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# Influence of Different Fluxes on Angular Distortion of A-TIG Welded 316L Steel Plates

Hemant Rawat[1,*], Amit Verma[1], Abhishek Kumar[1], Sonu Yadav[1], Pradeep Khanna[2]

***Abstract***

*The conventional Tungsten Inert Gas (TIG) welding process is an autogenous welding process primarily used to weld thin metal sheets in the food processing and chemical industry. The process can weld almost all engineering materials but suffers from the limitation of slow speed and inability to weld thick sections. With the development of A-TIG welding, some of the drawbacks of traditional TIG welding have been addressed, where the activated flux is used to modify the welding arc, and the effect is shown in various aspects. The present investigative work aims to demonstrate the capability of A-TIG welding by using 316 L austenitic stainless steel as work material with CaO, TiO2, SiO2, Al2O3, and ZnO as flux. The input parameters like speed, voltage, and welding current were kept constant during the process to understand the effect of these fluxes on angular distortion and their subsequent comparison with conventional TIG welding. The work carried out shows that there is a reduction in the resulting angular distortion when fluxes are used.*

**Keywords:** A-TIG, stainless steel, angular distortion, fluxes, input parameters

## INTRODUCTION

High-quality joints and adaptability are hallmarks of TIG welding. Numerous materials, particularly highly reactive or refractory metals, can be employed with it. These benefits are negated, though, by the process's low productivity and the maximum thickness of material that can be welded in a single pass. A-TIG gets around these restrictions [1]. A-TIG welding is different from conventional TIG welding as it uses activated fluxes. Activated flux in A-TIG welding is a granular mineral material when melted releases greater amounts of gas to provide a more stable arc and a higher-quality joint [2].

Due to weldment's irregular temperature distribution the cycles of heating and cooling cause non-uniform thermal strains in the weld metal, which cause plastic upsetting. Internal pressures that result in shrinkage and deformation are created when these non-uniform heat stresses combine and react. [3]. Figure. 1 displays the angular distortion schematic diagram.

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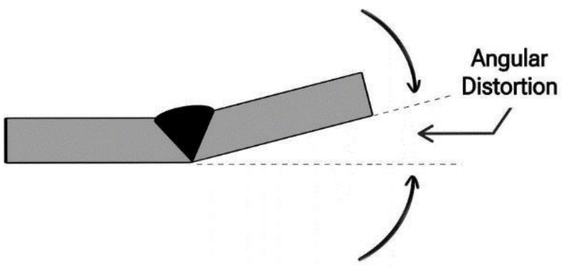


**Figure 1.** Angular distortion

A-TIG welding process employs low residual stresses and distortion within the welded joint when it comes to double-sided welding [4]. “Four physical processes have been identified as potential sources of the A-TIG mechanism. The first is that a lowering of the surface tension of the molten pool by the flux results in an increased depression of the surface of the weld pool to provide an increased radius of curvature of the weld pool surface to support the arc pressure, which is also called the TIG keyhole mode, second is arc constriction theory, third one is the reversal of the Marangoni convection which is induced by the change in the sign of the temperature coefficient of the surface tension when the surface active element is over the critical value in the liquid pool and the fourth one is flux insulation model" [5-8].

$MoO_3$, $SiO_2$, CuO, and $Cr_2O_3$ all improve the depth of penetration in mild steel; however, $TiO_2$ reduces the depth of penetration in mild steel when it comes to A-TIG. Using $SiO_2$, $TiO_2$, and $Cr_2O_3$ results in a decrease in bead width and an increase in weld depth. [9,10]. The weld aspect ratio and depth of penetration of the weld are greatly impacted by using the A-TIG welding process. The weld joints may be impacted by variables such as arc voltage, arc length, joint angle, and welding polarity [11, 12].

For industrial applications, the A-TIG process may easily and reliably increase productivity and quality by up to 86% of traditional TIG welding. [13]. It has become evident that A-TIG welding is an area that demands further research to fully comprehend its potential, optimize its applications, and address various challenges. As the demand for high-quality welds continues to grow in various industries, further research in A-TIG welding can provide valuable insights and innovations to improve the performance, quality, and reliability of weld joints in diverse applications.

## MATERIALS AND METHODOLOGY

### Base Metal

Stainless steel plates of 316L grade were used each of dimensions 150 mm x 100 mm x 6 mm with composition as shown in Table 1. The common molybdenum-containing grade, 316, is ranked second among austenitic stainless steels, after 304. Compared to Grade 304, molybdenum gives 316 superior overall corrosion resistance. Its mechanical and physical properties are shown in Table 2 and Table 3 respectively [14]. Metal plates were cleaned thoroughly and polished with emery paper of 180 grade for a smooth and even surface.

**Table 1.** 316L Stainless Steel's Chemical Composition (Wt%, balance Fe) [4]

| N | Cr | Ni | Mo | Mn | C | S | P |
|---|---|---|---|---|---|---|---|
| 0.07 | 18.1 | 12 | 2.3 | 1.4 | 0.03 | 0.02 | 0.025 |

**Table 2.** Mechanical Properties of 316L Stainless Steel [14]

| Tensile Strength (MPa) min | Yield Strength (MPa) min | Elongation (% in 50 mm) min | Rock wel Hardness (HR B) max | Brinell Hardness (HB) max |
|---|---|---|---|---|
| 485 | 170 | 40 | 95 | 217 |

**Table 3.** Physical Properties of 316L Stainless Steel [14]

| Density ($kg/m^3$) | Elastic Modulus (GPa) | Coefficient of Thermal Expansion | | | Thermal Conductivity | | Specific Heat (J/Kg. K) 0-100°C |
|---|---|---|---|---|---|---|---|
| | | *0-100°C* | *0-315°C* | *0-538°C* | *At 100°C* | *At 500°C* | |
| 8000 | 193 | 15.9 | 16.2 | 17.5 | 16.3 | 21.5 | 500 |

### *Flux and other chemicals*

Before welding, acetone was applied over cleaned base metal plates and then a coat of flux was applied of a paint-like consistency that was prepared by mixing flux powder with ethanol. Activated fluxes used in the study are CaO, ZnO, $TiO_2$, $SiO_2$, and $Al_2O_3$.

