23	8.17	0.0170	
A^2	15338.67	1	15338.67	70.85	< 0.0001	
B^2	46593.34	1	46593.34	215.22	< 0.0001	
C^2	57874.36	1	57874.36	267.33	< 0.0001	
Residual	2164.89	10	216.49			
Lack of Fit	1232.56	5	246.51	1.32	0.3834	not significant
Pure Error	932.33	5	186.47			
Cor Total	1.855E+005	19				

To validate the adequacy of the quadratic model based on its ability to maximum compressive strength the goodness of fit statistics is presented in table 4

Table 4: GOF for validating model significance towards maximizing compressive strength



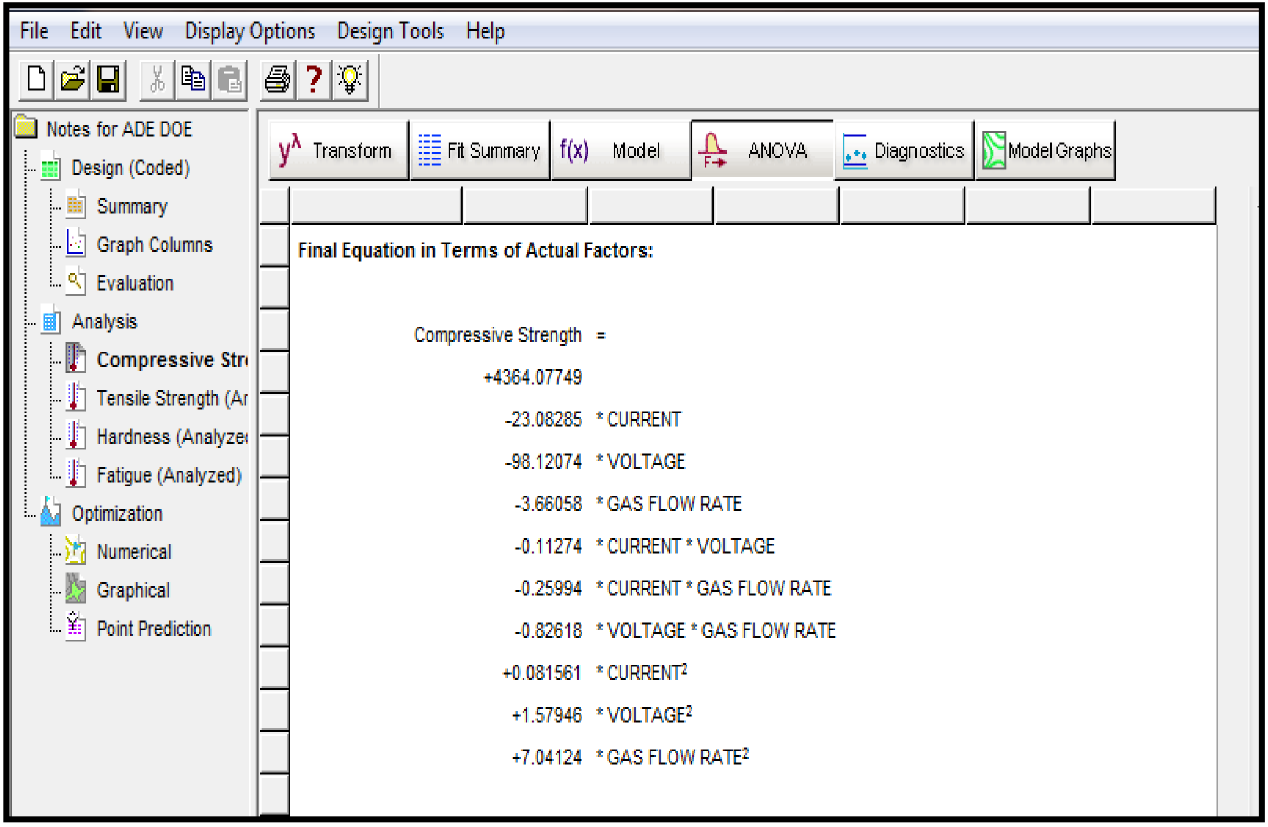
Std. Dev.	14.71	R-Squared	0.9883
Mean	544.99	Adj R-Squared	0.9778
C.V. %	2.70	Pred R-Squared	0.9415
PRESS	10844.72	Adeq Precision	24.518

The "Pred R-Squared" of 0.9415 is in reasonable agreement with the "Adj R-Squared" of 0.9778.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 24.518 indicates an adequate signal. This model can be used to navigate the design space.

