

## Process Parameter Optimization for Tensile Strength for Plasma Arc Welding of SS304

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### ABSTRACT

The Joining of the Austenitic Stainless Steels is often used in the pressure vessels, chemicals and processing industries. The mechanical properties at the weld bead should also fulfill requirement of applicable code. Several process parameters interact in the complex manner resulting in direct or indirect influence on the mechanical properties. It is necessary to find out the optimum process conditions which are capable of producing desired weld quality. Therefore to achieve the typical tensile strength in Plasma Arc Welding (PAW) is the primary objective of this study. The parameters Current (I), Voltage (V), Wire feed ( $W_f$ ) were optimized using Taguchi Orthogonal Array and Analysis of Variance (ANOVA) is used for the analysis. The optimum parameters observed are Current: 230A; Voltage: 28V; Wire feed: 740mm/min resulting UTS of 687.35 MPa for SS304 of 6mm thickness..

**Keywords** - Taguchi, ANOVA, PAW

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### I. INTRODUCTION

Plasma arc welding (PAW) is an arc welding process similar to gas tungsten arc welding. The electric arc is formed between an electrode (which is usually but not always made of sintered tungsten) and the work piece. The key difference from GTAW is that in PAW, by positioning the electrode within the body of the torch, the plasma arc can be separated from the shielding gas envelope. The plasma is then forced through a fine-bore copper nozzle which constricts the arc and the plasma exits the orifice at high velocities (approaching the speed of sound) and a temperature approaching 28,000 °C (50,000 °F) or higher.

### II. EXPERIMENTAL DESIGN

In order to optimize the tensile strength levels of parameter Current, Voltage and Gas flow are decided after pre experimentation done for various levels of these process parameters.

| Parameter          | Level 1 | Level 2 | Level 3 |
|--------------------|---------|---------|---------|
| Current (A)        | 210     | 220     | 230     |
| Voltage (V)        | 24      | 26      | 28      |
| Wire feed (mm/min) | 700     | 740     | 780     |

**Table 1:** Level of Process parameters

The experimentation was conducted for L9 orthogonal array. The plates were tacked first and then the sample number identification was done by

itching sample number on the plate. The process parameters were written on the plate by means a permanent marker.

### III. MATERIAL SPECIFICATIONS

Flat plates of SS 304 with dimension 300x150x6 mm are taken. The chemical composition is verified with the Material Test Certificate received with the material. Additionally PMI testing is done.



**Figure 1:** Raw material

| BASE METAL | Chemical Composition |      |       |      |     |       |       |      |           |
|------------|----------------------|------|-------|------|-----|-------|-------|------|-----------|
|            | %C                   | %Mn  | %Cr   | %Ni  | %Mo | %S    | %P    | %Si  | %Fe       |
|            | 0.061                | 0.83 | 18.14 | 8.02 | -   | 0.002 | 0.041 | 0.43 | Remaining |

**Table 2:** Chemical composition of SS 304

#### IV. TESTING AND ANALYSIS OF RESULTS

The samples were tested for non destructive testing such as Visual Inspection, Dye Penetration Testing and Radiographic Testing. The reports are examined by certified Level-II inspector and all the results are found satisfactory.

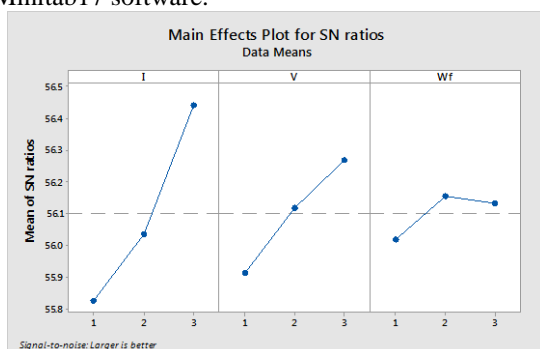
The tensile test was conducted with reference to standard ASTM A370-2017. Following are the obtained results.

| Sample no | Ultimate Tensile Strength in MPa |
|-----------|----------------------------------|
| 1         | 650.14                           |
| 2         | 616.16                           |
| 3         | 684.09                           |
| 4         | 645.11                           |
| 5         | 653.08                           |
| 6         | 642.19                           |
| 7         | 654.44                           |
| 8         | 640.35                           |
| 9         | 667.53                           |

