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Research Article

# Optimization of Process Parameters for Tungsten Inert Gas Welding of AISI 316L using Cacl$_2$ and Tio$_2$ as flux Materials

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***Abstract***

*AISI 316 is the standard molybdenum-bearing grade, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. 316L stainless steel offers higher creep, stress to rupture and tensile strength at elevated temperatures. Tungsten Inert Gas (TIG) welding continues to be one of the major welding processes used in the industry for high quality joints. Numerous developments have taken place in TIG welding technology over the past in power supply, shielding gas, tungsten electrode and welding torches, the productivity improvements were marginal. An increase in productivity can be achieved by increasing the penetration depth, as it helps reducing the number of welding passes. Activated TIG welding process known as A-TIG can be beneficial in this respect. In this work an attempt is made to study the feasibility of joining AISI 316 by A-TIG welding. In addition ANOVA analysis with three factors is performed and results indicate that among the parameters considered (flux material, weld current, root gap) the most significant parameter is flux material followed by weld current and root gap.*

***Keywords:*** *Activated TIG Welding, Flux material, Root gap, Weld current, ANOVA.*

## 1. Introduction

TIG welding also called as Gas Tungsten Arc Welding (GTAW) is a welding process in which the heat necessary to melt the metal is provided by a very intense electric arc which is struck between a virtually non-consumable tungsten electrode and metal work piece. The electrode does not melt and become a part of the weld. On joints where filler metal is required, a welding rod is fed into the weld zone and melted with base metal in the same manner as that used with oxyacetylene welding.

**Figure 1** Joint Configuration

The weld zone is shielded from the atmosphere by an inert-gas which is ducted directly to the weld zone where it surrounds the tungsten. The major inert gases that are used are argon and helium. The A-TIG welding process involves a method of increasing the penetration capability of the arc in TIG welding. This is achieved through the application of a thin coating of activating flux material onto the joint surface prior to welding as shown in the figure 1

The effect of flux is to constrict the arc which increases the current density at the anode and the arc force acting on the weld pool increase the penetration of TIG weld.

## 2. Method

The material used in this investigation is 4 mm thick AISI 316L Steel of dimensions 150 mm length and 50 mm width. Material properties and chemical composition are given in Table 1 and Table 2 respectively.

**Table 1** Mechanical properties of AISI 316L

| Tensile stress (MPa) | Yield stress (MPa) | Poisson's ratio | Elongation (%) |
|---|---|---|---|
| 650 | 205 | 0.27 | 40 |

**Table 2** Chemical Composition of AISI 316L

| Mo | Si | Ni | Cr | Fe |
|---|---|---|---|---|
| 3% | 1% | 14% | 18% | 64% |

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Three process parameters Flux material, Weld current, Root gap which influence the Activated TIG welded joints, were selected for this study. This paper, by using full factorial experimental design ($2^3$) with taguchi's design concept, analyses the effect of Flux material, Weld current and Root gap for optimum tensile strength.

**Table 3** process parameters with their two levels

| Process parameters | Level 1 | Level 2 |
|---|---|---|
| Flux Material | $Cacl_2$ | $Tio_2$ |
| Weld Current | 100 A | 150 A |
| Root Gap | 0 mm | 1 mm |

The initial joint configuration was obtained by securing the plates in the position using the mechanical clamps. Flux is applied on the joint using a brush. Welding is carried by using Zogo TIG 200 machine having tungsten electrode of 2 mm diameter on all the specimens by altering levels of the process parameters. Tensile test specimens prepared as per ASTM E8M- 04 standard.

## 3. Results

The experimental results for tensile strength were given in table 4.

