Study of Filler Wires Effect on Weld Characteristics of Aluminium Alloy (6351) during Gas Tungsten Arc Welding (GTAW)

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Abstract: Gas tungsten arc welding (GTAW) is an electric arc welding process that produces an arc between a nonconsumable electrode and the work to be welded. This paper details the study of the mechanical properties of the weldments of Aluminum Alloy during Gas Tungsten Arc Welding(GTAW) process with Non-Pulsed and Pulsed Current Welding at different frequencies. During this process voltage, gas flow rate and weld speed are kept constant. The weld beads were given post weld heat treatment. The mechanical properties like Tensile Strength, % Elongation, 0.2% Yield Strength of Aluminum Alloy have been studied. The main objectives of the work are to study the effects of filler materials and welding current, penetration of weld beads, tensile properties and the microstructural characteristics of weld beads. Non-destructive and Destructive tests have been conducted on the weldments of Aluminum Alloy. These results have been compared with other specimens, which are welded at Non-pulsed and at different pulsed current welding. To improve the mechanical integrity of the weldments, the Microstructures of the weld Fusion zone (FZ) and Heat Affected Zone (HAZ) are studied and are compared at various currents.

Keywords - **Ginzburg-Landau model, Temperature modulation, Anisotropic rous media, Temperature-dependent viscosity, Internal heating.**

I. INTRODUCTION

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) [1] welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma. GTAW [4] is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. Aluminum and magnesium are most often welded using alternating current, but the use of direct current is also possible, depending on the properties desired.

II. EXPERIMENTATION & PROCEDURE

A. Aluminium Alloy 6351

Aluminium alloy 8351 is opted for its low weight to strength ratio, better surface finish and its large number of applications in different areas such extrusions, window outlines, entryways, shop fittings and water system tubing.

Elements	Weights
Al	Remainder
Si	0.83
Cu	0.037
Mn	0.49
Zn	0.02
Cr	0.01

Table: 1 Composition of 6351

B. Process for Welding

During TIG welding,an arc is maintained between a tungsten electrode and the work piece in an inert atmosphere (Ar,He, Ar-He mixture). Depending on the weld preparation and the work-piece thickness, it is possible to work with or without filler. The filler can be introduced manually or half mechanically without current or ony half mechanically under current. The process itself can be manual, partly mechanised, fully mechanised or automatic. The power source of welding delivers, direct or alternating current (partly with modulated or pulsed current).

A major difference between the welding of steel and the TIG welding of aluminum is the adhering oxide film on the aluminum surface which influences the welding behavior and has to be concerned. This oxide film has to be removed in order to prevent oxides from being entrapped in the weld. The oxide film can be removed by varying the current type or polarity or also through the use of suitable inert gases.

Material Thickness(mm)	Weld Layer	Filler Wire Dia (mm)	Polarity	Current I (amps)	Voltage V (volts)	Arc Travel Speed (cm/min)
2.5	Root	2.5	DCSP	130	14.5	7.8
	1st Layer	2.5	DCSP	130	13.5	7.6

C. Procedure for Edge Preparation of Aluminum Alloy 6351

The work pieces were made of Aluminum Alloy 6351 of thickness 2.5mm, desirable for space applications. The tests were machined in the size of 150X300mm welded with constant current GTAW process. The alloy steels ER 4043 and ER 5356 are chosen as filler wires and were used during the welding of these alloys, which fuses with parent metal easily, and gives good strength [3].

The work piece is cut into required dimensions and the edge preparation is done using an angle cutter on a CNC milling manchine.

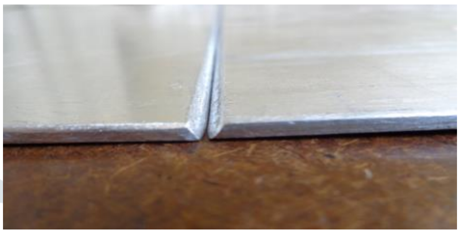

Fig. 1 Edge Preparation

The Aluminum alloy is polished with an abrasive paper and pneumatic rotary brush to remove surface impurities and then cleaned with acetone. Master TIG with DC striaght polarity was used for welding of aluminum alloy 6351 with filler wires of 5356 and 4043.

Filler Wire 5356

Washington Alloy 5356 (commonly referred to as AIMg5) is a 5% magnesium aluminum filler metal that is available for MIG or TIG welding processes. The weld deposit of Washington Alloy 5356 offers much better corrosion resistance when exposed to salt water.

Tensile Strength	39,000 PSI
Yield Strength	19,000 PSI
Elongation	17%
Thermal Conductivity	116 (W/mK)

Table 2: Properties of 5356

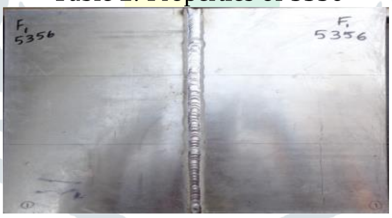

Fig. 2 Weld using 5356

Welding Parameters of Constant Current Welding for Aluminum alloy (6351) of Filler wire F1 (5356)

Weldcote Metals 4043 (commonly referred to as AlSi5) is a 5% silicon aluminum filler metal that is available in spools or cut lengths for MIG or TIG processes. This alloy is recommended for welding 3003, 3004, 5052, 6351, 6063 and casting alloys 43, 355, 356, and 214 is used with DC current Reversed Polarity, Shielding gas, Argon required.

Tensile Strength	27,000 PSI
Yield Strength	18,000 PSI
Elongation	8%

Table 3: Properties of 4043

Fig. 3 Weld using 4043

III. TESTING

A. Radiography Test

Radiography has been conducted to the weldments of Aluminum Alloy 6351 of filler wire F1 and filler wire F2. These are conducted to check for any cracks and pores present in the weldments which are formed during welding due to several reasons. Table 4 shows the various parameters which are specified while conducting Radiography.

