Study and Empirical Modeling Relating Welding Parameters and Mechanical Properties of Metal Inert Gas Welded SS304 and C28 Plate

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Abstract: The present work deals with optimization of welding process variables by using regression analysis. Stainless Steel AISI SS304 was welded to AISI C-28 carbon steel using a metal inert gas welding which also known as gas metal arc welding with the help of filler wire of stainless steel. The effect of welding current, welding speed and gas flow rate has been evaluated on the Tensile Strength, of the butt weld bead deposited. These responses have been analyzed using the analysis of variance (ANOVA) and empirical modeling. Plots of significant factors and empirical modeling have been used to determine the best fit relationship between the responses and the model parameters using MINITAB 15. This has been used to determine which is the most influencing factor or parameter. The weld tensile strength has been found to increase with decrease of welding current and gas flow rate.

Keywords: Welding of Dissimilar metal, Metal inert gas welding, Empirical Modeling, and tensile strength of weld bead, ANOVA technique.

I. INTRODUCTION

Gas Metal Arc Welding (GMAW), sometimes referred to by its subtypes Metal Inert Gas (MIG) welding or Metal Active Gas (MAG) welding, is a semi-automatic or automatic 0020 Arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. Gas metal arc welding is one of the conventional and traditional methods to join materials. A wide range of materials may be joined by Gas metal arc welding—similar metals, dissimilar metals, alloys, and nonmetals. In the present scenario demand of the joining of similar materials continuously increases due to their advantages, which can produce high yield strength, deeper penetration, continuous welding at higher speed and small welding defects.

II. DESIGN OF EXPERIMENT AND EXPERIMENTAL WORK

The design of experiment is based on ²ⁿ factorial design which is known as full factorial technique. Here n is number of variables taken during the experiment [8]. In my experiment n= 3.A full factorial design contains all possible combinations of a set of factors. This is the most fool proof design approach, but it is also the most costly in experimental resources. The full factorial designer supports both continuous factors and categorical factors with up to nine levels. In full factorial designs, an experimental run at every combination of the factor levels. If there are n factors that we need to evaluate in a process we need to run the experiment ²ⁿ times. Each factor will have two levels, a “high” and “low” level. Table 1 shows the factorial design in a standard order matrix. The ²ⁿ factorial design has two levels of each of the three variables requires 2×2×2= 8 run. The ²ⁿ design matrix is shown in Table 1.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>X₁ (Ampere)</th>
<th>X₂ (Voltage)</th>
<th>X₃ (Q) l/min</th>
<th>T Strength (N/m²)</th>
<th>P Stiffness (N/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
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<td>4</td>
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<td>High</td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“High” indicates the maximum value of input parameter
“Low” indicates the minimum value of input parameter
Where X₁= Input current in ampere
X₂= Welding voltage in volt
X₃= Gas flow rate in l/min
A total of 8 experiments have been conducted using 3 different parameter. The combination of input parameter is taken on the basis of full factorial technique. Three parameter have been taken as current, weld speed and gas flow rate of the shielding gas. Detail description of input parameter is given below:

A. Input Parameters Taken In Experiment

Maximum Current \((I_{\text{max}})\) = 180 ampere
Minimum Current \((I_{\text{min}})\) = 140 ampere
Maximum Voltage \((V_{\text{max}})\) = 26 volt
Minimum Voltage \((V_{\text{min}})\) = 28 volt
Maximum Gas Flow Rate \((Q_{\text{max}})\) = 15 l/min
Minimum Gas Flow Rate \((Q_{\text{min}})\) = 18 l/min

Tests have been being conducted on tensile testing machine. Range of the load is up to 400kN. When gradual load (tensile) is applied to the work piece, work piece suffered a little deflection before fracture.

III. TESTING OF WELDED WORK PIECE

Table II. Tensile strength of weld bead at different parameter

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Voltage</th>
<th>Current</th>
<th>Gas flow rate</th>
<th>Tensile Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>26</td>
<td>140</td>
<td>15</td>
<td>544.33</td>
</tr>
<tr>
<td>2.</td>
<td>28</td>
<td>140</td>
<td>15</td>
<td>658.33</td>
</tr>
<tr>
<td>3.</td>
<td>26</td>
<td>180</td>
<td>15</td>
<td>476.00</td>
</tr>
<tr>
<td>4.</td>
<td>28</td>
<td>180</td>
<td>15</td>
<td>550.33</td>
</tr>
<tr>
<td>5.</td>
<td>28</td>
<td>180</td>
<td>18</td>
<td>485.00</td>
</tr>
<tr>
<td>6.</td>
<td>26</td>
<td>180</td>
<td>18</td>
<td>313.67</td>
</tr>
<tr>
<td>7.</td>
<td>28</td>
<td>140</td>
<td>18</td>
<td>384.67</td>
</tr>
<tr>
<td>8.</td>
<td>26</td>
<td>140</td>
<td>18</td>
<td>613</td>
</tr>
</tbody>
</table>

