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OPTIMIZATION OF TUNGSTEN INERT GAS WELDING PROCESS FOR A36 LOW CARBON STEEL ON TOUGHNESS ENGINEERING PROPERTY

Chukwuedo Joses Azuka*[1], And Emifoniye Elvis[2], Oyibo Alfred Onakemu[3]

[1]Chemical Engineering Technology Department, Delta State Polytechnic Ogwashi Uku.

[2]Mechanical Engineering Technology Department, Delta State Polytechnic Ogwashi Uku.

[3]Department of Welding and Fabrication, Delta State Polytechnic, Ogwashi Uku.

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***Corresponding Author**

Chukwuedo Joses Azuka

Department of Chemical Engineering Delta State Polytechnic Ogwashi-Uku.

ABSTRACT

Joining of A 36 grade steel with the process of welding can be a tasking with accompanying problems of cracking, and mechanical properties change of welded joing compared to the parent material. This is due to limited knowledge on parametric welding balance to obtaining efficient joint. The quality of welded joints depends primarily on the type of welding and the parametric value range chosen. The mechanical properties of impact strength on the welded joint using Tungsten inert gas welding process on A36 grade low carbon steel was studied with varied current, voltage and gas flow rate. The Box bekhken method of design on response surface method was used in the design of experiment that gave a total of (17) runs. Conclusively, Welding parameter of current 117A, Voltage 16V and gas flow rate resulted in a toughness value of 27Joules.

I. INTRODUCTION

[1]ASTM A36 steel is the most commonly available of the hot rolled steel. It is generally available in round rod, square bar, rectangular bar as well as I beam, H beam, angle and channels. It finds its application in areas like, bridge, ship, machine frame, and railway constructions. The chemical composition of A36 mild steel by weight (wt %) is given as follow C-0.26, Mn-0.75, Cu-0.2, P-0.04, S-0.05 and Fe. The prediction of the optimal weld deposit area is an important aspect in tungsten inert gas welding (TIG) process as it is related

to the strength of the weld. The goal of this research work is to optimize various parameters for TIG welding process, including welding voltage, welding current and electrode diameter by developing a mathematical model for sound weld deposit area of a mild steel specimen. Increasing of the arc welding current from 70-120A in A36 carbon steel will increase the welding heat input, it will affect the microstructure of the weld itself and give impact on the strength and hardness of the material. Increase in welding current results in increases in temperature of the weld and results in the depletion of toughness and hardness as a result of increased cooling time which gives rise to rapid growth of the grain.[2]

Parametric optimization for hardness of tungsten inert gas welding on copper reinforced mild steel composite was studied with varied current, gas flow rate and voltage on hardness response. Parameters set at (current 104A voltage 21V and gas flow rate of 11 lit/mins) with the goal of minimizing the hardness so that toughness should not be compromised gave the least hardness value of 66 BHN. Comparing of optimized output toughness and hardness mechanical properties of copper reinforced steel chip composite with the as cast and pure copper, optimized result showed superior enhanced toughness and hardness properties.[3]

Parametric optimization of metal inert gas welding by using taguchi approach was studied by.[4] The investigation resulted in the following conclusions. That current has the greatest influence on the mechanical property of hardness and toughness of ASTM A29.which was followed by welding voltage and wire speed. Current of 250A on the mechanical property of tensile strength was a dominant parameter on the sample tested for tensile strength. the next followed was welding voltage of 20volts and wire speed of 2.2mm./sec. This settings were the optimal optimized output settings.

The parametric sliding friction optimization of copper based composite was studied by.[5] Factors of percentage composition of steel chip, speed of slide, load and time of slide are considered with a goal of minimizing the coefficient of friction. The investigation is based on a user defined design that output a total of 25 runs. Factors effects on the response was covered in this research with a validation process of comparing predicted optimized output factor settings and experimented output results.

