

Mechanical Characterization of Welded Aa7075aluminum Alloy Using Tig Welding with Ceramic Interface

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Abstract

Gas metal arc welding is a fusion welding process having wide applications in industry. In this process proper selection of input welding parameters is necessary in order to obtain a good quality weld with good tensile strength and subsequently increase the productivity of the process. In order to obtain a good quality weld of high tensile strength, it is therefore, necessary to control the input welding parameters. Among different types of welding processes, TIG welding is the most widely used for joining the parts as it has significant advantages as compare with other welding processes. The current work is based on how to increase the tensile strength, Impact strength and micro structural properties of welding joints by applying the manual TIG welding process. To achieve the best possible solution experiments were conducted using Aluminum AA7075 plates by applying various welding parameters like voltage, current, welding speed etc.

Keywords: Aluminum AA7075 plates, TIG Welding, Welding parameters, Weld strength, Microstructure properties

1.0 Introduction

Aluminum AA7075, a high-strength heat-treatable alloy widely used in aerospace and structural applications, presents challenges in welding due to its high thermal conductivity, oxide layer formation, and susceptibility to hot cracking[1]. The use of a filler rod introduces additional material to strengthen the joint and minimize weld defects, while autogenous welding simplifies the process by relying solely on the base material[2]. The powder-based technique is an innovative approach where ceramic powder is applied to the weld zone, aimed at improving surface properties, wear resistance and joint strength[3]. During the welding process, parameters such as current, voltage, travel speed, and shielding gas flow rate are optimized for consistent results. Argon shielding gas is used to protect the weld pool from atmospheric contamination and ensure weld quality[4]. The objective of this research is to investigate the effect of welding parameters and the addition of a cerium powder in a fluxing compound cerium oxide (Ce O₂) on the mechanical and metallurgical properties of TIG-welded Aluminum AA 7075 joints.

2.0 Material Selection & Welding process

Aluminum and its alloys have become indispensable materials in modern engineering industries due to their exceptional combination of low density, high strength-to-weight ratio, corrosion resistance, and good thermal and electrical conductivity. Among the commercially available aluminum alloys, Aluminum AA7075 is one of the strongest heat-treatable aluminum alloys. It belongs to the Al–Zn–Mg–Cu alloy series and is known for its superior mechanical strength, good fatigue resistance and moderate corrosion resistance [5]. Due to these properties, Aluminum AA7075 is extensively used in aircraft structures, fuselage frames, wing spars, defense equipment, high-performance automotive components, and structural frameworks where high strength and low weight are essential [6]. Physical properties of the alloy chosen are given in Table1.



Figure 1. Aluminum 7075 T6 plate

Table.1 Physical properties of Aluminum AA7075-T6

Properties	Values
Density	2.81g/cm ³
Melting Point	477-635°C
Modulus of Elasticity	71.7 GPa
Thermal Conductivity	130-173 W/m-°K
Linear Coefficient of Thermal Expansion	23.6μ m/m-°C
Electrical Resistivity	5.15X10 ⁻⁶ ohm-cm
Specific Heat Capacity	0.96 J/g°C

Among various welding techniques, Tungsten Inert Gas welding (TIG welding), also known as Gas Tungsten Arc Welding (GTAW), is widely used for welding aluminum alloys (Figure.2). TIG welding offers precise heat control, high-quality weld finish, excellent arc stability, and minimal spatter. The process uses a non-consumable tungsten electrode to generate the arc and an inert shielding gas (usually argon) to protect the molten weld pool from atmospheric contamination.


Fig:2 TIG Welding process with equipment

The quality and mechanical performance of TIG welded joints is significantly influenced by welding parameters such as: Welding current, Arc voltage, Travel speed, Shielding gas flow rate, Filler material composition. In the present research, three different welding current values: 150 A, 170 A, and 200 A are selected to investigate their effect on the mechanical and microstructural characteristics of Aluminum 7075 welded joints. By varying the current while keeping other parameters constant, the influence of heat input on joint performance can be systematically evaluated.