Source Details	**Film Details**
Source: X-Ray	IQI: ASTM 12
Current: 3.5 Mev	Technique: Single Wall single image
Voltage: 150KV	SFD: 60cm
Focal Spot size: 1.1x1.1mm	Lead Screen: 0.02mm
	Film Type: D7
Exposure Details	
Exposure Time: 3.5min	
Film Density: 2T	

Table: 4 Radiography Test Parameters

B. Tensile Test

The tensile test [6] specimens were prepared on the milling machine as per ASTM standards. The finished specimens were tested using ultimate tensile testing machine of 10 ton capacity. The metascan microscope was used for microstructure study of these weldments. After welding the weld samples were cut into size 100X5 mm and placed in bakelite mounting and etched with aquaregia solution. The perpendicular sections of the weldments were examined at different locations with magnitude for a clear understanding of the microstructure features.

IV. RESULTS & DISCUSSIONS

After conducting tensile test to specimens, it is concluded that the Tensile Strength and 0.2% Yield Strength of the weldments of Aluminium alloy of two different filler wires are closer to of base metal (from the table) and the failure location of Aluminium weldments occurred at Heat Affected Zone(HAZ). It is interpreted that weldments have better weld joint efficiency.

S. No	Material thickness (mm)	Non-Pulsed Welding	Filler Wires	Observations
1.	2.5	Constant Current process	5356 (F1)	No defect seen
2.			4043 (F2)	No defect seen

Table: 5 Radiography Results of Aluminum alloy 6351

S. No	Sample Description		UTS (M Pa)	0.2%YS (M Pa)	%Elongation
1	Base Material		91.3	78.2	17.10
2	Non-Pulsed Current GTAW	Filler Wire F1 5356	86.90	68.97	14.30
			89.14	70.01	14.32
			88.72	71.54	15.20

Table: 6 Dye Penetrating Results of Aluminum alloy 6351

The following tables show the tensile test results of Aluminium alloy 6351 filler wires of 5356 and 4043 [1].

S. No	Sample Description		UTS (M Pa)	0.2%YS (M Pa)	%Elongation
1	Base Material		91.3	78.2	17.10
2	Non-Pulsed Current GTAW	Filler Wire F1 5356	86.90	68.97	14.30
			89.14	70.01	14.32
			88.72	71.54	15.20

Table: 7 Mechanical properties of Aluminum alloy (6351) of Filler wire 5356

S. No	Sample Description		UTS (M Pa)	0.2%YS (M Pa)	% Elongation
1	Base Material		91.3	78.2	17.10
2	Non-Pulsed Current GTAW	Filler Wire F2 4043	89.65	74.52	14.50
			89.26	71.85	13.20
			89.18	71.57	15.60

Table: 8 Mechanical properties of Aluminum alloy (6351) of filler wire 4043

Microstructure study of Aluminium Alloy (6351):

To improve the mechanical integrity of Al-Cr-Ni weldments, it would be desirable to study the microstructure of the fusion zone and heat affected zone [2]. The present study was carried out to show differences in macro and micro structures of weldments made with non-pulsed and pulsed current at various frequencies 2, 4 Hz GTAW process. During the cross-sectional photos at various weldments were compared as shown in fig (and). In Pulsed Current Welding [5] significant penetration was observed in the single pass with 70A current, 17.5 V volts and at 7.6 cm/min welding speed. In pulsed current welding the weld penetration is improved with all the frequencies 2 and 4 Hz. Welding with frequency of 4Hz has produced good penetration in a single pass with 75 A base current ,140 A peak current at 7.6 cm/min Welding speed

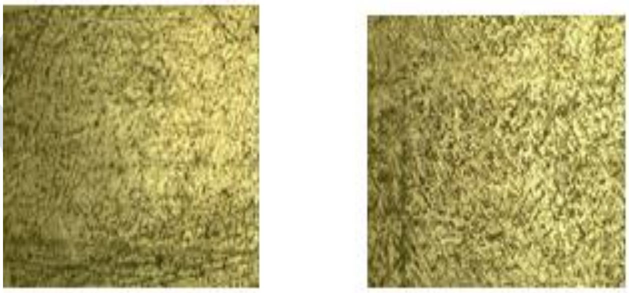

Fig: 4 Microstructure of Aluminum Alloy (6351) at Heat Affected Zone (HAZ) for Filler wires 5356 & 4043

Fig: 5 Microstructure of Aluminum Alloy (6351) at Fusion Zone (FZ) for Filler wires 5356 & 4043

V. FUTURE SCOPE

The performance of Pulsed Current GTAW is better than Non-Pulsed Current Welding. Further the work can be extended on fractography of tensile specimens in Pulsed and Non-Pulsed Welding.

An Electron Probe Micro Analysis (EPMA) can be extended to future work for the study of the composition details mainly, chromium, nickel, and carbon across welds. A study can also be made on different thickness of the material at different currents and the various properties are compared.

VI. CONCLUSION

Aluminium alloy produced Maximum Ultimate Tensile Strength (174.5 N/mm2), Maximum Yield Strength (163.3 N/mm2) with Pulsed Current Welding (f=2Hz). Aluminium alloy produced Maximum %Elongation (3.78) with Pulsed Current Welding (f=4Hz). So Aluminium alloy should be welded with Pulsed Current Welding process to get satisfactory results. By doing Pulse welding we get better depth of penetration and fusion of filler material with parent metal and by this it improves strength and ductility of weldments.

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