

# NON HEAT TREATABLE ALUMINUM ALLOY WELD JOINTS WITH POST WELD COOLING TECHNIQUES: A COMPARATIVE STUDY ON WELD MICROSTRUCTURES AND ITS EFFECTS

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**Abstract-** Aluminium alloys find their wide applications in automobile body works, boat hull, aircrafts and construction filed etc., because of its higher strength to weight ratio compared to steel. Many researchers have investigated the post weld heat treatment and its effects with Al-Cu, Al-Mg-Si and Al-Zn alloys. In this research, an effort is made to examine the microstructural changes and its effect on tensile properties when weldment is subjected to different post weld cooling techniques. The 6mm thick AA5754 H111, a non heat treatable aluminium alloy plate was taken to fabricate single V butt joint. An Alternating Current TIG welding machine was used with 170A and 180A and after 15 sec, the welded samples were cooled with three different cooling techniques such as room temperature, water and compressed air. The welded specimens were prepared as per the ASTM standards and tested for Mechanical and Metallurgical characterization such as tensile strength, hardness and microstructure. The results show that compressed air cooling technique yields better mechanical properties at 170A and it was observed that equiaxed fine grains at weld zone which causes about 6% increase in joint strength than other techniques. The hardness distribution across the weld is seemed to be similar in all zones.

**Keywords:** AA5754 H111, Tungsten Inert Gas welding, Hardness, Mechanical Properties, Cooling techniques

## I. INTRODUCTION

Aluminum alloys are far and wide used as structural materials in automotive and aerospace industries because of their superior characteristics such as low density, higher strength to weight ratio, excellent corrosion resistance, good ductility and recyclability. The problem associated with fusion welding process is that due to huge amount of heat coarser grains are developed during solidification which affects the mechanical properties seriously. It obvious that there are several heat treatment techniques available to recover the mechanical properties of heat treatable aluminum alloys. But for non heat treatable alloys, still researchers are finding new way to resolve it. Grain refinement has been considered as one of the most effective techniques to enhance the mechanical properties of metal castings and to improve the formability of metal ingots. For solid metals, severe plastic deformation is generally used to refine the grains to micrometer and even with nanometer scales. The possible techniques available for grain refinement of cast metals are rapid solidification, inoculation approach [11, 14], vibration and stir- ring [12, 13]. Coarse grains were formed at the tip and refined grains were possible as it goes beyond the V shaped Cast Al-Si with 3% alloy [1]. The challenges with welding process such as heat input control, hot cracking, porosity and weldable thickness vary with the process used and that there is no optimal general weld process for all aluminium alloys and thicknesses [2]. The resistance against initiation and propagation of cracks in the weld metal can be enhanced through grain refinement and the toughness is increased with no change in Tensile Strength in 5083 alloy [3]. The grain growth of 443 stainless steel is prejudiced by thermal cycle, migration of grain boundary and precipitates and lowest hardness observed in two phase region [8]. A mathematical model was developed to investigate the weld fusion zone grain size with pulsed current welding parameters using DoE and regression analysis and able to predict 95% grain diameter significantly [6]. The failure region is moved to HAZ region and pulse duration did not improve joint strength, but increased frequency aids in enhancing the strength [5]. It is probable to judge Coarser Grain at HAZ of quenched and tempered steel and with simulated CG HAZ, bainite is created at the lowest cooling rate, whereas martensite is formed at the maximum cooling rate [7].

GTA and GMA weld performances and bead characteristics on 5XXX alloys with ER5356 filler were appreciable [4]. In second weld pass, the recrystallization is visible with more refined grains than single pass at HAZ and rapid grain growth reduces refinement in ANSI304 steel [9]. A predictive model

was developed using Taguchi’s method against HAZ size, degree of dilution and grain size. Also the welding parameters influences on reducing these factors [10]. Nano scale grains were reported when cooling with mixture of water, methanol and dry ice. Also other possible methods are using compressed air, liquid nitrogen and normal water, among which cooling with water found to be more effective. [15]. According to Hall Petch model, ultra fine grained and nano structured materials have notable increase in strength but decrease in ductility when employing pulsating current mode than constant current [16 & 17].

The main objective of the present paper is to discover a new post weld cooling material and techniques with GTA weddling of non heat treatable aluminum alloy AA5754 H11 which is not tried so far.

## II. MATERIALS AND METHODOLOGY

Aluminum plates of size 100x75x5 mm<sup>3</sup> were taken for experimentation. AC square wave TIG welding machine was used to fabricate the joints. Single 60° V grooves were prepared and edges were cleaned sufficiently before welding. Table 1 depicts the composition of base metal and the filler and Table 2 shows the properties of the parent metal.

