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Optimization of Impact Energy of TIG Mild Steel Welds Using RSM

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Abstract

TIG welding, is about the most popular welding method, which finds its applications in the fabrication industry. The integrity and service life of engineering structures is a very important factor in the welding technology sector, one of the problem facing the fabrication industry is the control of the process input parameters to obtain a good welded joint. Research has shown that one of the practical ways to improving on weld qualities is to optimize the input process parameters. The aim of this study is to optimize the impact energy of TIG mild steel welds using RSM with the purpose of achieving the highest impact energy.In this study, twenty experimental runs were carried out, each experimental run comprising the current, voltage and gas flow rate, the TIG welding process was used to join two pieces of mild steel plates measuring 60 x40 x10 mm, the tensile strength was measured respectively. Thereafter the data collected from the experimental results was analysed with the RSM Analysis of variance (ANOVA) a p-value of 0.0001 which is <0.005 indicates that the model is significant. To validate the significance and adequacy of the model based on its ability to optimize the ultimate impact energythe goodness of fit statistics showns that the model posses an R^2 value of 0.705989 and R^2 adjusted of 0.537617a noise to signal ratio of 7.89717 was realized, a ratio greater tha 4 is desired indicating thatt the model possesed adequate signal to predict the target response.the result shows that a combination of current 90 amps,voltage 22volts and gas flow rate 13lit/min will produce an optimum UTS of 381Mpa and impact energyof 116.6898J with a desiribility value of 0.889.

1. Introduction

Tungsten inert gas (TIG) welding is also called the gas tungsten arc welding (GTAW) is a welding process that is widely used in modern industries for joining either similar or dissimilar materials. This process uses a non consumable tungsten electrode which has a very high melting temperature and has advantages of producing very high quality weld, low heat affected zone, and absence of slag . A common problem that has faced the fabrication industry is the control of the process input parameters to obtain a good welded joint with the required bead geometry and weld quality with minimal detrimental residual stresses. According to Myers et al(1989) many industries today, now apply the Response Surface Method in formulating new products, especially in the chemical engineering industries,where there is need for process optimization.

Alvarez et al (2009) reported that GAs are applied in RSM in several situations where an optimization technique is needed.Chen et al (2005) created response surface models through regression on experimental data and applied the SQP and GAs on the models so as to optimize the processing conditions of dairy tofu. Both techniques were able to determine the optimal conditions for manufacturing these products.

Ozcelik and Erzurumlu(2005) presented an optimization method using RSM and GA to minimize the warpage on thin shell plastic parts. Kim et al (2002) proposed a method to optimize the variables for an arc welding process using RSM. Correia et al (2005) presented a comparison between GAs and RSM techniques in the gas metal arc welding (GMAW) optimization. Oehlert and Gary(2000) described the response Surface Methods as models that works continuously with treatments so as to achieve an optimum goal, he mentioned that the RSM is a very good optimization technique and has one common goal of determining the optimum response of the process. He mentioned that the RSM has a second goal,which is to understand how the response changes in a particular process, the response Surface Methods can be expressed graphically in the form a saddle ,ridge ,hill and valley lines.

Khoo et al(2000) studied the integration between the RSM and GAs so as to determine the near optimal values in response surface design. They presented a framework of the prototype system. A pseudo-objective function, which can be used to deal with one response and two response problems, was derived. The prototype system was validated 94 using three case studies. Comparative studies showed that both the prototype system and the Design Expert, which is a commercial software package, produced similar results.

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Optimization of input process parameters can be done using mathematical methods, hence the Response Surface Methodology (RSM) was used to obtain optimize the output quality of the weld.

2. Materials and Method

The method of achieving the objectives of the research is explained in this chapter. It comprises of the following:

(i) research design
(ii) population
(iii) Sampling technique
(iv) Method of data collection
(v) Models employed
(vi) Method of data analysis
(vii) Model validation
(viii) Model adequacy

2.1 Research design

Experimentation is a very important part of scientific study, and designing an experiment is an integrated component of every research study. In order to get the most efficient result in the approximation of polynomial the proper experimental design must be used to collect data.

The Central Composite Design(CCD) was developed for this study using the design expert softwareThis design is for any input parameters considered within the range of 3- 5 levels.

The key parameters considered in this work is gas flow rate (f) welding current (i) welding voltage (v) welding speed and the output parameters are the weld undercut and reinforcement.