The optimal equation which shows the individual effects, and the combine interactions of the selected input variables, namely; current, voltage and gas flow rate against the measured compressive strength is presented based on actual factors in table 5

Table 5: Optimal equation in terms of actual factors for maximizing compressive strength



Final Equation in Terms of Actual Factors:

Compressive Strength =
+4364.07749
-23.08285 * CURRENT
-98.12074 * VOLTAGE
-3.66058 * GAS FLOW RATE
-0.11274 * CURRENT * VOLTAGE
-0.25994 * CURRENT * GAS FLOW RATE
-0.82618 * VOLTAGE * GAS FLOW RATE
+0.081561 * CURRENT^2
+1.57946 * VOLTAGE^2
+7.04124 * 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 compressive strength response was obtained as presented in Figure 4

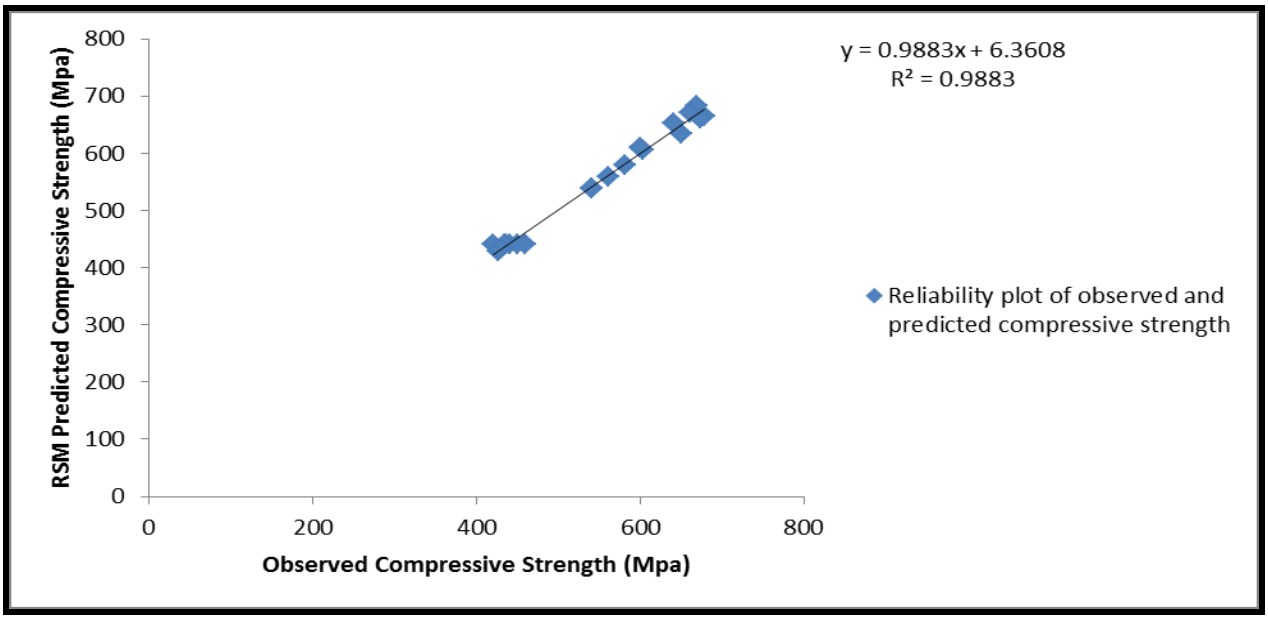
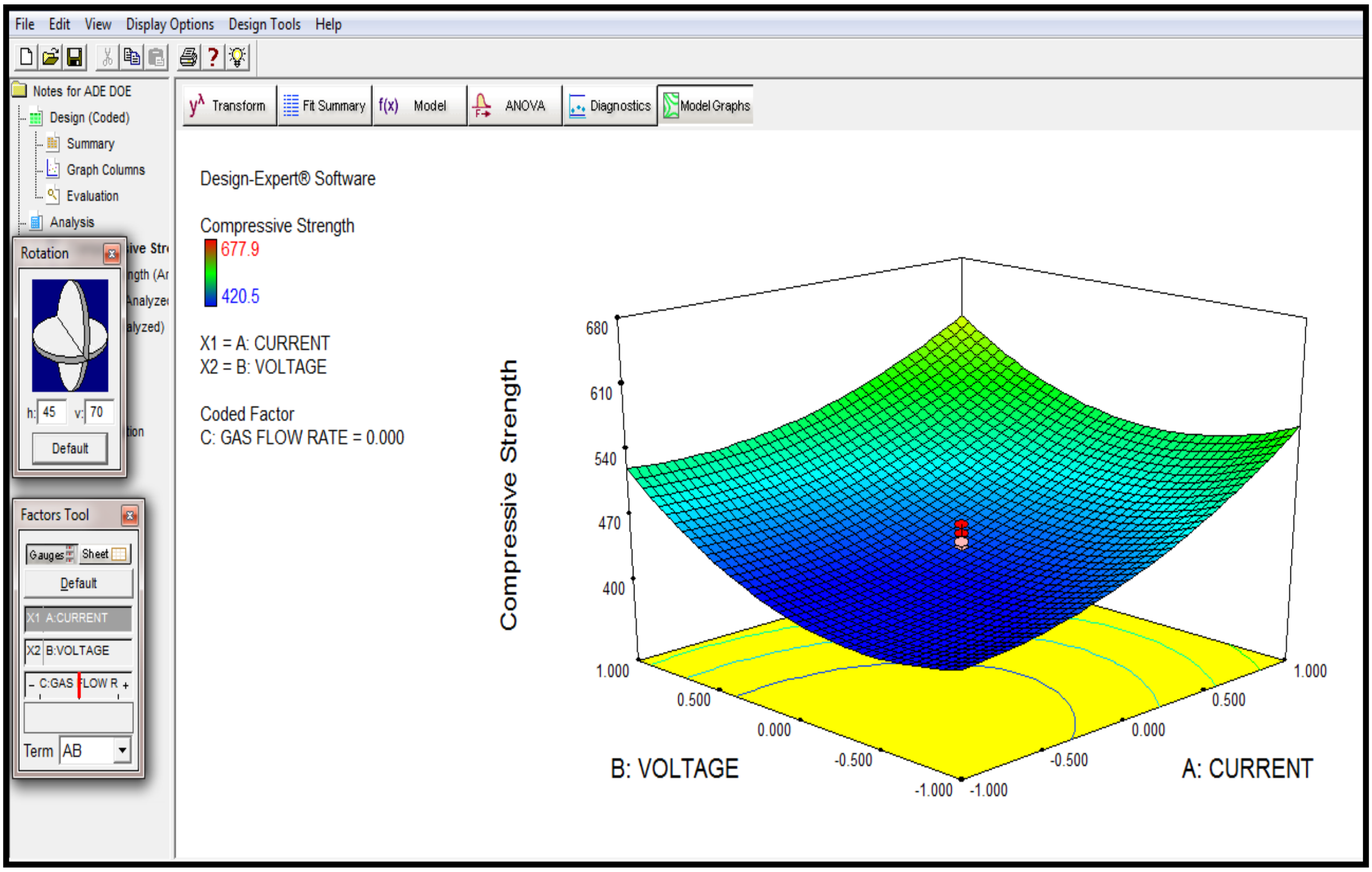


Figure 4: Reliability plot of observed versus predicted compressive strength

To study the effects of combine input variables on compressive strength variable), 3D surface plots presented in Figure 5