**Table 3: Results of Tensile Test**

#### V. ANALYSIS OF RESULTS

Taguchi method uses a statistical measure of performance, called as signal-to-noise (S/N) ratio. The S/N ratio is a logarithmic function of desired output serves as objective functions for optimization. The S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). This ratio is a measure of robustness used to identify control factors that reduce variability in a product or process by minimizing the effects of uncontrollable factors. The standard S/N ratios generally used are categorized as Nominal the best (NB), Lower the better (LB) and Higher the better (HB). The S/N ratio for each quality characteristic can be computed independently and regardless of the category of the performance characteristics, a larger S/N ratio corresponds to better quality characteristics. The analysis of the result was done by using Minitab17 software.



**Figure 2: Means Plot for Tensile Test from MINITAB 17**

The figure shows the variation of a particular factor away from the mean value. The more the deviation the greater is the effect of the factor on the response. Here current at level 3, Voltage at level 3, wire feed at level 2 observed to be most effective with the response Ultimate Tensile Strength.

ANOVA calculation for ultimate tensile strength. The analysis of variants was done using Minitab 17 software. Following results are obtained.

| Source    | DF | SS     | Mean of Squares | F     | % Contribution |
|-----------|----|--------|-----------------|-------|----------------|
| Current   | 2  | 3247.4 | 1623.72         | 10.35 | 67.825         |
| Voltage   | 2  | 1049.7 | 524.83          | 3.35  | 21.92          |
| Wire feed | 2  | 177    | 88.49           | 0.56  | 3.69           |
| Error     | 2  | 313.8  | 156.89          |       |                |
| Total     | 8  | 4787.9 |                 |       |                |

**Table 4: ANOVA results**

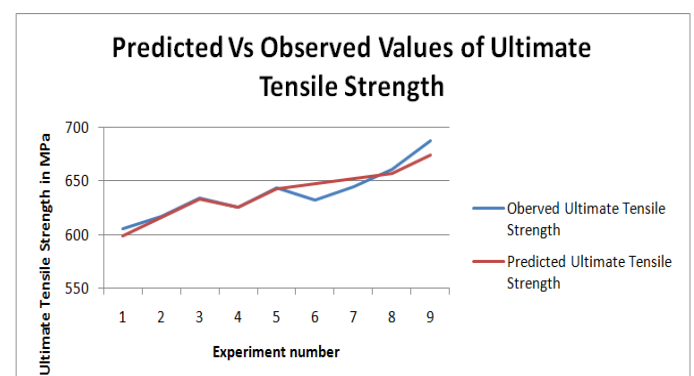
From the above results It can be seen that the Current being most dominant factor with percentage contribution of 67.825%, followed by Voltage with 21.92% and Wire feed with 3.69% contribution on ultimate tensile strength.

Regression Analysis

The regression model for the tensile strength is calculated from software MINITAB 17.

$$UTS = -109 + 2.282 I + 6.59 V + 0.100 W_f$$

The calculations are done for Predicted values of Ultimate Tensile stress are done and observed against the actual values of UTS. We could get following graphical relation



**Figure 3: Predicted Vs Observed values of UTS**

### Confirmation of Experiments

The confirmation of experiment is done with the process parameters Current: 230A, Voltage 28V and wire feed 740 mm/min.

Three samples were welded on the same parameter setting and the samples were tested. The testing results were as follows.

|                            | Sample 1 | Sample 2 | Sample 3 |
|----------------------------|----------|----------|----------|
| Observed Value of UTS(MPa) | 686.14   | 680.33   | 682.68   |
| Predicted Value UTS(MPa)   | 674.38   |          |          |

**Table 5: Confirmation Test Results**

## VI. CONCLUSION

The present work is concerned determining the optimum parameters for tensile strength for Plasma Arc Welding.

After the experimentation it was observed that the maximum tensile strength is achieved 687.53 MPa for the current as 230A, voltage as 28V and wire feed as 740 mm/min.

These results are confirmed by confirmation test taken on three samples for which tensile strength was found to be 686.14, 680.33, 682.68 MPa

The ANOVA analysis gives result that the current is the most dominant factor for tensile strength with 67.825% contribution followed by voltage with 21.92% contribution.

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