The range of values of the process parameters was obtained from the open literature accessed, and each parameter has two levels which comprise the high and low .This is expressed in Table 1

Table 1: Welding parameters and their levels

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

2.2 Population

30 pieces of mild steel plate measuring 60mm in length, 40mm in width and 10mm thickness was used for the experiment. This experiment was repeated 30 times

2.3 samples and sampling technique

The tungsten inert gas welding equipment was used to weld the plates after the edges have been beveled and machined

2.4 Experimental procedure

Mild steel plate of thickness 10 mm was selected as material used for the experiment. The mild steel plate was cut with dimension of 60 mm x 40 mm with the help of power hacksaw and grinded at the edge to smoothen the surfaces to be joined. The surfaces of the coupon were polished with emery paper,thereafter the mild steel plates were fixed on the work table with flexible clamp to weld the joints of the specimen.A TIG welding process was used with Alternate Current (AC) to perform the experiments as it concentrates the heat in the welding area, using 100% argon gas as the shielding gas, thereafter the impact energy was measured.

2.5 Models Employed

In this study the Response surface methods (RSM) was employed in the prediction of impact energy.

Model development

Mathematical model developed is given as y= f(V,I,S,G) where y is the measured response (tensile strength) and V is voltage ,I is current,S Welding speed,and G is gas flow rate.

The second order polynomial model for the response is shown in the equations (1)

$$y = \beta_0 + \sum_{j=1}^{q} \beta_{jj} x_j^2 + \sum \sum {}_{kj} \beta_{ij} x_i x_i + \varepsilon$$

Model validation

To validate the significance and adequacy of the model based on its ability to optimize the I pact energy, the goodness of fit statistics presented as shown in table 2 was used

Table 2: Goodness of fit statistics for validating model significance and adequacy

Std. Dev.	4.775859		**R-Squared**	0.705989
Mean	97.6		**Adj R-Squared**	0.537617
C.V. %	4.893299		**Pred R-Squared**	0.381921
PRESS	1115.769		**Adeq Precision**	7.89717

Coefficient of determination (R-Squared) of 0.705989indicates the strength of the model and its suitability for predicting the values of the selected variables that will maximize the impact energy. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. our ratio of 7.8971 indicates an adequate signal.

Final Equation in Terms of Coded Factors:

$CVN = 103.00 + 1.39*A + 2.77*B - 6.78*C - 7.87*A*B - 5.37*B*C - 4.79*A^2 + 2.37*B^2 - 5.29*C^2$

Final Equation in Terms of Actual Factors:

$CVN = 1729.81670 + 3.26813*I + 29.33994*V + 195.18926*GFR - 0.11250*I*V - 2.68750*V*GFR - 3.91318E-003*I^2 + 0.59325*V^2 - 5.29365*GFR^2$

Results And Discussion

Table 3: Optimal solutions of numerical optimization model

Number	I	V	GFR	UTS	CVN	Desirability
1	90	22	13	381.1352	116.6898	0.889155
2	96.41	22	13	377.6694	117.0978	0.880848
3	90	22	13.06	379.0684	116.5721	0.880678
4	90	21.81	13	377.2912	114.7388	0.856178
5	111.25	22	13	369.8424	116.8084	0.849544
6	132.13	18	13	372.7932	100.4106	0.685103
7	132.76	18.04	13	371.0095	100.5745	0.681854
8	121.53	18	13.29	367.9153	99.96527	0.665489
9	114.97	19.13	13	358.7798	99.62112	0.634063

From the results of Table 3 it was seen that current (**90**amp), voltage (**22**.00volt), and gas flow rate (**13**litre/min) will produce the highest tensile strength of **381.1352** and impact energy of 116.68J This solution was selected by design expert as the optimal solution having a desirability value of **0.889155**

The model graphs which show the interactions of the combine variables on the measured response (impact energy) was evaluated using the 3D surface plot as shown in Figures 1 and 2