Design-Expert® Software

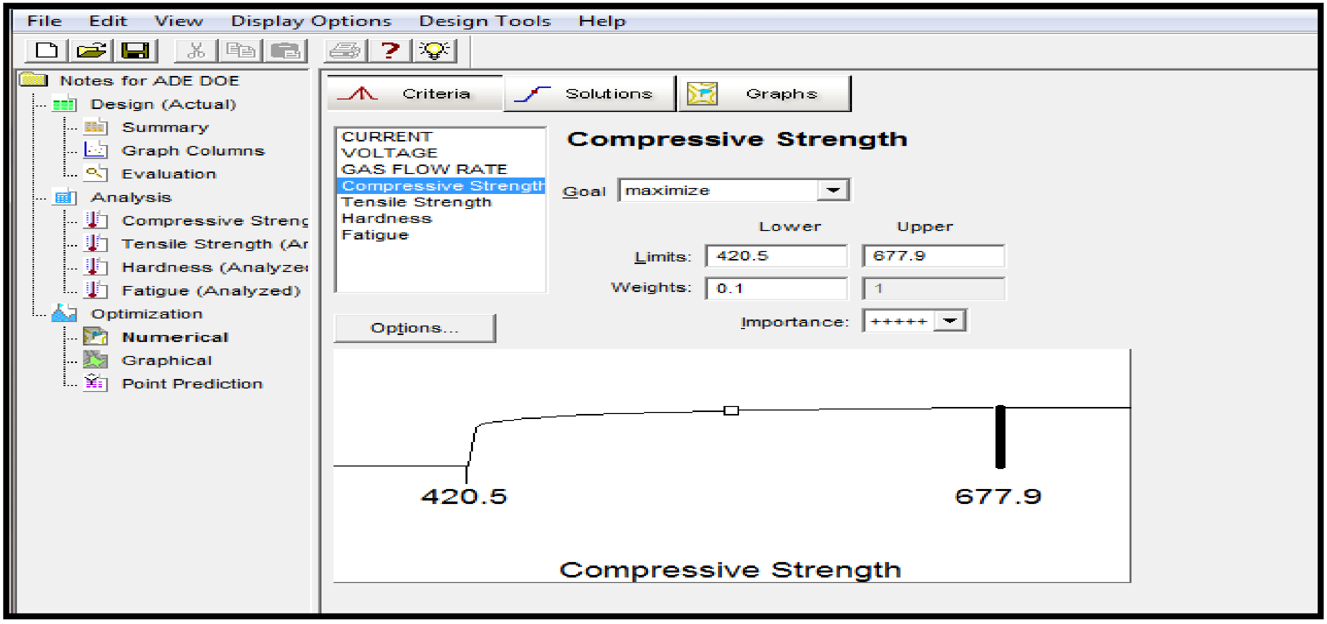
Compressive Strength
677.9
420.5

X1 = A: CURRENT
X2 = B: VOLTAGE

Coded Factor
C: GAS FLOW RATE = 0.000

Figure 5: Effect of current and voltage on compressive strength

The objective of this study was to determine the optimum current (Amp), voltage (volts) and gas flow rate (L/min) that will maximized compressive strength. The interphase of the numerical optimization showing the objective function is presented in Figure 6



