International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 4, April - 2014

Weld Strength Optimization by using Box-Behnken Design

P. Vigneshwaran[1],
PG Student, Department of Mechanical Engineering
RVS College of Engineering & Technology, Dindigul-624 005

M. P. Prabakaran[2]
Assistant professor, Department of Mechanical Engineering
SBM College of Engineering and Technology, Dindigul-624 005

T. Selvaraj[3]
Assistant professor, Department of Mechanical Engineering
SBM College of Engineering and Technology, Dindigul-624 005

G. R. Kannan[4]
Professor, Department of Mechanical Engineering
PSNA College of Engineering and Technology, Dindigul-624 622

***Abstract* - The gas tungsten arc welding (GTAW) process is generally for fusion welding of stainless steel, magnesium alloys, nickel base alloys, carbon steel and low alloy steels. The project deals with the similar welding of austenitic stainless steel 3mm sheet metal. There are several process parameters namely arc voltage, gas flow rate, torch distance, current, welding speed to used, to determine the quality of weld strength. Among the following process parameter the arc voltage, gas flow rate and welding speed for the purpose of analysis. The seventeen experiments were conducted as per box-behnken design for gas tungsten arc welding the process of austenitic stainless steel 3mm sheet and the results are tabulated for the response surface of tensile strength. Response surface methodology is utilized to develop an effective mathematical model to predict weld strength. A comparison study is made for tabulated values and experimental values for tensile strength by using analysis of variance. The model found statistically fit for 95% confidence level. It's observed that the tensile strength occurs at higher voltage, higher gas flow rate and at lower welding speed.**

***Key words- TIG welding, Sheet metal, Tensile Strength, RSM, ANOVA*.**

1. INTRODUCTION

Gas tungsten arc welding (GTAW) process is an important process in many industrial operations. It is possible to weld on both non-ferrous and ferrous materials with the gas tungsten arc welding process [1, 2]. Depending upon the amperage used, a variety of plate thicknesses can be welded. The process can be used for welding anything from thick material down to very thin material and produce high quality welds. Stainless steel is an alloy, which is iron based and contains various combinations of other elements to give it characteristics suitable for a wide range of applications [3, 4]. Austenitic stainless steel has become a staple material across many industries and austenitic stainless steel having corrosion resistance. Also known as 316L austenitic stainless steel poses distinct challenges when TIG welded, the greatest of which are carbide precipitation and distortion. The key to preventing these pitfalls is good heat control, correct travel speeds and adequate gas coverage. The presence of nickel (14%), along with chromium (18%), enhances its corrosion and/or stain resistance, but these and other elements-often titanium or molybdenum-also cause it to react to heat differently than other materials. Effectively, austenitic stainless steel conducts heat at around half the rate of mild steel, but has a much higher rate of thermal expansion when welded. Response surface methodology is utilized to develop an effective mathematical model to predict weld strength by using RSM [5-7]. Ahmed Khalid Hussain et al. These papers consider the welding speed on tensile strength on welded joints in GTAW process of aluminium alloys. Experiments were conducted on specimens of single V butt joint having different bevel angles and bevel heights. The experimental results show that depth of penetration of weld bead decreases with increase in bevel height. The tensile strength increased with lower weld speed and decreasing heat input rate. It was also found that bevel angle of the weld joint has profound effect on the tensile strength. In this investigation the response surface methodology to be used develops mathematical models to predict the weld strength in the butt joint of austenitic stainless steel AISI 316L sheets.

2. EXPERIMENTAL DETAILS

The austenitic stainless steel (316L) contain 18% chromium and 14% nickel. They have an excellent corrosion resistance, weldability, formability fabricability, ductility, cleanability and hygiene characteristics. The chemical composition of austenitic stainless steel specimen 316L is given in the Table1

Table: 1 Chemical composition of stainless steel

Elements	C	Si	Mn	P	S	Cr	Mo	Ni	N
Wt%	0.03	0.75	2.0	0.045	0.03	18.0	3.0	14.0	0.1

2.1 Plan of Experiments

An important stage in response surface model generation by RSM is the planning of experiments. The factors which have a significant influence on weld strength of tungsten inert gas welding were identified they are arc voltage, shield gas flow rate and torch distance of tungsten inert gas welding. Large numbers of trial runs were carried out using 3 mm thick stainless steel specimens to determine maximum and minimum values of gas tungsten arc welding parameters.

