Process Parameter Investigation Of TIG Welding On SS316L Using RSM

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Abstract— In this work, Process parameters of TIG welding for Austenitic stainless steels (316L) is analyzed using Response Surface Methodology. The SS316L contains high Chromium and Nickel content with less carbon content therefore it is highly resistant to corrosion. It is mainly widely used in the application of orthopedic implants, aircraft engine parts, heat exchangers, furnace parts. SS316L is generally used as thin materials hence it is preferred to use TIG welding to obtain perfect weld. The input process parameters are taken as current, voltage and gas pressure. The output parameters tested are hardness using Rockwell hardness testing machine and Tensile strength using Universal testing machine. The Box-Behnken method is used to analyze the input and output parameters of 17 samples to obtain the suitable process parameters for getting the strongest weld.

Keywords— TIG Welding, Stainless Steel 316L, Response Surface Methodology, Optimize, Process Parameters.

I. INTRODUCTION

The stainless steel 316L is used as precise material for several applications, so we preferred TIG welding as suitable welding process. The main concept of our project is to obtain the optimized solution to increase the strength of weld. By considering the three factors (Current, Voltage, Gas Pressure) in Response Surface Methodology (RSM) we will find the optimized solution. Grade 316L, the low carbon version of 316 and is immune from sensitization (grain boundary carbide precipitation). Thus it is extensively used in heavy gauge welded components (over about 6mm). There is commonly no appreciable price difference between 316 and 316L stainless steel. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures. Compared to chromium-nickel austenitic stainless steels, 316L stainless steel offers higher creep, stress to rupture and tensile strength at elevated temperatures. Type 316L offers improved weld ability and also reduces the possibility of lower corrosion resistance around welded areas.

1.1. Welding variables
- Welding current
- Arc voltage
- Arc Travel speed (or) chuck speed
- Electrode Extension (or) stick out
- Gas flow rate

1.2. TIG welding benefits
- Superior quality welds
- Welds can be made with or without filler metal
- Precise control of welding variables (heat)
• Free of spatter
• Low distortion
• Slag removal is not required (no slag)

1.3. TIG welding limitations
• Requires greater welder dexterity than MIG or stick welding
• Lower deposition rates
• More costly for welding thick sections

II. OBJECTIVE
Gas tungsten arc welding is one of the widely used techniques for joining ferrous and nonferrous metals. TIG welding offers several advantages like joining of dissimilar metals, low heat affected zone, there is no slag to clean off after welding because no flux used. TIG weld quality is strongly characterized by weld bead geometry. From the experiments to study the effect of process parameters on tensile test and hardness. The main objective of this project is to find the optimized process parameters to weld SS316L using the Response Surface Methodology to get the maximum weld strength.

III. METHODOLOGY
3.1. Excremental work
Design of Experiments (DOE) is a set of techniques that revolve around the study of the influence of different variables on the outcome of a controlled experiment. Generally, the first step is to identify the independent variables or factors that affect the product or process, and then study their effects on a dependent variable or response.

In statistics, Box–Behnken designs are experimental designs for response surface methodology, devised by George E. P. Box and Donald Behnken in 1960, to achieve the following goals:

• Each factor, or independent variable, is placed at one of three equally spaced values, usually coded as −1, 0, and +1. (At least three levels are needed for the following goal.)
• The design should be sufficient to fit a quadratic model, that is, one containing squared terms, products of two factors, linear terms and an intercept.
• The ratio of the number of experimental points to the number of coefficients in the quadratic model should be reasonable (in fact, their designs kept it in the range of 1.5 to 2.6).
• The estimation variance should more or less depend only on the distance from the centre (this is achieved exactly for the designs with 4 and 7 factors), and should not vary too much inside the smallest (hyper) cube containing the experimental points.
3.2. Work Methodology

![Block diagram of working process](image)