Compressive Strength

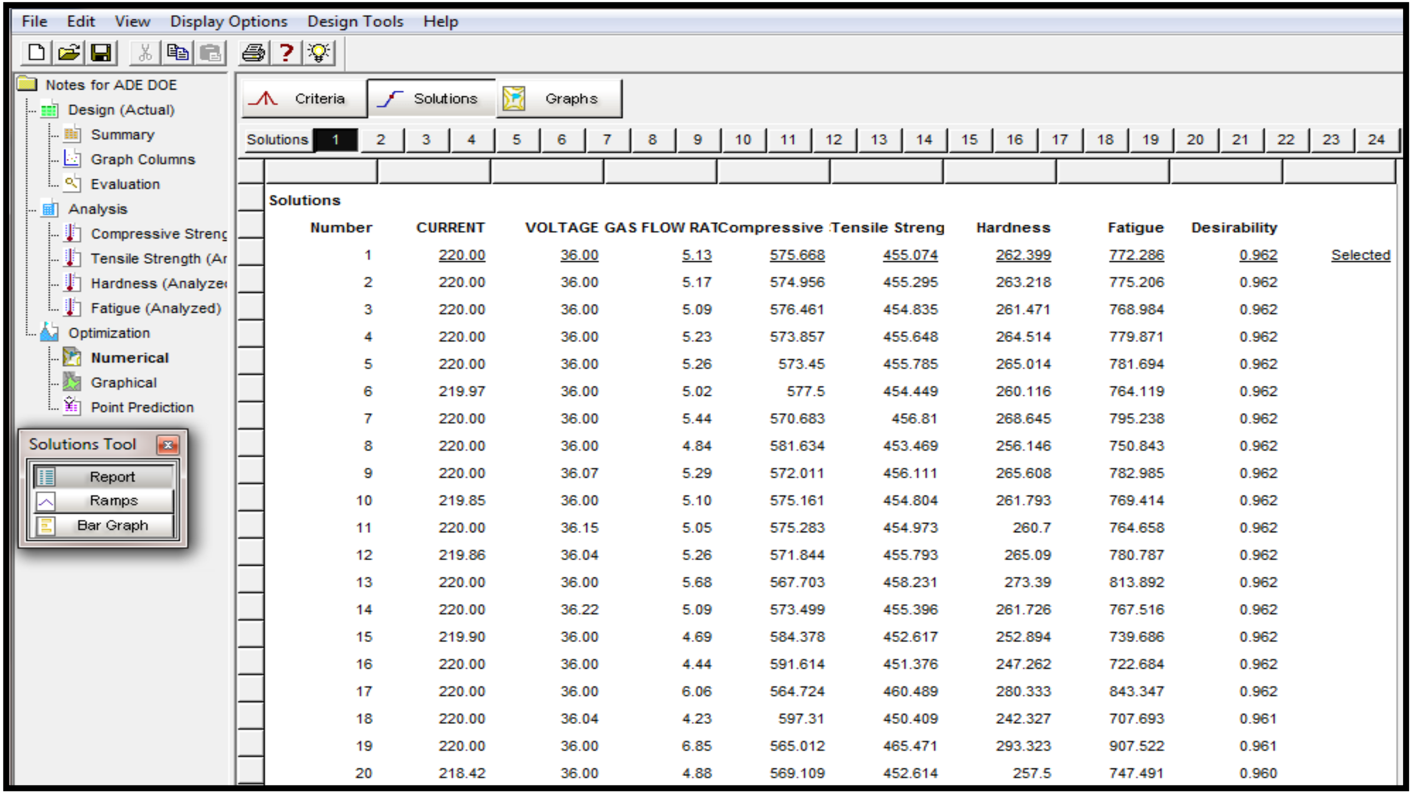
Goal: maximize

	Lower	Upper
Limits:	420.5	677.9
Weights:	0.1	1

Importance: +++++

The design expert software was used to produce the best optimal solution that will maximized the compressive strength present in the welds, the optimal solutions is shown in table 6

Table 6: The numerical optimal solution showing maximized compressive strength response



Solutions

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 study, the compressive strength response of TIG welding process has been maximized so as to increase the strength of the weldments. This study has systematically applied the Response Surface Methodology (RSM) to maximize compressive strength of Tungsten inert gas mild steel weld. The results obtained showed that the compressive strength of TIG mild steel weld are strongly influenced by input variables such as current, voltage and gas flow rate. The surface plot showed that current and voltage were observed to have the highest significant effect on the compressive strength of TIG mild steel weld. The result showed that a current of 220 amp, voltage of 36volt, and gas flow rate of 5.13L/min will result in a welding process with maximum compressive strength of 575.This solution was selected by design expert as the optimal solution with a desirability value of 96%.

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