Table: 2 Process parameters and their actual values

Factors	Notation	Unit	Factor Level		
			Low	Middle	High
Voltage	V	Volts	110	120	130
Gas Flow Rate	G	lpm	10	12.5	15
Welding speed	S	Mm/min	8	10	12

2.2 Experimental observations

Tensile specimens were prepared to ASTM E8M-04 guidelines were followed for preparing the test specimens.

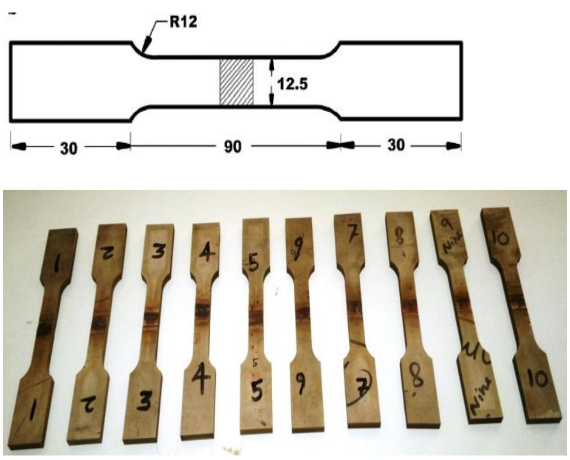

Fig: 1 Tensile test specimen ASTM E8M-04.

The specimen was loaded at 40 tone universal testing machine as per ASTM specification, so that tensile specimen underwent uniform deformation. The specimen finally failed after the necking and then the load versus displacement was recorded [10, 11]. The present study to predict the weld strength on TIG welding process parameter and maximize the weld strength using response surface methodology.

2.3 Response surface model for weld strength

The second order mathematical models have been developed predict the weld strength.

$$yi = \beta_0 + \sum_{j=1}^{q} \beta jxj + \sum_{j=1}^{q} \beta jjxj^2 + \sum \sum_{i<j}^{s} \beta ij\, xi\, xj$$

Where y_i is response, i.e., weld strength; x_j represents voltage, gas flow rate and welding speed β_0, β_j, β_{jj}, and β_{ij} represent the constant, linear, quadratic, and interaction terms, respectively. The three factors, the selected polynomial could be expressed as

$TS=b_0+b_1 (V) +b_2 (G) +b_3 (S) +b_{11} (V^2) +b_{22} (G^2) +b_{33} (S^2) +b_{12} (VG) + b_{13} (VS) +b_{23} (GS)$

The weld strength obtained from experimental results for different combination of parameters is given as input to the design expert software, and a second order mathematical model for predicting weld strength is developed. The developed mathematical model for Tungsten inert gas welding is given below.

Tensile strength (TS) = +29.70 + 0.75× (V) +0.10× (G) +0.075×(S) +0.025× (VG) +0.23× (VS) +0.13 × (GS)-0.49× $(V)^2$-0.014× $(G)^2$-0.087×$(S)^2$

A total of 17 experiments were conducted at different levels of parameters to obtain a gas tungsten arc welded joints of specimens. The values of weld strength obtained from experiments and those predicted from response surface model along with design matrix tabulated.

Table: 3 Process parameters and their experimental values.

S.No	**Voltage (V) volts**	**Gas flow rate (G) lpm**	**Welding speed (S) mm/min**	**Weld strength (TS) kN/mm²**
1	120	15	12	29.9
2	120	12.5	10	29.6
3	130	12.5	12	30.1
4	110	15	10	28.3
5	130	15	10	29.9
6	120	10	8	29.3
7	120	12.5	10	29.6
8	130	10	10	29.8
9	110	12.5	8	28.6

ISSN: 2278-0181
Vol. 3 Issue 4, April - 2014

10	120	12.5	10	29.8
11	120	12.5	10	29.7
12	120	10	12	29.3
13	130	12.5	8	29.6
14	120	15	8	29.4
15	110	10	10	28.3
16	120	12.5	10	29.8
17	110	12.5	12	28.2

3. RESULTS AND DISCUSSION

3.1 Analysis of variance

Analysis of variance is the separation of variance ascribable to one group of causes from the variance ascribable to other group. It is nothing but an arithmetical procedure used to express the total variation of data as the sum of its non- negative components. Analysis of variance (ANOVA) is similar to regression in that it is used to investigate and model the relationship between a response variable and one or more independent variables.