**Figure 1. Block diagram of working process**

**IV. PROCESS PARAMETERS**

**4.1. Constant parameter**
- Work Piece Thickness
- Wire rod diameter
- Welding speed
- Welding technique (Down hand welding)

**4.2. Input Parameter**
- Factor A: Welding Current
- Factor B: Welding Voltage
- Factor C: Gas Flow Rate

**4.3. Input process parameters using Box–Behnken array**
Table 1. Input process parameters

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Current (Amp)</th>
<th>Voltage (V)</th>
<th>Gas Pressure (Lit/min)</th>
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<td>1</td>
<td>70</td>
<td>11.5</td>
<td>13</td>
</tr>
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<td>12.9</td>
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<tr>
<td>17</td>
<td>90</td>
<td>12.05</td>
<td>16</td>
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</table>

4.4. Material edge preparation
The test specimen is 3mm thickness, it is machined in such a way that it can be tested in UTM machine. The below figure shoes the dimensions of single piece, similar piece will the welded with this and it will be tested.

Figure 2. 2D Diagram of single work piece
V. RESULT AND DISCUSSION

5.1. Comparing test results

Table 2. Comparing test results

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Hardness (HRC)</th>
<th>Tensile Strength (N/mm2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>82.6</td>
<td>447.6</td>
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<tr>
<td>2</td>
<td>86</td>
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<td>3</td>
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<tr>
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<td>500.83</td>
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</table>

Figure 3. Specimen after welding
5.2. Rockwell hardness test result

![Rockwell hardness test result graph](image1)

*Figure 4. Rockwell hardness test result graph*

5.3. Ultimate tensile strength result

![Ultimate tensile test result graph](image2)

*Figure 5. Ultimate tensile test result graph*
5.4. Graphs from Response Surface Mythology

**Figure 6. Hardness vs. voltage vs. current graph**

For any value of voltage when there is increase in current the hardness gradually increases. For any value of current with decrease in voltage the value of hardness in considerably decreases. To obtain the maximum hardness it is preferable to have maximum voltage and current.

**Figure 7. Hardness vs. gas pressure vs. voltage**

For any value of gas pressure when there is increase in voltage the hardness increases considerably. For any value of voltage with decrease in gas pressure the value of hardness in gradually decreases. To obtain the maximum hardness it is preferable to have maximum gas pressure and voltage.
Figure 8. Hardness vs. current vs. gas pressure

For any value of current when there is increase in gas pressure the hardness decreases gradually. For any value of gas pressure with decrease in current the value of hardness in gradually increases. To obtain the maximum hardness it is preferable to have minimum gas pressure and current.

Figure 9. Tensile vs. voltage vs. current

For any value of voltage when there is increase in current the tensile increases considerably. For any value of current with decrease in voltage the value of tensile in considerably decreases. To obtain the maximum tensile it is preferable to have maximum voltage and current.
For any value of gas pressure when there is increase in current the tensile decreases considerably. For any value of current with decrease in gas pressure the value of tensile in gradually decreases. To obtain the maximum tensile it is preferable to have maximum gas pressure and minimum current.

For any value of gas pressure when there is increase in voltage the tensile increases considerably. For any value of voltage with decrease in gas pressure the value of tensile in increases considerably. To obtain the maximum tensile it is preferable to have minimum gas pressure and maximum current.
VII. CONCLUSION

Hence in this work, the process parameters of TIG welding for Austenitic stainless steels (316L) is analyzed using Response Surface Methodology. The input process parameters are taken as current, voltage and gas pressure, and the output parameters tested are hardness using Rockwell hardness testing machine and Tensile strength using Universal testing machine. The Box-Behnken method is used to analyze the input and output parameters of 17 samples to obtain the suitable process parameters for getting the strongest weld. The various graphs are obtained from the Design Expert software and the effect of input process parameters are discussed and evaluated. Therefore from the result, for obtaining maximum hardness the tensile strength in the weld is evaluated.

REFERENCES