3.0 Methodology

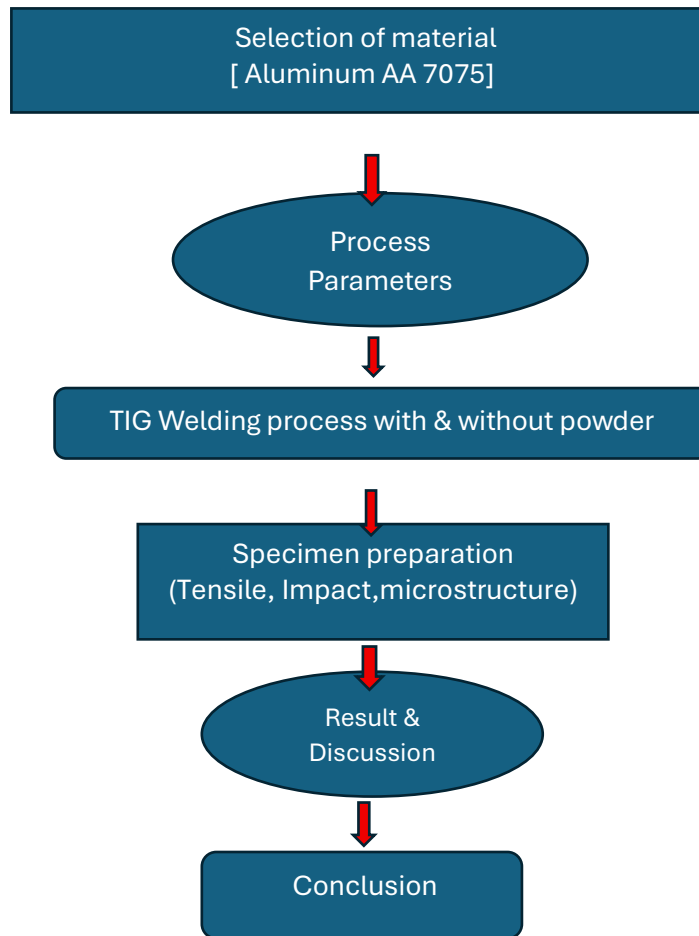


Fig.3.0 Schematic Diagram of TIG Welding process chart

3.1 Experimental Setup

The primary objective of this experimental study is to investigate and compare the mechanical and microstructural properties of Aluminum Alloy 7075 (AA7075) joints produced by conventional Tungsten Inert Gas (TIG) welding and Flux-Assisted TIG (A-TIG) welding. The study utilizes varying welding currents (150 A, 170 A, and 200 A) and introduces Cerium Oxide (CeO_2) as an activating flux to evaluate its effect on weld penetration, bead geometry, and resultant mechanical properties [7]. The material chosen in the form of a plate 6mm thickness is shown in Figure.1 and the methodology adopted for the current research is given in Figure.3. The plates are machined before welding by employing a milling machine (Figure.4)



Figure 4.a Before Machining of plates



Figure 4.b After Machining of plates

Figure.4 Experimental Setup for Machining of plates

3.2 Filler Metal Specification: ER4043 (Al-Si5)

To systematically counteract the severe hot cracking tendencies inherent to the 7xxx series quaternary system, a specialized, non-heat-treatable Aluminum-Silicon filler wire, designated as AWS ER4043, is strictly specified for the entirety of the experimental matrix. For this study, a standardized filler wire diameter of 1.6 mm is utilized to ensure precise volumetric addition to the weld pool across all variable amperages(Figure.5).



Figure. 5 ER4043 filler rod

3.3 Process Parameters:

Following are the process parameters introduced in the experimental process, while considering for making the weldments using TIG welding process. In this making of weldments, ceramic powders are introduced with TIG (fluxed) welding approach for three samples out of the six samples.