Table: 4 ANOVA Result

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	6.07	9	0.67	42.91	< 0.0001
A-Voltage	*4.5*	*1*	*4.5*	*286.36*	*< 0.0001*
B-Gas flow rate	*0.08*	*1*	*0.08*	*5.09*	*0.0587*
C-Welding speed	*0.045*	*1*	*0.045*	*2.86*	*0.1344*
AB	*2.50E-03*	*1*	*2.50E-03*	*0.16*	*0.7019*
AC	*0.2*	*1*	*0.2*	*12.89*	*0.0089*
BC	*0.062*	*1*	*0.062*	*3.98*	*0.0863*
A^2	*1*	*1*	*1*	*63.68*	*< 0.0001*
B^2	*0.08*	*1*	*0.08*	*5.07*	*0.0591*
C^2	*0.032*	*1*	*0.032*	*2.05*	*0.1952*
Residual	0.11	7	0.016		
Lack of Fit	*0.07*	*3*	*0.023*	*2.33*	*0.2155*
Pure Error	*0.04*	*4*	*1.00E-02*	**R-Squared= 0.9822**	
Cor Total	6.18	16		**Adj R-Squared= 0.9593**	

The adequacy of the developed relationship is tested using the analysis of variance (ANOVA) technique. As per this technique, if the calculated value of the F-ratio of the developed model is less than the standard F-ratio value at a desired level of confidence, then the model is said to be adequate within the confidence limit. ANOVA test results are presented in Table 12 for the model. From the table, it is understood that the developed relationship is found to be adequate at 95% confidence level. The Model F-value of 42.91 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

3.2 Analysis of response surface graphs

Response surfaces were developed for the empirical relationship, taking two parameters in the 'X' and 'Y' axis and response in 'Z' axis. The response surfaces clearly indicate the optimal response point. The maximum tensile strength of TIG welded stainless steel sheet is exhibited by the apex of the response surface. The surface plots showing the effect of input parameters taken two at a time on weld strength. The different colored surfaces show that the values of weld strength obtained for the corresponding values of input parameters.

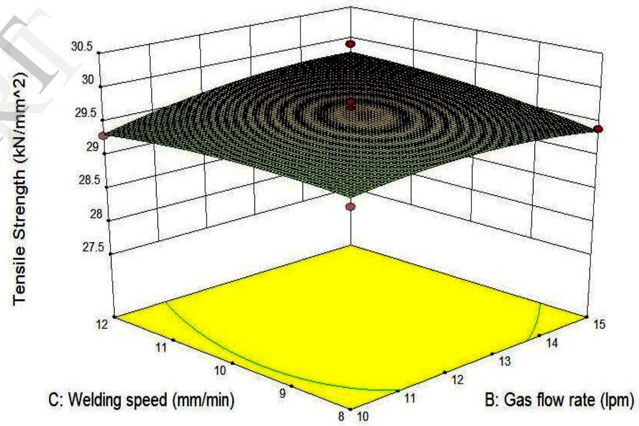

Figure: 2 Response surface due to interaction of gasflow rate and welding speed on tensile strength

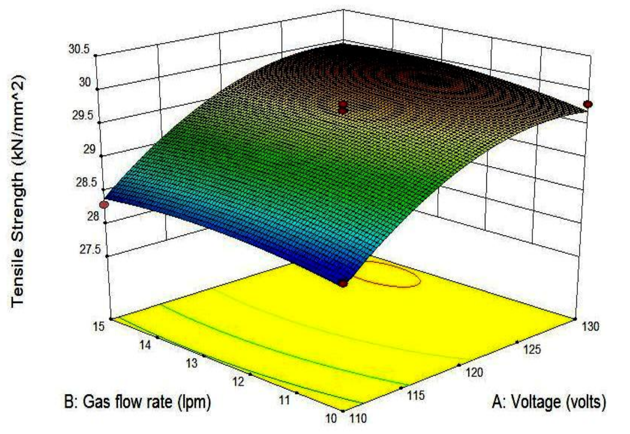

Figure: 3 Response surface due to interaction of gas flow rate and voltage on tensile strength

