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Evaluation of Structural and Mechanical Properties of TIG Welded Aluminium Alloy AA-5083 Subjected to Post Cryogenic Treatment

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Abstract—*Cryogenic treatment is a low temperature treatment process widely used in recent years to enhance the material properties without considerable sacrifice of other properties at the same time. Cryogenic engineering is a branch of material handling process which has significant commercial applications. In this study, TIG welded Aluminium alloy AA-5083 plates were subjected to cryogenic treatment after welding and their structural and mechanical properties were evaluated. This is done in order to reveal the weld strength, hardness of welded joints by using weld current as varying parameter. In this process, AA-5083 alloy plates were joined by TIG welding technique by using current as the varying parameter, later the welded plates were subjected to cryogenic treatment. After cryo processing these welded specimens were subjected to tensile test, micro-hardness test and optical microscopy (which reveals the microstructure and macrostructure of specimens). This analysis was done in order to determine the homogeneity of the welding, the joint efficiency of welded plates and to analyze the changes in grain structure after cryogenic treatment in welded region and HAZ. AA-5083 is very commonly used in the manufacture of welded pressure vessels, marine, auto aircraft cryogenics, transportation equipment such as building of railroad cars, tip truck bodies, in missile components. Finally after observing the outcomes of the above mentioned tests cryogenic treatment was successful on TIG welded joints of aluminium alloy AA-5083.*

Keywords*: AA-5083, Cryogenic Treatment, Arc Voltage, Welding current, TIG Welding.*

1. INTRODUCTION

The use of thermal treatments to improve mechanical properties of metal components is an ancient art expanded down the ages until today. The first attempts to perform subzero treatments were investigated at the beginning of the 20th century, but the actual interest on cryogenic treatment (or cryotreatment) was developed during the last years of the century [1]. Interest has been shown in the effect of low-temperature treatment on the performance of ferrous and non-ferrous metals. Low temperature treatment is generally classified as “cold treatment” (at temperature down to about -800c and “cryogenic treatment” (at temperature down to about at liquid nitrogen temperature -1960c). There are claims by researchers, that the desired properties like strength, wear resistance, toughness, dimensional stability can be achieved at -85°C.But when treated for a particular deep freeze time at -1960c there was a tremendous improvement in the above mentioned properties. “Cryo” means cold. Cryogeny means low temperature science [2]. The basic cryogenic treatment consists a gradual cooling of the component until the defined temperature, holding it for a given time (freezing time) and then progressively leading it back to the room temperature [1].

Among the non -ferrous materials Aluminium and its alloys have been of interest in almost all the fields, due to their modest specific strength, ease of manufacture and low cost [4]. There is a huge interest in use of aluminium alloys in applications as house hold appliances, automotive, railway vehicles and many other applications [5]. Aluminium alloys are the dominant set of industrial alloys which are widely used in various fields where a high weight to strength ratio is required. Aluminium alloy have long been of interest in various industries due to its increased performance in comparison with ferrous alloys. These alloys in its various compositions exhibits different set of properties. Due to this diversification they have various field of applications and very large commercial use. Aluminium alloys are the prime candidates in the aerospace community due to their modest specific strength ,ease of manufacture and low cost[6] .Increase in payloads and fuel efficiency of air craft has become a important issue for aerospace industry which requires increased performance above the existing alloys requires the development of more advanced materials with high specific properties[4]. The AA 5XXX, 6XXX and 7XXX series alloys have good structural and mechanical properties in the class. The AA5XXX series are the alloys with prime alloying element as magnesium they have high resistance for corrosion when compared to other alloys [7]. Due to its high corrosion resistance behavior it is used in the manufacture of submarines and other marine applications [8].

