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Experimental Investigation on Effect of TIG Welding Process on Chromoly 4130 and Aluminum 7075-T6

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ABSTRACT

The detail study of Tungsten Inert Gas (TIG) welding process on AISI Chromoly 4130 and Aluminum 7075-T6 is presented in the paper. The application of Al-Zn or Al-Zn-Mg-Cu alloys are often used in aerospace fabrication and are supplied in the form of sheet, plate, forgings and bar, as well as extrusions. For the study of TIG welding process ceriated tungsten electrode was selected because it has excellent arc start at low amperage. The material selected for experimental investigation was tube of Chromoly 4130, outer diameter (OD) 29.21 mm and thickness 1.65 mm. The other material used was tube of Aluminum 7075-T6 with OD 25.4 mm and thickness 3 mm. Amperage setting selected was 1 amp per 0.001 inch of wall thickness and DC negative electrode was used. Filler metal used for welding Chromoly 4130 is ER70S-2 and for aluminum 7075-T6 is ER5183. Both the welding processes were performed by the same welder. The tensile test was carried out on UTM which resulted that weld strength for Chromoly 4130 was 57535.455 psi were as for aluminum 7075-T6 resulted in low weld mechanical properties and does not hold good for welding application. In general Aluminum 7075-T6 results in poor weld penetration due very high strength. TIG Welding on Chromoly 4130 shows very good weld penetration characteristics without risk of compromising material properties.

Keywords: TIG welding, Chromoly 4130, Aluminum 7075-T6, ER70S-2, ER5183

1. Introduction

Gas Tungsten Arc Welding (GTAW) or Tungsten Inert Gas (TIG) uses a non-consumable tungsten electrode made of tungsten or a tungsten alloy with cerium, thorium, lanthanum or zirconium oxide improving arc stability. The electric discharge through electrode generates a plasma arc between the electrode tip and the base metal, arc is normally initialized with a power source with a high frequency generator, which produces a small spark that provides the initial conducting path for the welding current through the shielding gas and allows the arc to be initiated while the electrode and the base metal are separated. Three different alternatives of current namely; Direct current with positively charged electrode (DCEP), Direct current with negatively charged electrode (DCEN) and Alternating current (AC) are used. AC commonly used for welding aluminum, when exposed to air this metal form an oxide layer that melts at much higher temperature then the base metal. The electrode positive (EP) portion of AC cycle where current flow from base metal to the electrode removes surface oxides and the base metal is heated during the electrode negative (EN) portion of the cycle where the current flows from the electrode to the base metal. DCEN is produced when electrode is connected to negative terminal of the power source the electron flow from the electrode to the base metal approximately 70% of heat of the arc is concentrated at the work and approximately 30% at the electrode end and thus produces narrow concentrated arc and has deep penetration with narrow bead [1]. Ceriated tungsten electrode contains a minimum of 97.30% tungsten and 1.80 to 2.20% cerium and can be used in AC or DC applications using transformer based constant current power source. It is good for low-alloyed steels, aluminum alloys, magnesium alloys, titanium alloys, nickel alloys and copper alloys. Due to its good ignition, re-ignition properties and low erosion rate it has long service life and excellent arc stability. ER70S-2 are primarily used for single-pass welding of steels, because of the added deoxidants, these filler metals can be used for welding steels that have a rusty or dirty surface, with a possible sacrifice of weld quality depending on the condition of the surface. ER70S-2 filler metals are used extensively to produce high quality high toughness welds with the GTAW process. This filler metal is also well suited for use in single side, melt through welding without a protective root shielding gas on the backside of the joint [2]. ER5183 contents magnesium up to 5.2% and addition of manganese to aluminium increases strength to an extent through solution strengthening and does not significantly reduce ductility or corrosion resistance, ER5183 is often used where tensile strength is required. The Mg content in 7075 would generally increase the cracking sensitivity. However, zirconium is added to refine grain size, and this effectively reduces the cracking tendency. This alloy is easily welded with the high-magnesium filler metals, such as ER5183, which ensures the weld contains sufficient magnesium to prevent cracking. Silicon based filler metals, such as ER4043, are not generally recommended for these alloys because the excess Si introduced by the filler metal can result in the formation of excessive amounts of brittle Mg_2Si particles in the weld. The Al-Zn-Mg-Cu alloy 7075, have small amounts of Cu added. The small amounts of Cu, along with the Mg, extend the coherence range [3] and, therefore, increase the crack sensitivity. AISI 4130 steel is a medium carbon low alloy steel containing 0.8-1.1 wt% Cr and 0.15-0.25 wt% Mo, which is also commonly referred to as Chromoly steel. The added chromium helps to increase the steels hardenability and also the corrosion resistance and added molybdenum helps to increase the toughness.