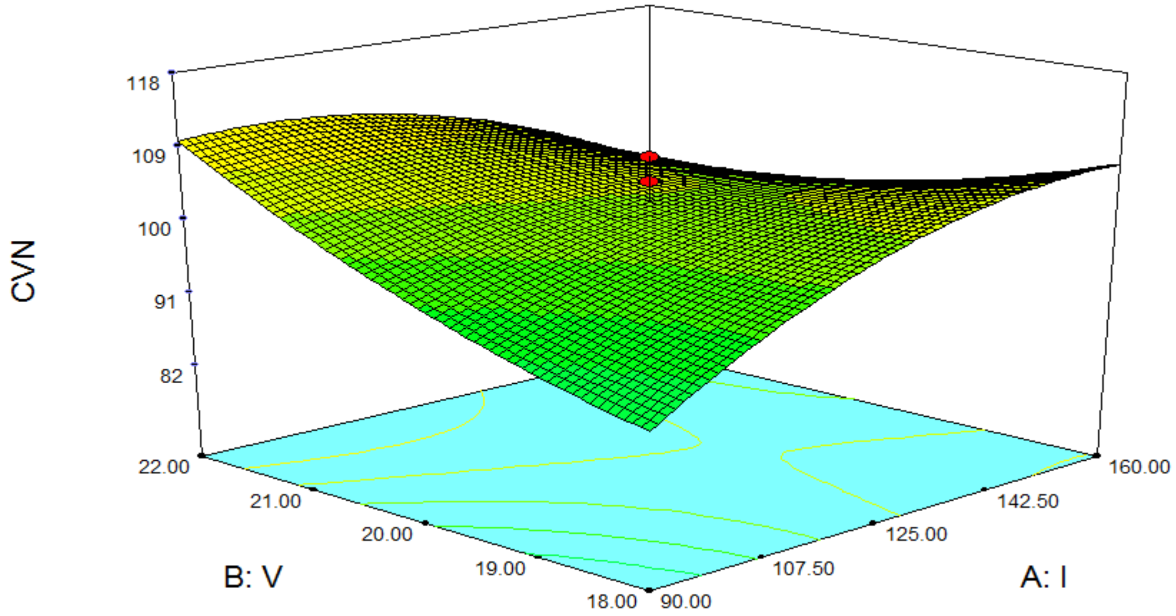

Fig 1: **Effect of voltage and current on impact energy**

Finally, based on the optimal solution, the contour plots that show the effects of each variables on the Impact energy was aslo produced and the results are presented as shown in Figure

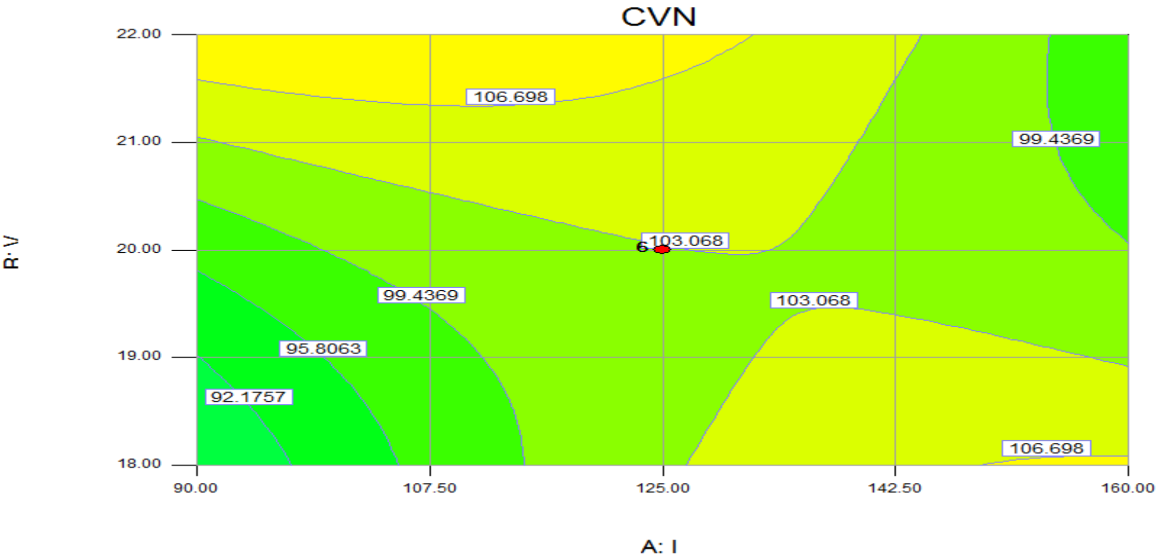

Fig 2 : Effect of voltage and current on impact energy

Coefficient of determination (R-Squared) of 0.705989indicates the strength of the model and its suitability for predicting the values of the selected variables that will maximize the impact energy. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. our ratio of 7.8971 indicates an adequate signal.

Conclusion

In this study, the Response Surface methodology was used to optimize the impact energy of TIG weld. The relationship between the process parameters and the impact energy is quadratic, and shows a strong correlation between the current and the response formed with a coefficient of correlation value of 70%

Analysis of variance (ANOVA) a p-value of 0.0001 which is <0.005 indicates that the model is significant To validate the significance and adequacy of the model based on its ability to optimize the uultimate tensile strength and impact energythe goodness of fit statistics showns that the model posses an Coefficient of determination (R-Squared) of 0.705989indicates the strength of the model and its suitability for predicting the values of the selected variables that will maximize the impact energy. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. our ratio of 7.8971 indicates an adequate signal to predict the target response.the result shows that a combination of current 90 amps,voltage 22volts and gas flow rate 13lit/min will produce an optimum UTS of 381Mpa and impact energy of 116.68J with a desiribility value of 0.889.

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