AC square wave TIG welding machine was used to fabricate the joint with current of 170A & 180A and Voltage of 13V ±2. The shielding Gas of pure Argon (40 L/min) is supplied to guard weld pool. Different post weld cooling methods were employed namely open air conditions, compressed air with 1 bar pressure and water at room temperature. The welded specimen in kept 10 sec idle and then allowed to cool with different techniques.

**Table 1 Chemical composition of AA5754 H111 and ER5356**

AA5754 H111	Mg	Mn	Si	Fe	Cu	Cr	Zn	Ti	Al
Wt%	3.092	0.396	0.178	0.175	0.032	0.063	0.022	0.077	Rest
ER5356	Mg	Mn	Si	Be	Cu	Cr	Zn	Ti	Al
Wt%	4.5-5.5	0.05 - 0.20	0.25%	0.0008	0.10	0.05 - 0.20	0.10	0.06 - 0.20	Rest

**Table.2 Mechanical properties of AA5754 H111**

Property	Value
Density	2.66 g/cm <sup>3</sup>
Melting Point	600 °C
Thermal Expansion	24 x10 <sup>-6</sup> /K
Tensile Strength	224-240 MPa
Yield Strength	120-125MPa
Shear Strength	140 Mpa
Hardness Vickers	65-70 HV

Samples are then cut in to required standards ASTM E8M and subjected to tensile test for property investigations. For microstructure examination, the sample is molded, polished and etched with Keller agent carefully. Samples and Machine are shown on Fig1.

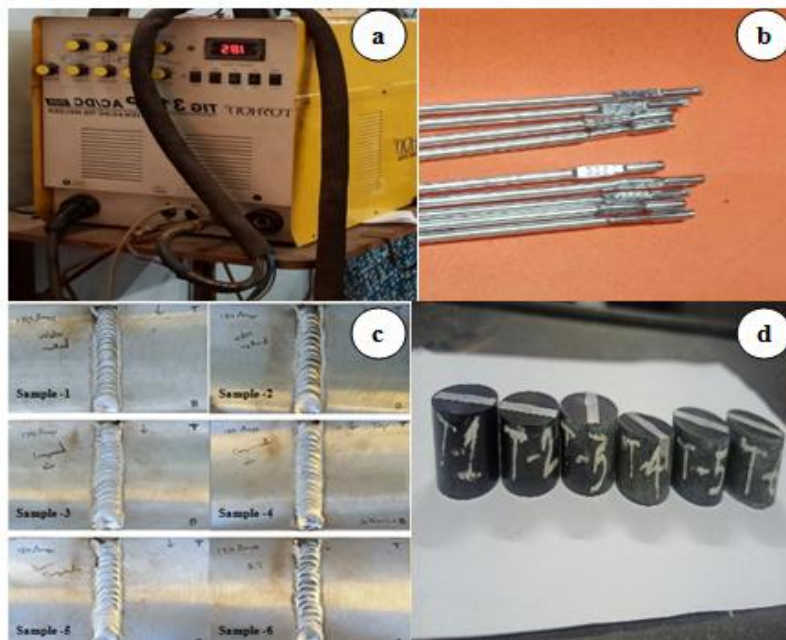


Fig 1 a) Welding Machine, b) Filler Rod, c) Weld Samples, d) Molded Samples

Table 3 Weld Sample Specification

Samples	Specifications of Cooling methods	Current (Amps)
T1	Open Air Condition	170
T2	Open Air Condition	180
T3	Water at room temperature	170
T4	Water at room temperature	180
T5	Compressed air at 1 bar	170
T6	Compressed air at 1 bar	180

### III. RESULTS AND DISCUSSION

Micro Vickers hardness survey is taken across the weld region with 0.5Kg load on each sample. The results clearly shown there is no peak found in hardness values because of the reason that the grain growth happened due to much heat input at all six samples even then the mode of cooling is changed. The average hardness recorded in HAZ is 65.9 HV, 69.8 HV at parent metal and 72.9 HV in fusion zone which is due to the exposure of weld fusion region and speedy solidification. When compared to the other cooling modes, compressed air results in better hardness distribution across the weld owing to forced convection nature.