Table.2 Process Parameters selected

S.NO	Welding process	Current (amp)	Filler rod	Root gap(in mm)
Bare weld				
1	Conventional TIG	150	ER4043	1
2	Conventional TIG	170	ER4043	1.25
3	Conventional TIG	200	ER4043	1.5
Insertion of powder in the weld				
1	TIG (Fluxed)	150	ER4043	1
2	TIG (Fluxed)	170	ER4043	1,25
3	TIG (Fuxed)	200	ER4043	1.5

3.4 Interface Cerium powder (CeO₂):

The core independent variable explored in this framework involves the highly controlled application of a rare-earth oxide flux, specifically Cerium Oxide (CeO₂). Rare earth elements, including Cerium, possess extremely low solid solubility limits within an aluminum matrix(Figure.6). Consequently, as the weld pool begins to cool, the Cerium atoms rapidly segregate ahead of the advancing solidification front. These highly stable intermetallics serve as potent heterogeneous nucleation sites. They effectively pin the grain boundaries, restricting the thermodynamic growth of coarse, brittle columnar dendrites and instead promoting a highly refined, equiaxed grain architecture throughout the fusion zone.



Figure.6 Cerium oxide powder

3.5 Experimentation:

In this research, the aluminum TIG welding is used to weld the AA7075 plate. The size of the plate is 150 X80 X 6mm thick. During experimentation, ER4043 welding wire was used as the filling material for TIG welding [8]. The single - pass welding were carried out on the plate(Figure.7).



Figure.7 Conventional TIG welding Process

Here 3 samples have been made, to welded normally with 3 different current parameters and another 3 samples welded by introducing cerium oxide powder in the weld with the same parameters used before. To make the weld joints slot have been made on the plates, in order to introduce the cerium oxide powder into the weld(Figure.8).



Figure.8 (a) Filling of cerium oxide powder in the grooves (b) Weldment specimen

4.0 Results:

4.1 Mechanical Characterization

To empirically quantify the structural integrity and mechanical viability of the weldments, a highly rigorous testing protocol adhering strictly to the American Society for Testing and Materials (ASTM) standards is executed. From each of the six 150 mm × 160 mm × 6 mm assemblies, individual test specimens are extracted transversely to the longitudinal welding direction. The extraction is performed utilizing precision Wire Electrical Discharge Machining (WEDM).

4.2 Tensile Testing

The ultimate tensile strength (UTS), the precise yield strength (calculated via the 0.2% plastic strain offset method), and the total percentage of elongation at fracture are determined through destructive uniaxial tensile testing, executed in strict accordance with the ASTM E8M standardization.



Figure.9 Tensile Specimen

A computer-controlled Universal Testing Machine (UTM) equipped with a highly calibrated 200 kN load cell is utilized. Strain deformation is continuously monitored, mapped and recorded using a high-precision Class B-1 or B-2 clip-on extensometer, securely mounted directly to the 50 mm gauge length. The UTM operates at a constant crosshead displacement rate establishing a uniform strain rate of 1.0 mm/min until the specimen undergoes catastrophic, ultimate fracture(Figure.9).

The following Table shows the result of tensile test of the plates which are bare welded as well as flux welded with cerium powder at the interface.

Table 3 Tensile Results of Bare welded specimen

Specimen ID	Current (amps)	Max Load (KN)	Yield Stress (N/mm ²)	UTS (N/mm ²)	Load at Break (KN)	% Elongation
Sample-1	150	5.759	59.268	72.917	5.112	1.52
Sample-2	200	19.664	197.189	251.200	19.664	0.90
Sample-3	170	2.422	23.716	31.066	1.788	1.30

Table .4 Tensile results of the induced flux welded specimen with cerium oxide powder

Specimen ID	Current (amps)	Max Load (KN)	Yield Stress (N/mm ²)	UTS (N/mm ²)	Load at Break (KN)	% Elongation
Sample-A	150	3.995	43.856	51.349	3.995	1.18
Sample-B	200	2.962	33.927	38.137	1.831	1.34
Sample-C	170	2.625	26.759	33.641	1.854	5.60