2. Welding Material

The material used in this study is Chromoly 4130 produced as tube of OD 29.21mm with thickness of 1.65mm as a base metal along with ER70S-2 as a filler metal having OD of 2.4mm another material used is Aluminum Alloy 7075-T6 produced as tube of OD 25.4mm and thickness of 3mm as a base metal along with ER5183 as a filler metal with OD of 2mm and ceriated tungsten electrode having OD of 2.4mm .The chemical compositions of base metal and filler metal are given in Table 1. Selection of filler metal was done on the bases of principal effects of alloying element in aluminum given in Table 2. The aluminum/magnesium alloys (5 series) have the highest strengths of the non heat-treatable aluminum alloys and, for this reason are very important for structural applications. Magnesium (0.5% to 3.0%) in an aluminum weld produces a crack-sensitive weld metal composition. As the Al/Mg base alloys with less than 2.5% Mg content can be welded with either the Al/Si (4 series) or the Al/ Mg (5 series) filler alloys dependent on weld performance requirements. The Al/Mg base alloys with more than about 2.5% Mg typically cannot be welded successfully with the Al/Si (4 series) filler alloys because excessive amounts of magnesium silicide Mg_2Si develop in the weld structure, decreasing ductility and increasing crack sensitivity. The base alloys with more than 2.5% Mg are welded with the Al/Mg (5 series) filler alloys, usually with a similar chemistry to the base alloy [3].

Table 1. Chemical composition of base metal and filler metal

Type of material / Chemical composition (wt.%)	Si	Fe	Cu	Mg	Mn	Mo	Cr	Ni	C	Zn	Al
Base metal Al 7075-T6	0.474	0.564	0.068	5.22	0.103	-	0.012	0.008	-	0.164	Bal.
Filler metal ER 5183	0.40	0.40	0.10	4.3-5.2	0.05-0.10	-	0.05-0.25	-	-	0.25	Bal.
Base metal AISI 4130	0.234	Bal.	-	-	0.531	0.166	0.933	0.014	0.319	-	-
Filler metal ER70S-2	0.45	Bal.	-	-	1.15	0.15	015	0.15	0.05	-	0.09

Table 2. Principal effect of alloying element in aluminum

Alloying Elements	Effects
Copper (Cu)	Increases strength, reduce ductility and corrosion resistance
Manganese (Mn)	Increases strength
Silicon (Si)	Reduces melting temperature and improves fluidity
Magnesium (Mg)	Improves strain hardening ability
Zinc (Zn)	Increases strength and permits precipitation hardening
Iron (Fe)	Increase in strength
Chromium (Cr)	Improves hardenability and wear resistance.
Nickel (Ni)	Improves hardness and strength
Molybdenum (Mo)	Wear resistance and improves hardenability

3. Welding Parameters

The welding on Chromoly 4130 was done at 66 amp with DC negative polarity having filler metal diameter of 1.6mm and 2% type Ceriated tungsten having diameter of 2.4 mm with pointed tip, electrode sticking out was no longer than the inside diameter of the cup and shielding gas flow was 15 CFH with pre flow of 1.3 seconds and post flow of 2.4 seconds. Tack weld was done at 180° apart, T-joint preparation was prepared by tube notcher for final fit up, whereas welding on Al 7075-T6 was iterative and is shown in Table 3. To have sufficient penetration general thumb rule by using 1 amp per 0.001 inch of metal thickness was followed [4], arc length and puddle size were controlled since a longer arc length, or tungsten tip working distance increases overall heat input because power source automatically increases voltage when arc length increases. Ador chamtig 400AD 10-200 amps AC/DC machine was used for this experimental investigation.