Response Surface method is used to find the optimal conditions for dry sliding wear of the steel chip reinforced composite. The following conclusions are drawn from the present study. This research gave understanding to coefficient of friction of Copper matrix reinforced steel chip composite with different percentage composition of steel chip. Optimized parametric effects of sliding speed, load, time and steel chip reinforcement was understood. Coefficient of friction is dominated by different parameters in the order of percentage of reinforcement, sliding speed, applied load and sliding time.

- The coefficient of friction is affected by different parameters in the order of percentage of reinforcement, speed of slide, load and time.
- With a desirability factor of 0.9, optimized coefficient of friction with a goal of minimize was output as 0.2484 with a parametric setting of Steel chip reinforcment percentage of 8.6, sliding speed of 41.5m/s load 15.5N and time of 7 minutes respectively

The effect of shielded metal arc welding was studied by[6] The mechanical properties of heat treated S45C steel was examined which resulted in an increase temperature causing an increase in strength of the material. The tensile test calculation shows that in the heating material in the heat treatment process the higher the heating temperature (0oC - 300oC) the average tensile load until the maximum condition increases, on the welding material without heating. Impact Testing With a constant cross-sectional area for each test specimen, with the decreasing of the effort, the material impact energy decreases.

II. EXPERIMENTAL PROCEDURE

2.1 *Material*

A36 Mild Steel of the required dimension was purchased from the local market and the test specimen was prepared from it. The chemical composition of A36 mild steel by weight (wt %) is given as follow C-0.26, Mn-0.75, Cu-0.2, P-0.04, S-0.05 and Fe.

2.2 *Design of Experiment*

Design of Experiment was done using the Box beknken design on response surface method. Notables for design of experiment (coded and real value) are represented in table 1. Factors varied are current and voltage and gas flow rate.

Table I: Notable for Design of Experiment.

Factors	Coded Value			Real Values		
Voltage	-1	0	1	14	16	18
Current	-1	0	1	100	120	140
Gas Flow rate	-1	0	1	12	14	16

2.3 *Welding of Sample*

Tungsten Inert welding machine was used in executing TIG welding on samples according to design of experiment. Current Voltage and gas flow rate were repeatedly altered according to combinations from design of experiment sheets. Values used in the design were from consulted welding procedure qualification for steel.

2.4 *Die Penetrant Test.*

According to ASTM SE 165-95, welded joint were cleaned before carrying out liquid penetrant inspection. After cleaning, die penetrant was applied to the surface of welded joints and allowed to dwell for 10 minute before cleaned away from surface. Absorber was then applied on cleaned surface then kept for another 5minutes to indicate surface defects in weld. Samples with defects were rejected.

2.5 *Impact Strength Testing*

The Charpy test standard sample of 55mm by 3mm by 3mm dimensions according to ASTM E23 -07, using the impact tester machine with a sample of geometry 45o V notch of 2mm deep and 0.25mm root radius is hit using the pendulum of the impact tester at the notch area to measure the amount of absorbed in joules. During toughness measurement, potential energy is converted to kinetic energy. A brittle nature of fracture indicates lower absorption of energy while ductile fracture surface indicates more energy absorbed**.** Figure 1 is the welded joint of the low carbon steel.

Figure 1: Impact welded sample.

III. RESULT AND DISCUSSION

Table 2 is the actual design of experiment achieved with the box-behnken design with three factors and three levels. A total of 17 runs was achieved as shown in the table. A mixture of factors was achieved and represented in a coded form.

Table II: Box- Behkhen Design of Experiment.

Runs	Voltage V	Current A	Gas flow rate (Lit/Min)	Impact strength (j)
1	18	100	12	22
2	18	140	12	23
3	18	140	16	24
4	16	100	12	25
5	16	140	16	23
6	14	140	12	23
7	14	100	14	22
8	18	140	14	25
9	18	100	14	24
10	14	100	12	26
11	18	100	16	22
12	16	120	12	24
13	14	140	16	23
14	16	140	12	23
15	14	120	16	23
16	16	120	14	25
17	18	120	12	25