4.3 Impact Testing:

To accurately evaluate the dynamic fracture toughness and the instantaneous energy-absorbing capability of the weldments under high-strain-rate, shock-loading conditions, Charpy V-notch impact tests are conducted. Aluminium AA7075-T6 plates were 6 mm thick, standard 10 mm x 10 mm Charpy specimens precisely machined sub-size rectangular specimens were extracted from the weldments, measuring 10 mm in width, 5 mm in thickness and 55 mm in overall length. A standard V-shaped notch, precisely 2 mm deep with a defined root radius, was milled exactly into the center of the weld fusion zone to act as a standardized stress concentrator and dictate the plane of fracture.



Figure.10 Impact Specimen

The following Table shows the result of Impact test of the plates which are bare welded as well as flux welded with cerium powder at the interface.

Table .5 Charpy V-Notch Impact Test (Bare Welded)

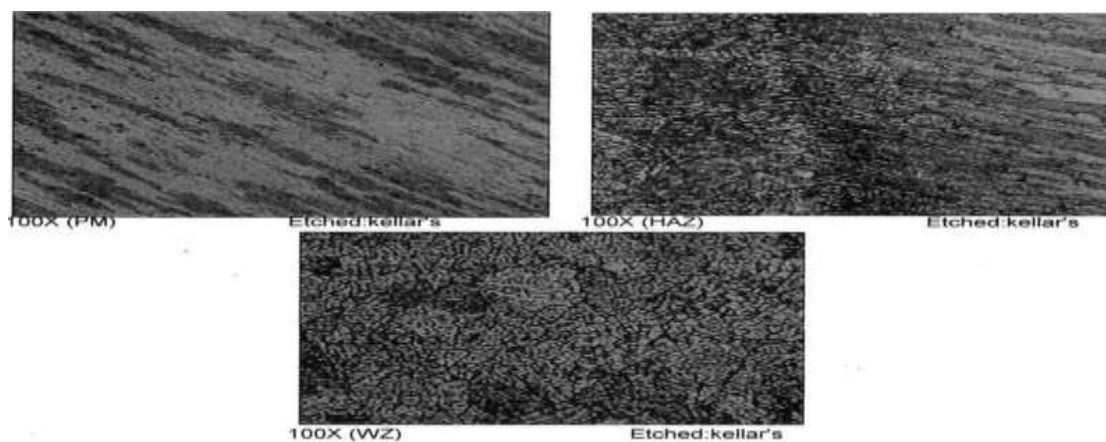
Specimen Identification	Current (amps)	Impact Energy (Joules)	Specimen Dimension (mm)	Observation
Sample 1	150	2	10 x 5 x 55	Brittle fracture
Sample 2	200	4	10 x 5 x 55	Brittle fracture
Sample 3	170	2	10 x 5 x 55	Brittle fracture

Table .6 Charpy V-Notch Impact Test (Fluxed Welded)

Specimen Identification	Current (amps)	Impact Energy (Joules)	Specimen Dimension (mm)	Observation
Sample A	150	2	10 x 5 x 55	Brittle fracture
Sample B	200	2	10 x 5 x 55	Brittle fracture
Sample C	170	2	10 x 5 x 55	Brittle fracture

4.4 Microstructure

Metallographic examination provides the fundamental physical evidence required to explain the mechanical behaviors observed during tensile, impact, and hardness testing. These specimens were encapsulated in thermosetting resin mounts. The exposed cross-sectional surfaces were then subjected to a rigorous mechanical grinding protocol using successively finer grits of silicon carbide (SiC) abrasive papers, followed by final polishing using sub-micron diamond suspensions on soft cloth wheels to achieve a scratch-free, mirror-like finish.