Table 3. Welding parameter for Al 7075-T6

Sr No.	Welding Current (A)	Polarity	Shielding Gas (CHF)
1	118	AC	15
2	120	AC	15
3	122	AC	15
4	124	AC	15
5	95	DC-	15
6	105	DC-	15

Fig 1. Welded Al 7075-T6 with filler metal ER 5183 shows lack of weld penetration

4. Result and Discussion:

Tensile test was performed on Krystal Met, 400N servo-hydraulic universal testing machine (UTM), from Table 4 ultimate tensile strength of welded T-joint was found to be 396.693MPa and failure occurred at Heat Affected Zone (HAZ) on welded T-joint which implies that weld portion has high strength than the base metal from figure . The amount of heat input is large under high current from Table 3 for Al 7075-T6, as a result the width and depth of the weld pool are large, and the root of welding joint appears to be un-welded from figure 1. The increase of welding current brings about the enlargement of the width and depth of the weld pool. When the current is too large, the amount of heat input is also increased and even much more molten metal penetrates the face, which leads to the collapse of the face of aluminum tube. This situation causes the stress concentration and so degrades the strength of welded joint and mechanical properties of the welded joint is decreased.

Table 4. Tensile properties of chromoly 4130 TIG welded

Ultimate tensile strength	Yield strength	Total Elongation %
396.693MPa	294.981 MPa	16.667

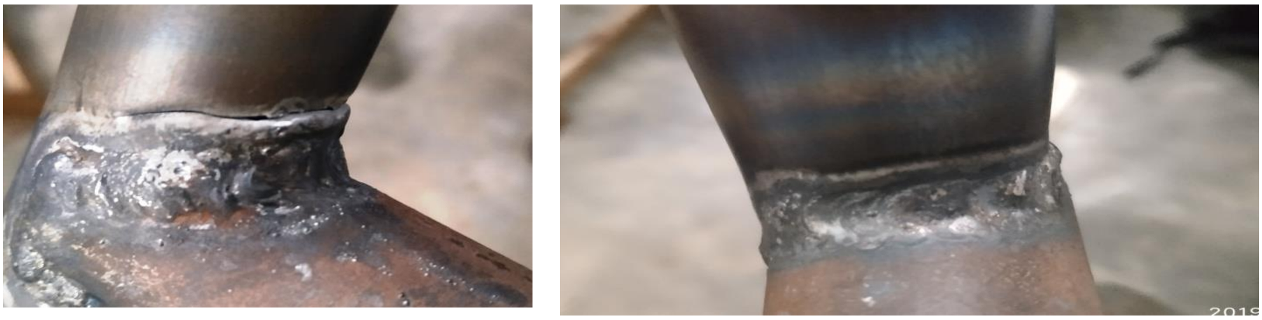

Fig 2. Welded joint on Chromoly 4130 using ER70S-2 cracked metal near welded portion at HAZ

