Prediction of Impact Energy of TIG Mild Steel Welds Using RSM

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Abstract

The present trend in the fabrication industries is the use of automated welding processes to obtain high production rates and high quality output.TIG welding, happens to be the best welding method employed in the manufacturing industry. one of the problem facing the fabrication industry is the control of the process input parameters to obtain a good welded joint . however it is essential to establish the relationship between process parameters and weld quality output to predict and control weld bead quality .The aim of this study is to predict the impact energy of TIG mild steel welds using ANN.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 impact energy was measured respectively. 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 predict the impact energy,the goodness of fit statistics shonws that the model posses an R^2 value of 0.705989and 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 posseed adequate signal to predict the target response.

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.

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. 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.

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.

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.

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 predict the impact 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

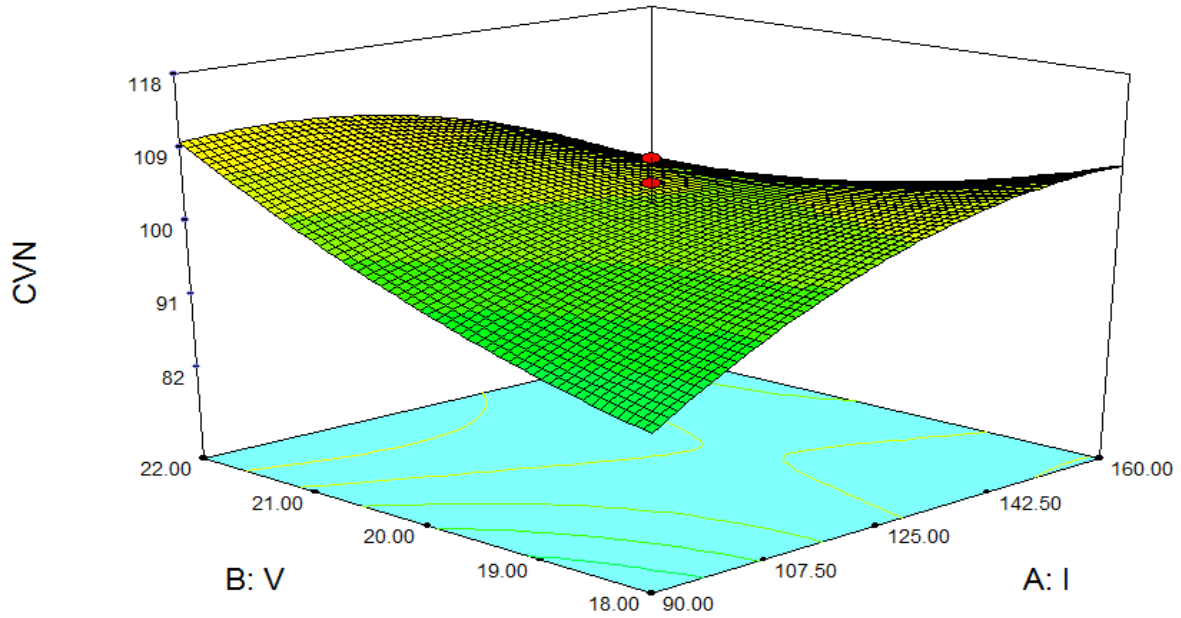**Final Equation in Terms of Actual Factors:**

CVN   =   1729.81670 + 3.26813*I + 29.33994*V + 195.18926*GFR - 0.11250*I*V - 2.68750*V*GFR -

$3.91318E\text{-}003*I^2 + 0.59325*V^2 - 5.29365*GFR^2$

Results And Discussion

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
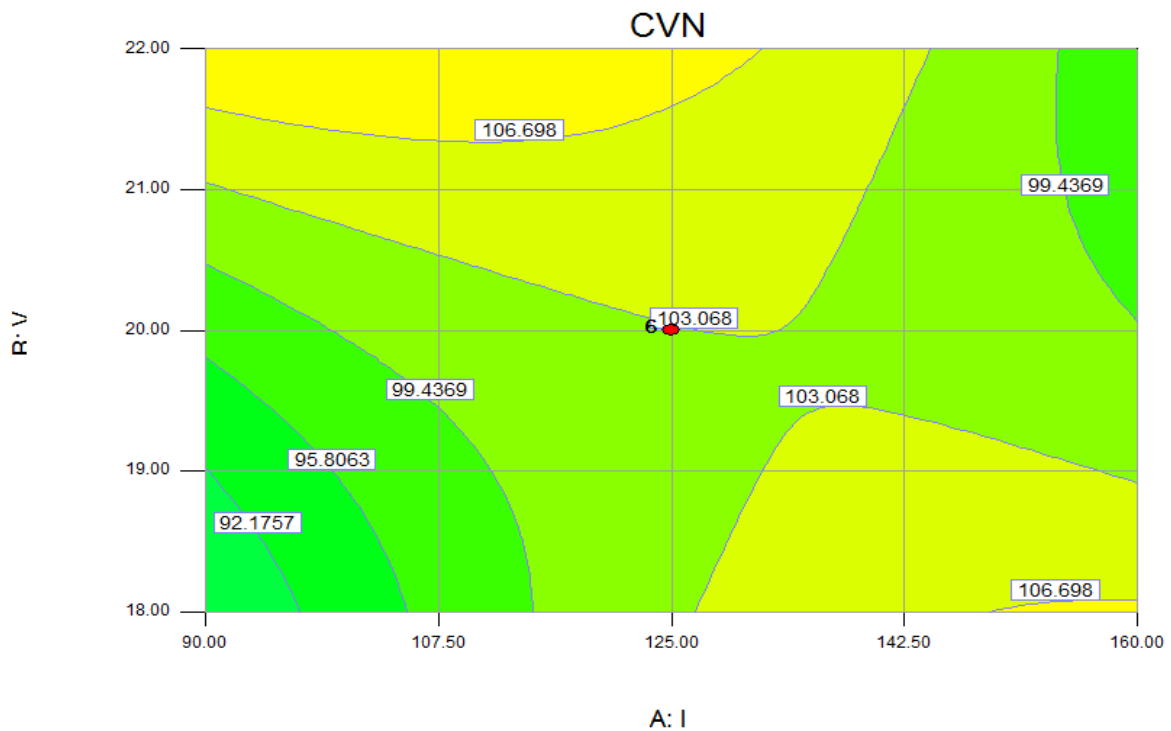
Fig 2 : Effect of voltage and current on impact energy