Today's aluminum alloys together with their various tempers, comprise a wide welding procedure development. It is important to understand the differences between various aluminium alloys available and their various performances and weldability characteristics[9].High heat transfer in aluminium, laser welding technique is not feasible and due to high electrical conductivity, use of resistance welding is not preferable[5]. It is often said that welding of aluminum is not difficult, it is just different. It is believed that an important part of understanding in differences is to become familiar with the various alloys [9].Fusion welding is the most common method of joining these alloys [4].Among fusion welding processes, Tungsten Inert gas welding (TIG) is one of the most suitable and best method of joining aluminium alloys. TIG welding is the process of joining different materials with high quality weld bead by electric arc generation between electrode and work piece in the presence of inert gas. TIG welding technique was demonstrated first by Russell Meredith in 1930 during Second World War for welding aluminium and magnesium in aircraft industry [10]. TIG welding has been used in modern industry, especially for aluminium, stainless steel, titanium alloys and other materials for high quality weld. TIG welding process has some advantages, including high quality weld, easy and precise control of welding parameters [11].

TIG welding is preferred mainly for aluminium alloys because it starts to spread out from weld pool during the welding operation when compared to other processes [12]. Usually, the microstructure and the mechanical properties of an aluminium alloy will change after the welding because of the melting of the base material during the welding process [13]. Pulsing the current in gas tungsten arc welding and gas metal arc welding technique has been investigated to obtain refined grain in fusion zone and enhance the weld mechanical properties, results shows significant enhancement of welded aluminium alloys [14]. To overcome some problems related to mechanical and other structural problems, a heat treatment is applied to the welded part to obtain the good mechanical properties and to release the residual stress on the part. Heat treatments for aluminium alloys are usually performed by solution heat treatments followed by water quenching and aging at a certain temperature or by natural aging in air [12]. Presently cryogenic treatment has been widely utilized in many industries such as aerospace, automotive, electronic and mechanical engineering to improve mechanical strength and dimensional stability of components [15]. The present work deals with evaluation of structural and mechanical properties of TIG welded Aluminium alloy joints that is subjected to cryogenic treatment.

2. MATERIAL AND METHODOLOGY

Aluminium alloy AA-5083 (Composition shown in Table 1) plates of the dimension 125*60*3 mm were taken for TIG welding technique. These plates are cleaned from dirt, grease and other foreign materials by using cleansing agents, dirt removers and other re-agents. Edge preparation is carried out where double V edge is prepared for an angle of 450.The Aluminium plates are placed on welding table where the welding process is carried out. In this process, all the various welding parameters such as the welding speed, flow rate, inert gas used and the number of passes is kept constant for all the trails and the welding current is used as varying parameter to study the effect of welding current on the structural and mechanical properties of weldments. The inert gas used in this investigation is 99.9% pure argon keeping the flow rate constant. The filler metal selected for the process is AA-5356 which is the standard filler rod to be used for AA-5083 alloy (According to AWS Standards). In this study, TIG welding technique was adopted with three different welding currents for the Aluminum plates i.e., 70A, 75A and 80A respectively.

Once the welding process is completed then the welded plates were subjected to deep cryogenic treatment which is as follows:

The following process has been followed for the welded specimens:

1. Descend the specimen from room temperature to -1930c.
2. Soak the specimen at -1930c for a certain period of time.
3. Ascend the specimen from -1930c to normal room temperature.

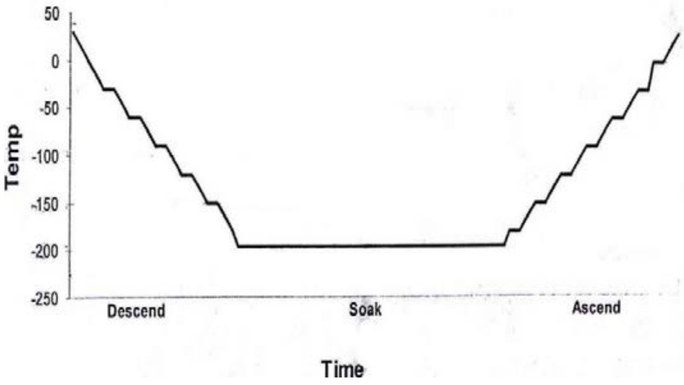


Fig.1. Characteristic graph of the cryogenic treatment to the material

and these cryo-treated welded joints were further subjected to the following mechanical tests and metallographic analysis**.** AA-5083 cryo-treated plates were subjected to tensile test following ASTM E-08 standards (Fig.2.a.). In order to determine the structural aspects welded region was subjected to microstructure and macrostructure analysis.