B. Regression Analysis for Tensile Strength of the Obtained Weld Bead

Equation 2 is the regression equation obtained from regression analysis. ANOVA for the regression has been given in table 3. Regression table also suggests that welding current is most significant factor. Table 3 indicates that p value for regression equation is significant.

The regression equation is –

\[
T = 1030 + 16.4 V - 2.35 I - 36.1 Q
\]

Where V = Voltage
I = Current
Q = Gas flow rate

S = 109.445  R-Sq = 47.39%  R-Sq(adj) = 7.94%

B. Residual Analysis for Tensile Strength

Residual is the difference between the observed and fitted value of the response. There are four different graphs are available as normal probability plot, histogram, versus fit and versus order as shown in given graphs.

1) Normal probability plot ( residual Vs percent variation in Tensile Strength)
2) Residual Vs frequency histogram.
3) Residual Vs fitted value.
4) Residual Vs observation order. (see figure 2, 3, 4, and 5)

![Normal Probability Plot](image1)

**Fig. 2. Normal probability plots for Tensile Strength**

![Histogram](image2)

**Fig. 3. Histogram for Tensile Strength**

![Versus Fits](image3)

**Fig. 4. Versus fits for Tensile Strength**

![Versus Order](image4)

**Fig. 5. Versus order plot for Tensile Strength**

The abscissa of histogram plot shows the residuals and vertical axis demonstrates the recurrence of event of that residuals. The ordinary likelihood plot and histogram recommends inexact ordinary dissemination of residuals. In remaining plot of fits x-hub speak to the elasticity reaction and y-hub the residuals. Straight flat line leftover versus fits demonstrates the zero lingering or the fitted model line which implies every one of the focuses would have been lying on that if there is zero leftover or no remaining which is about unrealistic. The scattered focuses in leftover versus fits demonstrate the residuals lying far from the fitted esteem. Nonappearance of a specific pattern of residuals in versus fitted esteem plot demonstrates the solid match of the model.

V. RESULT AND DISCUSSION

The effect of input parameter was studied on stiffness of the butt weld bead by using Regression analysis and full factorial design. Stiffness is measured as the response parameter. Regression analysis was completed for all the responses to analyze the significance of the input factors. Regression equation was developed to predict the relationship amongst the dependent and independent variables.

**TABLE V. SHOWS THE VALUES OF STIFFNESS OBSERVED AND PREDICTED.**

<table>
<thead>
<tr>
<th>S.No</th>
<th>V (Volt)</th>
<th>I (Amp)</th>
<th>Q Lit/min</th>
<th>T (Predicted) MPa</th>
<th>T (Observed) MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>140</td>
<td>15</td>
<td>585.9</td>
<td>544.33</td>
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<tr>
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<td>140</td>
<td>15</td>
<td>618.7</td>
<td>658.33</td>
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<tr>
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<td>550.33</td>
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<td>180</td>
<td>18</td>
<td>416.4</td>
<td>485.00</td>
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<tr>
<td>6</td>
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<td>180</td>
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<td>383.6</td>
<td>313.67</td>
</tr>
</tbody>
</table>
A. Weld current has been observed to be a critical factor as to tensile strength with p estimation of 0.292. Aside from weld current other huge factor is weld voltage however it is lesser critical than weld current. The p estimation of speed is 0.693. Mass stream rate did not demonstrate any huge effect on the rigidity of the weld dab.

B. From the above data it is clear that the ultimate tensile strength of weld bead has a highest value at low welding current and gas flow rate.

VI. CONCLUSION

The present work has been carried out to study the effect of input parameters on the some mechanical properties (i.e. Tensile strength and stiffness) of butt welds, made on AISI C-28 and AISI SS304 using MIG welding. These parameters (Current, voltage and gas flow rate) are varied at two levels as higher level and lower level. The main factor to affect tensile strength is welding current

REFERENCES

[1]. Prakash Ahirwar et al. “Welding is an efficient and economical method for joining of metals
[3]. Ajit Hooda, Ashwani Dhingra and Satpal Sharma “optimization of mig welding process parameters to predict maximum yield strength in AISI 1040”, 2012