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## Experimental Setup

After the base metal was prepared with flux, the workpiece was placed on the platform of semi-automated TIG welding setup as shown in Figure. 2 that used a welding power source of 200 Amps capacity and flat VI characteristics, argon as an inert gas supplied at 20 psi, a tungsten electrode of 2.5mm diameter with a 90˚with base metal. In this experiment, a bead on the plate weld was performed.

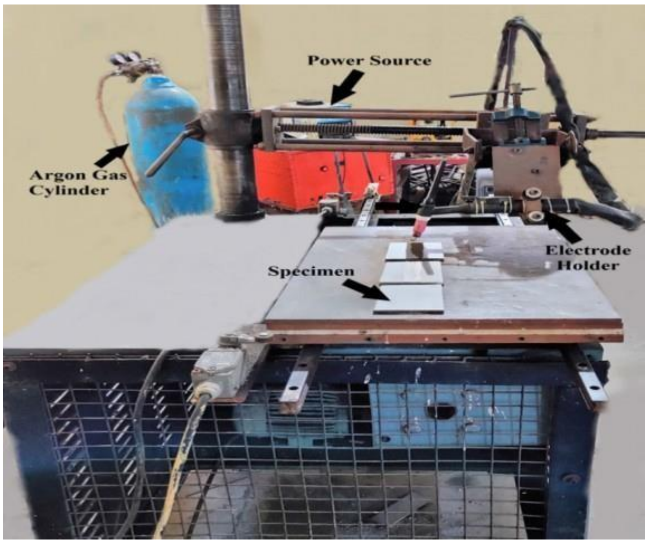


**Figure 2.** Experimental setup [15]

### *Input Parameters*

Table 2 lists the input parameters that are utilized for welding.

**Table 2.** Input Parameters

| **Parameters** | **Value** |
|---|---|
| Welding Current | 175 Amp |
| Welding Speed | 0.0042 m/s |
| Shielding Gas | Argon |
| Electrode Diameter | 2.5 mm |
| Torch Angle | 90˚ |
| Polarity | DCEN |

## RESULTS AND DISCUSSIONS

16 experiments were performed, 3 iterations for each flux and one experiment for the conventional TIG sample. Their angular distortion readings were measured with the ImageJ software. For the final measurements, as indicated in Table 3, the arithmetic mean of the readings of the three samples of each flux is computed, and the result is displayed graphically in Figure. 3.

**Table 3.** Average Angular Distortion

| **Flux Used** | **Images** | **Average Angular Distortion (Degrees)** |
|---|---|---|
| CaO |  | 4.12 |

 

| | | |
|---|---|---|
| SiO2 |  | 5.20 |
| ZnO |  | 4.20 |
| TiO2 |  | 4.31 |
| Al2O3- |  | 3.91 |
| NoFlux |  | 5.90 |

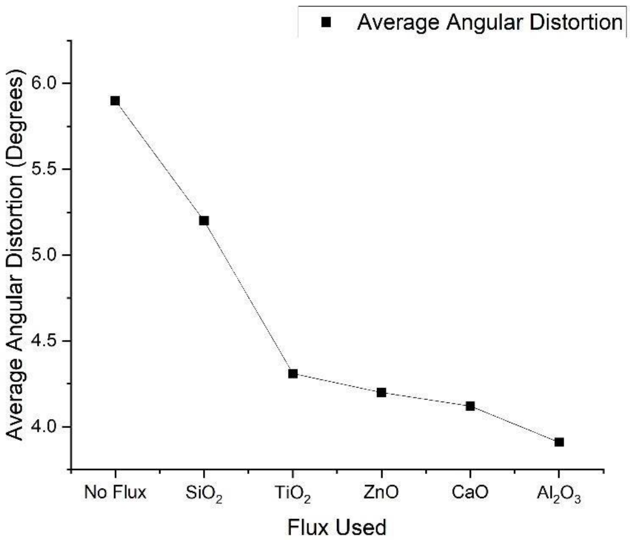


**Figure 3.** Graphical representation of trend of average angular distortion (degrees)

The maximum angular distortion came out to be 5.90 degrees in the case of no flux and in case the fluxes were used, it was in the range of 3.91-5.2 with different fluxes. This reduction in the angular distortion could be attributed to the fact that the arc is constricted while using the fluxes, causing a lesser spread of heat energy, resulting in correspondingly less angular distortions.

 

## CONCLUSION

The experiment mentioned above leads to conclusions as follows.:

1. Conventional TIG welding with No flux showed maximum angular distortion.
2. A-TIG with various fluxes shows relatively lesser angular distortions.
3. Among all the fluxes used, $Al_2O_3$ showed minimum angular distortion.

## DECLARATION OF INTEREST

The author(s) state (s) that they have no conflict of interest with the manuscript's publication.

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