3. RESULTS AND DISCUSSIONS

3.1 Tensile test

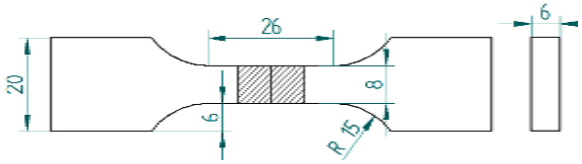
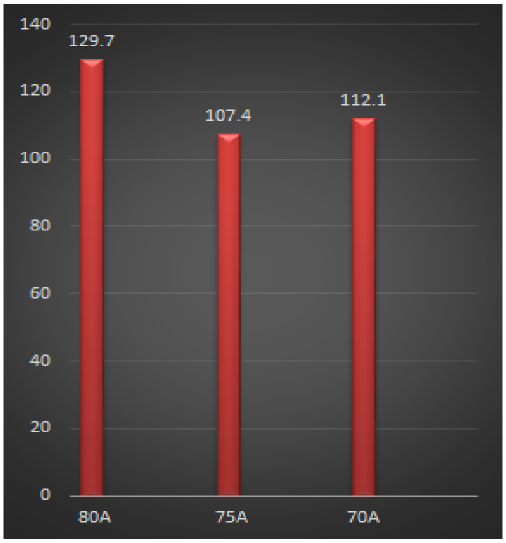


Fig.2.a. Specimen prepared for tensile test

Tabe.1. Tensile properties of cryotreated welded specimens

Current (A)	Ultimate Tensile Strength, (UTS) N/mm^2	Elongation (on 26mm gauge length) %
80	129.7	1.15
75	107.4	1.62
70	112.1	1.85



Scale:
x axis: Current in Amperes(A)
y axis: Ultimate Tensile Strength(N/mm²)

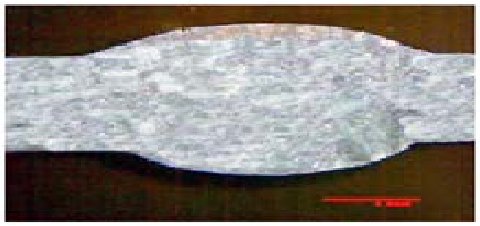
Fig.2.b. Representation of UTS for different weld currents

Ultimate Tensile Strength obtained for three different weld currents

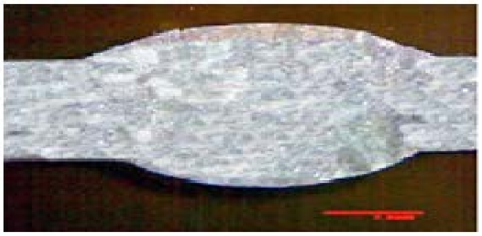
From the values of UTS obtained for 80A, 75A and 70A, it is observed that 80A weldment depicted maximum ultimate tensile strength when compared to weldments of 70A and 80A. There are no significant changes in the value of percentage in elongation because almost all the three weldment accounts for 1%.

3.2 Macrostructure analysis

(a)



(b)



(c)

Fig.3. Macrostructure of weldments with different currents (a-80A, b-75A, c-70A)

Weld portion revealed very minute porosities on the weld zone (Fig.3.a andFig.3.b). No macro defects are observed at the weld portion (Fig.3.c).