3.1 *Analysis of Variance for Toughness Model*

Table 3 below is the analysis of variance for the toughness model. With a model F value of strength 7.30, this indicates that the model is significant. It also indicates that the chance for the F value to deviate from the mean is 0.79%. the values of probability less of the "F"than 0.0500 indicate model terms are appropriate. In this analysis, it indicates the square independent values of A and C (Current and and Gas flow rate) are significant model terms. With a value of 2.50 for the lack of fit, it implies the lack of fit is not significant in comparism to pure error. Table 4 is the adequacy measure table. A negative Predicted R square value is an indication that the total mean may be an improved predictor on the response than the current model. The measure of signal to noise is termed adequate precision. Basically, a value with ratio greater than 4 is preferred. In this analysis, the value of 7.279 indicates an adequate signal which is sufficient to navigate the design space.

Table III: ANOVA Table.

Analysis of variance table [Partial sum of squares - Type III]						
Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	11.75	3	3.92	4.20	0.0278	Significant
A-Voltage	*1.13*	*1*	*1.13*	*1.21*	*0.2922*	
B-Current	*0.50*	*1*	*0.50*	*0.54*	*0.4772*	
C-Gas flow rate	*10.12*	*1*	*10.12*	*10.85*	*0.0058*	
Residual	12.13	13	0.93			
Lack of Fit	*4.93*	*9*	*0.55*	*0.30*	*0.9361*	*not significant*
Pure Error	*7.20*	*4*	*1.80*			
Cor Total	23.88	16				

Table IV: Model Summary Table.

Std. Dev.	0.57	R-Squared	0.9037
Mean	23.65	Adj R-Squared	0.7799
C.V. %	2.42	Pred R-Squared	-0.0573
PRESS	25.25	Adeq Precision	7.279
-2 Log Likelihood	14.24	BIC	42.57
		AICc	70.91

The perturbation plot as plotted below is a representation of the effect of varied factors on the response. Notable A, B and C represents Current, Voltage and gas flow rate respectively. As seen from the plot increases in all the factors causes a decline on the toughness value beyond the central design space. From this figure, it can be seen that the toughness increases as gas flow rate increases which is due to adequate shielding of welding pool from atmospheric contamination which leads to annealing of the weld pool and the heat affected zone which would enhance their toughness. As seen from the perturbation plot, increase in argon gas flow rate increases the toughness until just after the central point and starts to record decline in toughness. This is because further increase in gas flow causes splatters to increase around the weld region. Splatters causes small pores to be present in the welded joint thus causing reduction in toughness strength. Also from the perturbation plot, an increase in current causes increases in heat input which results in large heat affected zone (HAZ).[7] The effect of cooling accounts for the increased toughness strength because of the ample time for cooling from elevated temperature which causes grain to grow thus making it coarse. A coarse grain indicates the toughness of the composite. Generally, as the results indicate, too high current is detrimental to the toughness of the welded composite using Tungsten Inert gas Welding process. Figure 5 and 6 are the contour plots for gas flow rate and current on toughness response.[8] An elliptical shape contour indicates interaction between factors on response while a circular shape contour indicates negligible interaction between factors on response.

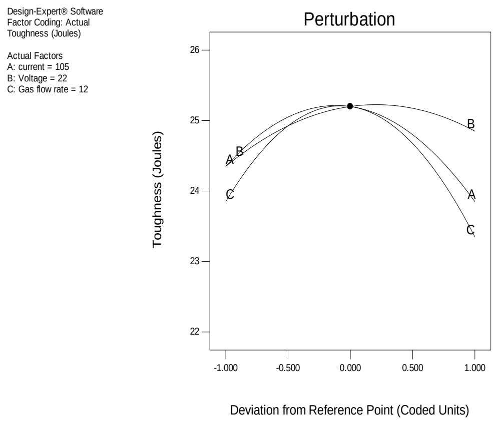

Figure 3: Perturbation Plot.