Table 4.10: Diagnostics case statistics of first twenty runs

Std Order	Actual Value	Predicted Value	Residual	Leverage	Internally Studentized Residual	Externally Studentized Residual	Influence on Fitted Value DFFITS	Cook's Distance	Run Order
1	90	84.65943	5.340568	0.535714	1.641131	1.80065	1.934208	0.345296	4
2	98	103.1975	-5.19753	0.535714	-1.59718	-1.7376	-1.86648	0.327047	18
3	115	116.6898	-1.68983	0.535714	-0.51928	-0.50129	-0.53848	0.03457	10
4	100	103.7279	-3.72793	0.535714	-1.14557	-1.1639	-1.25022	0.168249	5
5	83	81.8435	1.1565	0.535714	0.355387	0.34081	0.366089	0.016192	6
6	105	100.3816	4.618405	0.535714	1.419214	1.497162	1.60821	0.258227	12
7	95	92.3739	2.626098	0.535714	0.806987	0.793272	0.852111	0.083491	2
8	77	79.412	-2.412	0.535714	-0.74119	-0.72504	-0.77882	0.070432	1
9	82	86.20449	-4.20449	0.619048	-1.42635	-1.50639	-1.92028	0.367336	13
10	95	91.03361	3.966392	0.619048	1.345578	1.403669	1.789334	0.32691	14
11	102	105.3296	-3.32958	0.619048	-1.12954	-1.14545	-1.46017	0.230365	7
12	118	114.9085	3.091484	0.619048	1.04877	1.054049	1.343654	0.198596	9
13	102	98.86749	3.132511	0.619048	1.062688	1.069626	1.363511	0.203902	17
14	72	75.37061	-3.37061	0.619048	-1.14346	-1.16146	-1.48057	0.236077	11
15	105	103	2	0.166667	0.458743	0.441639	0.197507	0.004677	16
16	100	103	-3	0.166667	-0.68811	-0.67068	-0.29994	0.010522	3
17	98	103	-5	0.166667	-1.14686	-1.16537	-0.52117	0.029228	19
18	105	103	2	0.166667	0.458743	0.441639	0.197507	0.004677	20
19	108	103	5	0.166667	1.146857	1.165375	0.521171	0.029228	8
20	102	103	-1	0.166667	-0.22937	-0.21922	-0.09804	0.001169	15

Conclusion

In this study, the Response Surface methodology was used to predict 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 the response formed with a coefficient of correlation value of 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 0.705989 indicates 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

REFERENCES

Myers, Raymond H. and Montgomery, Douglas C. 1995. *Response Surface Methodology: process improvement with steepest ascent, the analysis of response Surfaces, experimental designs for fitting response surfaces,* 183-351. New York: John Wiley and Sons, Inc.

Oehlert, Gary W. 2000. *Design and analysis of experiments: Response surface design.* New York: W.H. Freeman and Company

Khoo, L. P. and Chen, C.H. (2001): Integration of response surface methodology with genetic algorithms, *The International Journal of Advanced Manufacturing Technology,* 18 483-489.

Alvarez, M.J., Ilzarbe, L., Viles, E. and Tanco, M. (2009): The use of genetic algorithms in response surface methodology', *Quality Technology & Quantitative Management*, 6, 295-307.

Chen, M.J., Chen, K.N. and Lin, C.W. (2005): Optimization on response surface models for the optimal manufacturing conditions of dairy tofu, *Journal of Food Engineering*, 68 471- 480.

Özçelik, B. and Erzurumlu, T. (2005): Determination of effecting dimensional parameters on warpage of thin shell plastic parts using integrated response surface method and genetic algorithm, *International Communications in Heat and Mass Transfer*, 32 1085-1094.

Kim, D., Rhee, S. and Park, H. (2002): Modelling and optimization of a GMA welding process by genetic algorithm and response surface methodology, *International Journal of Production Research* 40 1699-1711.

Correia, D. S., Gonçalves, C.V., Sebastiao, S. C. and Ferraresi, V.A. (2005): Comparison between genetic algorithms and response surface methodology in GMAW welding optimization, *Journal of Materials Processing Technology*, 160 70-76.