3.4 Microstructure analysis

Fig.4.a.Base Metal microstructure for 80A

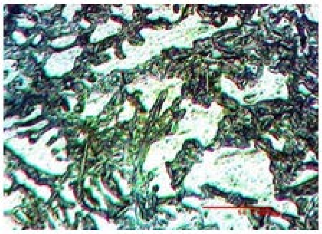


Fig.4.b.HAZ microstructure for 80A

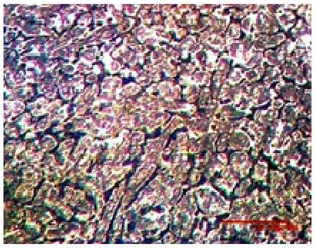


Fig.4.c. Weld Microstructure for 80A

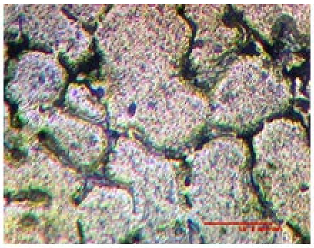


Fig.5.a.Base Metal microstructure for 75A

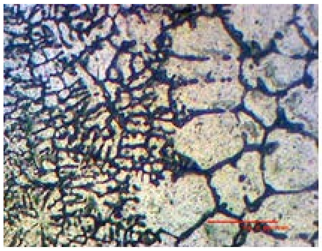


Fig.5.b. HAZ microstructure for 75A

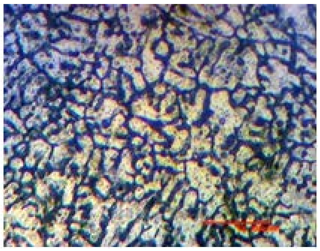


Fig.5.c.Weld Microstructure for 75A

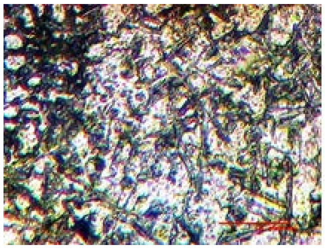


Fig.6.a.Base Metal microstructure for 70A

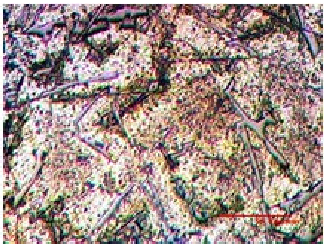


Fig.6.b.HAZ microstructure for 70A

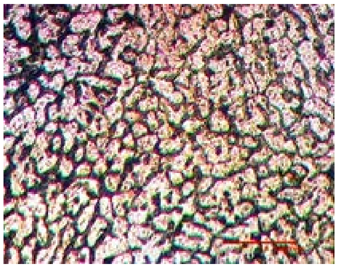


Fig.6.c.Weld Microstructure for 70A

Network of coarse silicon particles and needles which formed in the interdendritic Aluminium - silicon eutectic (Fig.4.a). Network of finer particles of silicon in the interdendritic aluminium - silicon eutectic (Fig.4.b). Network of silicon particles which formed in the interdendritic aluminium alloy eutectic (Fig.5.a). Network of finer particles of silicon in the interdendritic aluminium alloy eutectic (Fig.5.b). Network of coarse silicon particles and needles which formed in the interdendritic aluminium - silicon eutectic (Fig.6.a).Network of finer particles of silicon in the interdendritic aluminium - silicon eutectic (Fig.6.b). Cast dendritic structure with primary precipitates of silicon (Fig.4.c, Fig.5.c and Fig.6.c).

4. CONCLUSIONS

Through investigations it has been observed that maximum ultimate tensile strength was obtained at weld current of 80A in comparison with 70A and 75 A due to following reasons:

- Formation of fine particles of silicon in the interdendritic aluminium-eutectic found on photographs of microstructure of HAZ and high temperature sustainability of silicon particles.
- Formation of coarse grains in Heat affected zone were observed in the specimens of 70A and 80A thereby reducing the strength of the welded joint

Hence it can be concluded that Tungsten Inert Gas welded AA-5083 job that is subjected to post weld cryogenic treatment possess maximum tensile strength at weld current of 80A.

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