**Table 4** Experiment values of Tensile strength

| Flux Material | Weld current (Amps) | Root Gap (mm) | Tensile Strength (Mpa) | S/N Ratio dB | Means |
|---|---|---|---|---|---|
| $Tio_2$ | 100 | 0 | 296 | 49.4258 | 296 |
| $Tio_2$ | 100 | 1 | 218 | 46.7691 | 218 |
| $Cacl_2$ | 100 | 0 | 282 | 49.0050 | 282 |
| $Cacl_2$ | 100 | 1 | 619 | 55.8338 | 619 |
| $Tio_2$ | 150 | 0 | 496 | 53.9096 | 496 |
| $Tio_2$ | 150 | 1 | 291 | 49.2779 | 291 |
| $Cacl_2$ | 150 | 0 | 402 | 52.0845 | 402 |
| $Cacl_2$ | 150 | 1 | 624 | 55.9037 | 624 |

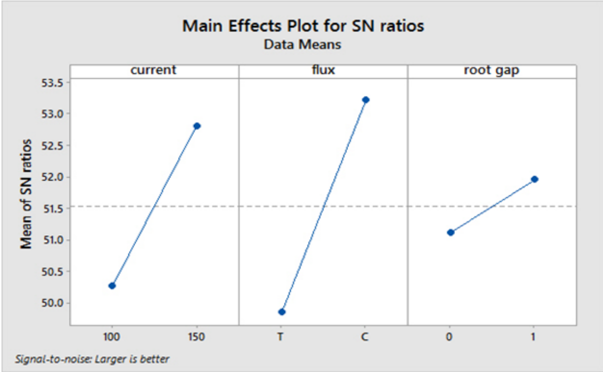
In taguhi method the S/N ratio is used to measure the quality characteristic deviating from the desired value. In this study, S/N ratio was chosen according to the criterion large – the – better, in order to maximize response.

$$S/N = -10\log\left(\frac{1}{n}\sum\frac{1}{y^2}\right) \quad (1)$$

Where n is the number of measurements and y is the desired value in a run. The S/N ratio values calculated by taking (1) into consideration were listed in Table 4 for tensile strength

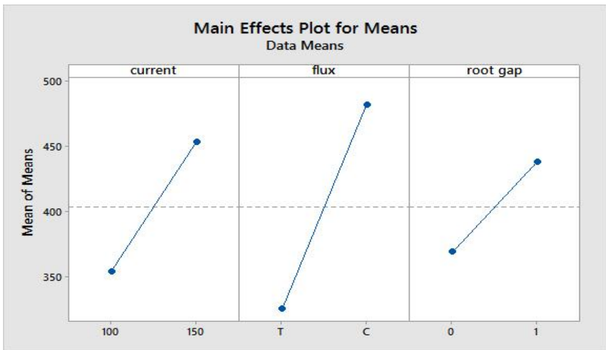
**Table 5** Response table for S/N Ratios

| Level | Flux Material | Weld Current (Amps) | Root Gap (mm) |
|---|---|---|---|
| 1 | 49.85 | 50.26 | 51.11 |
| 2 | 53.21 | 52.79 | 51.95 |
| Delta | 3.36 | 2.54 | 0.84 |
| Rank | 1 | 2 | 3 |




**Graph 1** Main effects plot for S/N Ratios

| Level | Flux Material | Weld Current (Amps) | Root Gap (mm) |
|---|---|---|---|
| 1 | 325.3 | 353.8 | 369.0 |
| 2 | 481.8 | 453.3 | 438.0 |
| Delta | 156.5 | 99.5 | 69.0 |
| Rank | 1 | 2 | 3 |




**Graph 2** Main effects plot for S/N Ratios

The experimental results were analyzed with the analysis of variance (ANOVA), which is used to investigate which design parameter significantly affect the characteristic. The contributions of input parameters on tensile strength are identified by ANOVA. Table 7 shows the ANOVA results for tensile strength.

**Table 7** ANOVA result for tensile strength

| Source | Degrees of freedom | Sum of squares | Mean of squares | F | % Contribution |
|---|---|---|---|---|---|
| Flux Material | 1 | 48985 | 48985 | 1.99 | 62.55 |
| Weld Current | 1 | 19801 | 19801 | 0.80 | 25.2 |
| Root Gap | 1 | 9522 | 9522 | 0.39 | 12.15 |

## Conclusions

1) Flux material has been found dominant parameter for tensile strength followed by weld current.

2) Root gap shows minimal effect on tensile strength compared to other parameters.
3) The optimum weld condition is obtained while using $Cacl_2$ as activated flux material and at 150 Amp with 1 mm root gap.

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