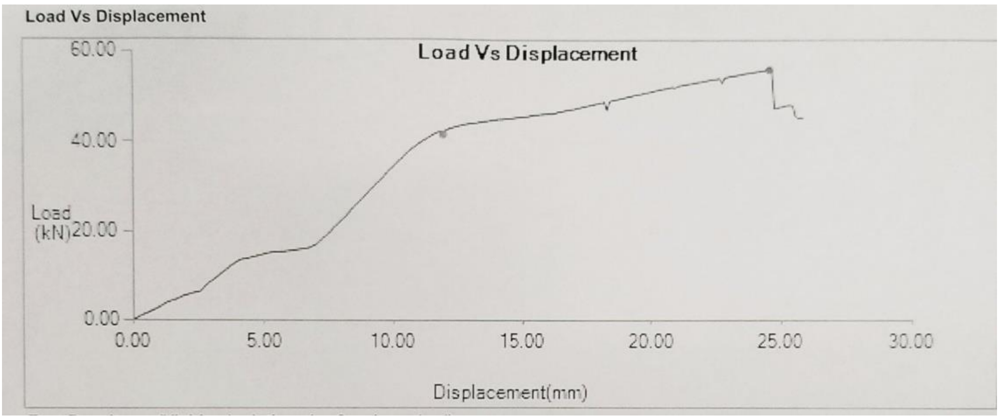

Fig 3. Load vs Displacement graph for chromoly 4130

5. Conclusion

The following conclusions can be derived from this study:

1. Chromoly 4130 showed excellent weld characteristics with ER70S-2 were as for Al 7075-T6 showed poor weld characteristics with ER 5183.
2. There is significant difference between the tensile strength of the HAZ and the tensile strength of the unaffected area of the welded component. The reduction in tensile strength of the HAZ under controlled conditions, particularly with the chromoly 4130, can be somewhat predictable.
3. The reduction in tensile strength of the HAZ in the heat-treatable alloys is more susceptible to welding conditions and strength can be reduced below the required minimum requirement if excessive heating occurs during the welding operation.
4. Al 7075 which is an aluminum-zinc-copper-magnesium alloy became susceptible to stress corrosion cracking after welding. This phenomenon is particularly dangerous because it is not detectable immediately after welding, but usually develops at a later date when the component is in service.
5. However, changes that occur within the base material adjacent to the weld during the welding process can produce a metallurgical condition that results in intergranular microcracking, which may be susceptible to propagation and cause failure of the welded component.
6. Failure probability can be high, and the time to failure is generally unpredictable and dependent on variables such as tensile stress applied to the joint, environmental conditions and the period of time the component is subjected to these variables, thus Al 7075-T6 base alloys are not suitable for arc welding.

Reference:

1] Peter W Muncaster, “Practical TIG (GTA) welding a survey of the process and equipment”, ABINGTON PUBLISHING Woodhead Publishing Ltd in association with The Welding Institute Cambridge England

2] AWS A5.18/A5.18M:2005 An American National Standard, Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding prepared by AWS A5 Committee on Filler Metals and Allied Materials.

3] Tony Anderson, CEng, FWeldI, CWEng, A Practical Guide for Troubleshooting Aluminum Welding-Related Problems 2nd Edition, ISBN: 978-0-87171-085-7.

4] Joining Aluminum with TIG/GTAW, https://www.millerwelds.com/resources/article-library/joining-aluminum-with-tiggtaw

5] Omar Hatamleh a, Jed Lyons b, Royce Forman c, “Laser and shot peening effects on fatigue crack growth in friction stir welded 7075-T7351 aluminum alloy joints” International Journal of Fatigue 29(3):421-434 · March 2007.

6] C. Yeni1, S. Sayer, M. Pakdil, “Comparison of mechanical and microstructural behaviour of TIG, MIG and friction stir welded 7075 aluminium alloy” Kovove Mater. 47 2009 341–347.

7] J.R. Davis (Ed.), ASM Speciality Handbook: Aluminium and Aluminium Alloys, ASM International, Metals Park, OH, 1993, p. 376.

8] Cavaliere P. Effect of friction stir processing on the fatigue properties of a Zr-modified 2014 aluminum alloy. Mater Character 2006;57(2): 100–4.

9] Effect of welding parameters on the solidification microstructure of autogenous TIG welds in an Al–Cu–Mg–Mn alloy A.F. Norman *, V. Drazhner, P.B. Prangnell.

10] I.N. Fridlyander, in: T.H. Sanders, Jr., E.A. Starke, Jr. (Eds.), Proceeding of the 5th International Conference on Al–Li Alloys, Williamsburg, Virginia, 1989, MCEP, Birmingham, 1989, p. 1359.

11] Mahoney MW et al. Properties of friction-stir-welded7075 T651 aluminum. Metall Mater Trans A 1998;29:1955–64.