Figure.11 Microstructural specimens

Figure.12 Microstructure of sample (Bare welded)

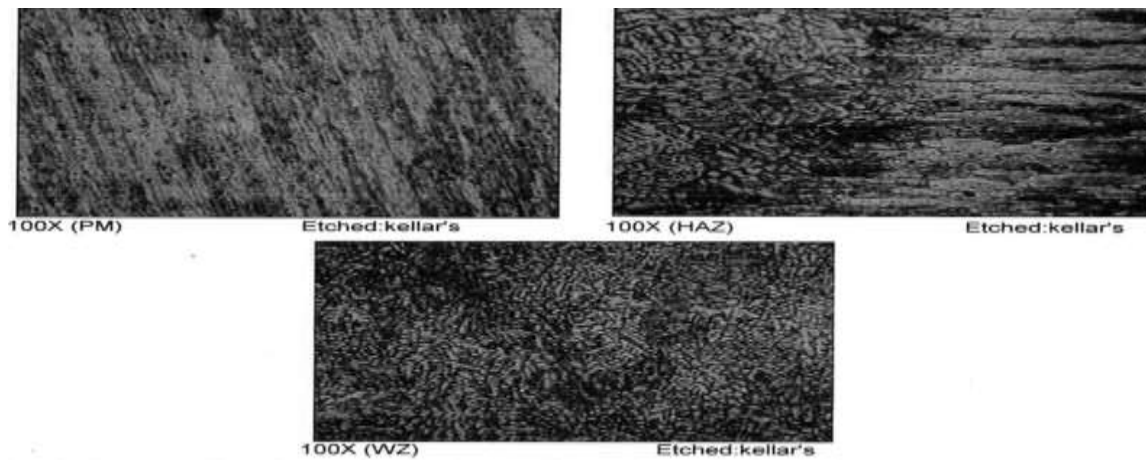


Figure.13 Microstructure of sample (Flux welded)

5.0 Discussion

For the tensile strength of the samples for bare welded sample at the current setting of 150 Amps & 170 Amps, the ultimate strengths measured to 72.97 N/mm^2 and 31.066 N/mm^2 where has at 200 Amps the Ultimate strength of the weldment is 251.02 N/mm^2 . Thus, the testing suggests that the Aluminium AA7075 has a good weldment strength at 200Amp current. In the samples of fluxed welded it's found that the poor strength of UTS values achieved as the weldments are carried out with the introduction of cerium oxide powder in the weldment.

In case of Impact test, the strength is improved to 4 Joules in bare weld at the current 200 Amps as compared to other current parameters. Where as in fluxed weldment, the impact strength remains same as 2 Joules. Hence, it suggests that, the weldment structure formed as brittle after the welding of specimens.

High-resolution optical micrographs were captured at 100X magnification across the three primary metallurgical regions of interest: the unaffected Parent Metal (PM), the heat-altered Heat-Affected Zone (HAZ), and the completely remelted Weld Zone (WZ). The fact that the Weld Zone (WZ) maintains a "fine equiaxed" structure similar to the Parent Metal is a positive indicator of weld quality, as aluminum AA 7075 typically prone to dendritic (tree-like) grain growth during cooling, which can lead to brittleness. The uniform distribution of particles across the HAZ and WZ suggests that the thermal input during the welding of these 6mm sheets was well-controlled, preventing significant grain coarsening or segregation of alloying elements.

6.0 Conclusion

The investigation into the mechanical characterization of AA7075-T6 TIG weldments establishes a clear hierarchy of process effectiveness. The use of conventional TIG welding on 6mm plates of AA7075-T6 is limited by the trade-off between penetration and thermal degradation. Based on the comparative analysis of 150A, 170A, and 200A current settings, the 200 Amp current with CeO_2 flux application represents the optimal welding parameter for 6 mm AA7075-T6 plates. This configuration maximizes joint efficiency by providing superior fusion zone properties while mitigating the softening of the heat-affected zone.

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