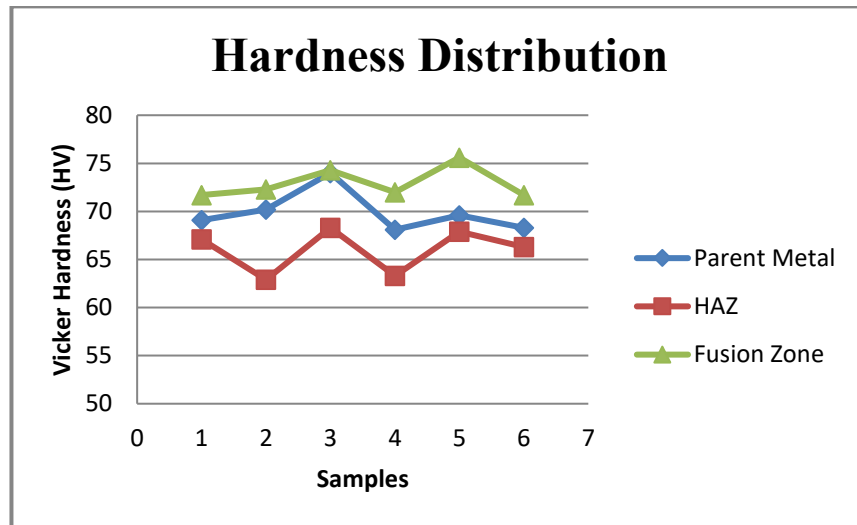


Fig 2 Hardness Distribution Across the Weld Region

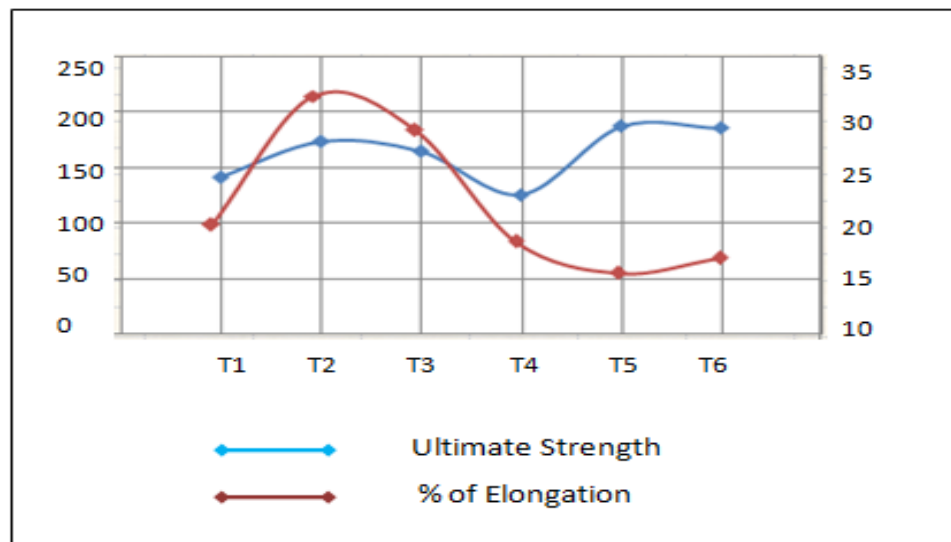
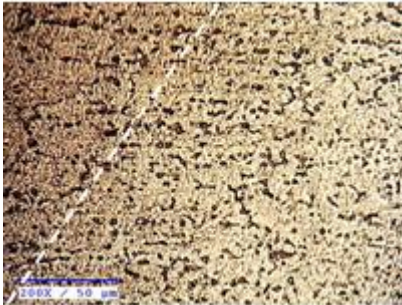
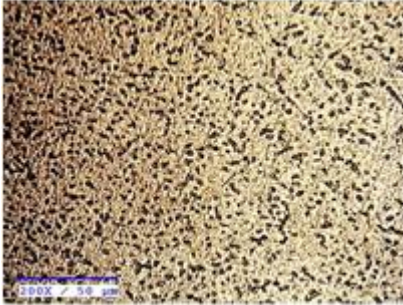
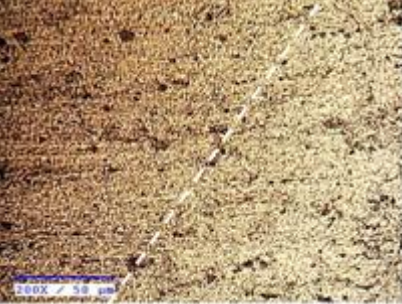
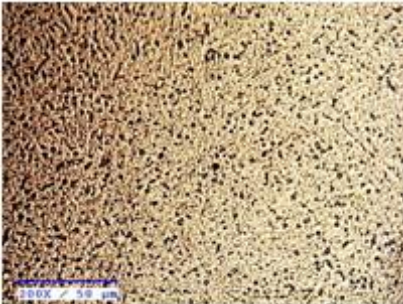
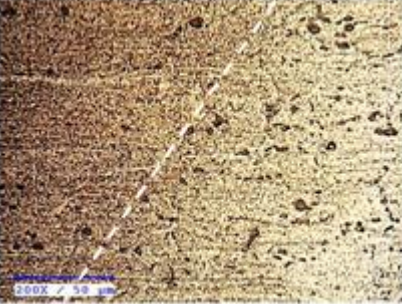