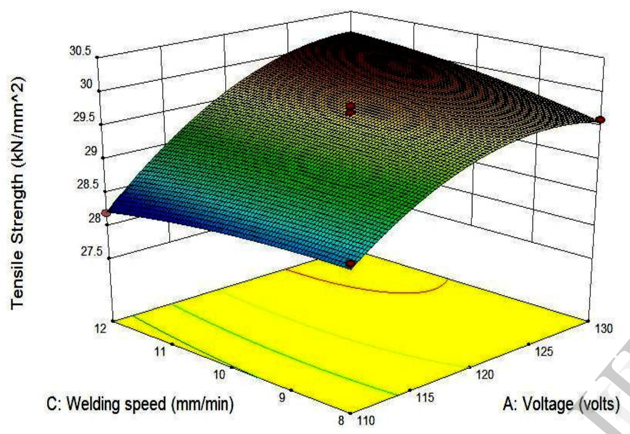

Figure: 4 Response surface due to interaction of voltage and welding speed on tensile strength

Figure (2, 3&4) represents the three dimensional response surface plots for the response tensile strength obtained from the regression model. The response surface graphs for the tensile strength between welding speed and gas flow rate. It can be seen from this figure that weld strength increases with increase of gas flow rate for any value of welding speed. The increase in voltage gives a good metal to metal contact leading to better penetration and increase of weld strength. So the combination of increase in voltage and gas flow rate leads to better penetration and its gives good weld strength.

CONCLUSION

The project deals with similar metal welding of austenitic stainless steel 3mm sheet using tungsten inert gas welding. In the study the following process parameter namely arc voltage, gas flow rate and welding speed considered for the effect on weld strength. Trail experiment of seventeen numbers is conducted as per the box-behnken design. The second order quadratic model was used to predict tensile strength values for experimental value by response surface methodology. A comparison study is made for tabulated values and experimental values for tensile strength by using analysis of variance the model is statistically fit found on 95% confidence level. The following are the observations made from the response surface plots .Higher Tensile Strength occurs for the following conditions:

- Higher voltage with the higher gas flow rate.
- Higher voltage with Lower welding speed.
- Lower welding speed with higher gas flow rate.

REFERENCE

1. G Vairamani, T. Senthil kumar, S. Malarvizhi, V. Balasubramanian, (2013). Application of response surface methodology to maximize tensile strength and minimize interface hardness of friction welded dissimilar joints of austenitic stainless steel and copper alloy, Trans. Nonferrous Met. Soc. China 23 2250-2259.
2. Benyounis KY, Olabi AG, Hashmi MSJ (2008) Multi-response optimization of CO2 laser-welding process of austenitic stainless steel. Opt. Laser Technol 40:76-87.
3. M. M. A. Khan, L. Romoli, Marco Fiaschi, G. Dini & F. Sarri (2012) Multiresponse optimization of laser welding of stainless steels in a constrained fillet joint configuration using RSM. Int J Adv Manuf Technol 62:587-603.
4. Myers RH, Montgomery DH (1995). Response surface methodology. USA: John Wiley & sons; 705 pp. S Elangovan, S Venkateshwaran and K Prakasan., 2012.
5. Experimental investigations on optimization of ultrasonic welding parameters for copper to brass joints using response surface method and genetic algorithm. Int J of Adv Engg Research and Studies E-ISSN2249–8974.
6. Benyounis KY, Olabi AG, Hashmi MSJ., 2005. Optimizing the laser-welded butt joints of medium carbon steel using RSM. Journal of Materials Processing Technology 164–165:986–989.
7. Manonmani K, Murugan N, Buvanasekaran G (2007). Effects of process parameters on the bead geometry of laser beam butt welded stainless steel sheets. Journal of Advanced manufacturing technology 32 (11-12): 1125-1133.
8. G Vairamani, T. Senthil kumar, S. Malarvizhi, V. Balasubramanian, (2013). Application of response surface methodology to maximize tensile strength and minimize interface hardness of friction welded dissimilar joints of austenitic stainless steel and copper alloy, Trans. Nonferrous Met. Soc. China 23 2250-2259.
9. Meshram S D, Mohandas T, Madhusudhan Reddy G, (2007) Friction welding of dissimilar pure metals. Journal of Materials Processing and Technology, 184: 330-337.
10. Paventhan R, Lakshminarayanan P R, Balasubramanian V., (2011) Prediction and optimization of friction welding parameters for joining aluminium alloy and stainless steel. Transactions of Nonferrous Metals Society of China, 21: 1480-148.