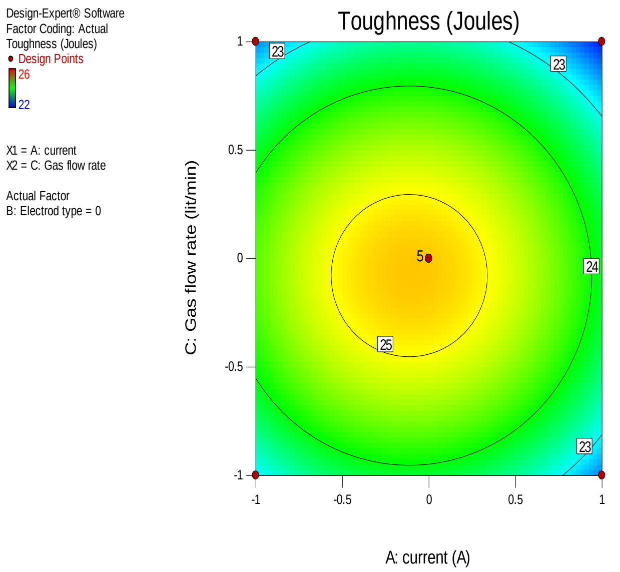

Figure 4: Contour plot of gas flow rate on current.

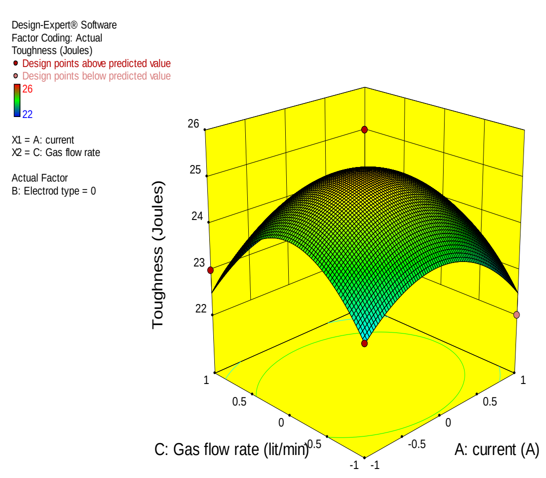

Figure 6: 3d contour plot.

3.2 Optimization

Table 5 is the representation for optimization setting for factors of voltage current and gas flow rate. All factors were set at in range with a goal of achieving in range values for factors. Ultimately, the response of toughness was set at maximize as shown in table 5. Table 6 is the output result for optimization corresponding to settings. Three solution were output.

Table V: Optimization Criteria Setting.

Factor and Response	Limits		Criterion	Goal
	Lower	Upper		
Voltage	14	18	In range	In range
Gas flow rate	12	16	In range	In range
Current	100	140	In range	In range
Toughness	22	26	In range	Maximize

Table VI: Summarized Output Result for Toughness Response.

Maximize output result				
Number	Voltage	Current	Gas flow	Toughness
1	16.5158	117.735	13.7637	25.2612
2	16.4100	116.532	13.4225	25.4200
3	15.9456	116.000	12.9679	25.0056

3.3 Validation of Test

Average values from table 6 were used for validation. Average value for current voltage and gas flow rate were calculated and used on the tungsten inert gas welding setting and used for welding samples. Samples were subjected to toughness test and result compared with predicted result as represented in table 7.

Table VII: Validation of Result Table.

Exp.no	Current	Voltage	G.F.R		Toughness Joules
1	116.7557	16.2905	13.3847	Actual	27
				Predicted	25.2289
2	116.7557	16.2905	13.3847	Actual	26
				Predicted	25.2289

IV. CONCLUSION

The effects of the variables of current, voltage and gas flow rate on A36 grade steel was tungsten inert gas welding was understood. Using statistical means, optimized process input was determined in terms of maximized properties of toughness.

The following conclusion can be draw from the research

- Welding parameter of Current 117A, Voltage 16V and gas flow rate resulted in a toughness value of 27Joules
- Comparing of optimized output mechanical properties of toughness on A36 welded joint with properties of non welded A36 grade steel gave result that were reasonable close to the mechanical properties of base material.

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