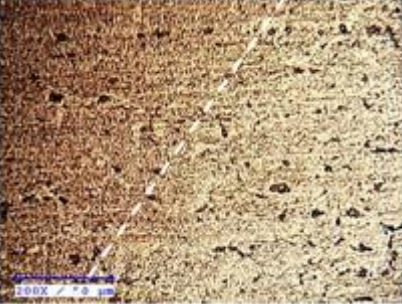
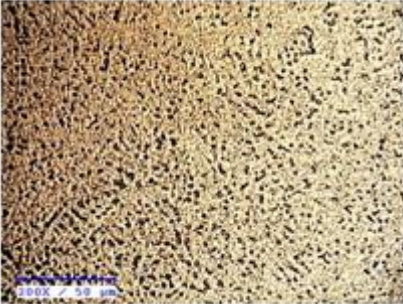
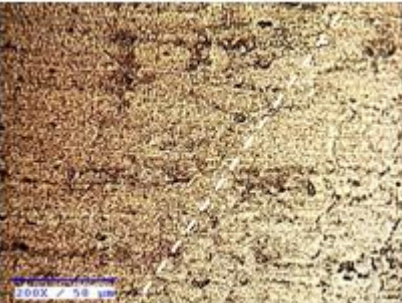
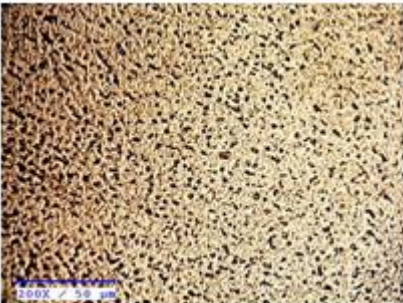


Fig 3 Ultimate Strength and Elongation Curves

The tensile property results have clearly indicated that enough solidification happens when subjected to compressed air as cooling agent and also about 82.5 % joint strength is achieved with 170A current which is slightly higher than that is with 180A. Also the water at room temperature as cooling medium gives 72.6 % joint strength at 170A.

Considering the elongation percent, normalization offers better ductility at 180A and that is the best next to water quenching at 170A. The sample with compressed air as post weld cooling agent shows the least elongation.

Conditions	Heat Affected Zone	Weld Zone
170A, Open air		
180A, Open air		
170A, Water Cooled		
180A, Water Cooled		
170A, Compressed Air		

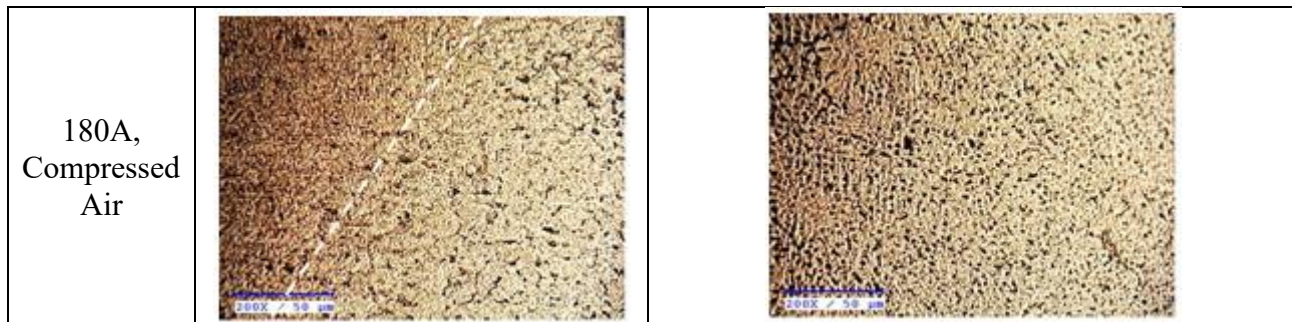


Fig 4 Microstructure Investigations

Microstructural examinations with 200X magnification were completed using Optical Microscope. Low tensile strength was achieved in sample T1 because of coarse grains formation at HAZ which weakens the joint and T4 as micro porosity and hot cracking observed at HAZ. Clear precipitates at HAZ and finer grains at weld zone cause the weld joint to be strong, almost 80-83% joint strength while using compressed air as post weld cooling agent. Similar microstructures were also observed in sample 1 ( Air cooled at 180A) and 3 ( water cooled at 170A) with almost 73-77% joint strength.

#### IV. CONCLUSION

After all cooling techniques, the welded specimens were prepared as per the standards and tested for Mechanical and Metallurgical characterization. The following conclusions were made:

Tensile Test:

- At Room Temperature, it is observed high value of UTS of 173.7 MPa and % of elongation is 22%.
- At Compressed Air, it is observed that Sample 5 which welded at 170A has higher value of UTM 187.5 than other samples with 18.5% elongation.

Hardness Test:

- With Compressed Air and water cooled samples, it was observed that almost similar Vickers Hardness at Weld zone 75.6 HV.

Microstructure Test:

- Precipitates were formed during rapid cooling with compressed air as cooling agent and also finer grains were observed which could be the main reason for higher joint strength.

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