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INVESTIGATION OF MECHANICAL PROPERTIES AND MICROSTRUCTURE OF AA1100 ALLOY AND AA3003 ALLOY WELDED JOINTS USING GTAW

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Abstract: **Gas Tungsten Arc Welding is a well-known welding technique, used in industries in the current age. Aluminium is the most commonly used material in all types of industries. Aluminium is the second material in case of annual consumption after steel. Pure aluminum melts at 660°C, and its alloys are at a slightly lower temperature. The crystal structure of aluminum is FCC. It is a very ductile material. It was observed that TIG welding has better Tensile strength, hardness, impact strength, and microstructure compared to another welding of aluminum alloys. AA1100 alloy and AA3003 alloy were joined by Gas Tungsten Arc (GTA) welding with Aluminium (ER4043) as a filler metal. The microstructure and its properties of the Aluminium alloy GTA weld joint were studied by means of Optical Microscopy, Universal Testing Machine, Charpy Impact, and Hardness Tests. It showed that Aluminium alloy metals could be successfully joined by GTAW under proper processing parameters.**

Index Terms **– GTAW, Aluminium alloy, L9 orthogonal array, Microstructure, Mechanical properties.**

I. INTRODUCTION

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing fusion. In addition to melting the base metal, a filler material is typically added to the joint to form a pool of molten material (the weld pool) that cools to form a joint that is usually stronger than the base material. Pressure may also be used in conjunction with heat, or by itself, to produce a weld.

Welding processes are essential for the manufacture of a wide variety of products, such as frames, pressure vessels, automotive components, and any product which have to be produced by welding. However, welding operations are generally expensive, require a considerable investment of time and they have to establish the appropriate welding conditions, in order to obtain an appropriate performance of the welded joint. There are a lot of welding processes, which are employed as a function of the material, the geometric characteristics of the materials, the grade of sanity desired, and the application type (manual, semi-automatic or automatic). The following describes some of the most widely used welding processes.

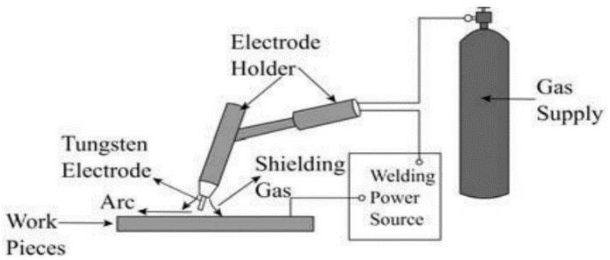


Fig. 1 TIG welding process

II. MATERIALS AND METHODOLOGY

The selection of welding process depends on various factors, which influence the joining of the material a lot. These factors are the material and geometry of the parts to be joined, the requirement of joint strength, type of joint, number of parts to be joined, appeal for the aesthetic look of the joint, and service conditions like moisture, temperature, inert atmosphere, and corrosion compared with steel, aluminum has a third the modulus of elasticity, weighs a third as much, and cost about three times as much per pound. Its coefficient of expansion is twice that of steel, a disadvantageous characteristic and the cause of warping during fusion welding.

This section mainly deals with experimental details and materials used in this investigation work, like welding technique, specimen size, testing conditions, etc. Aluminum alloy AA1100 and AA3003 are the most widely used medium-strength aluminum alloy and have gathered wide acceptance in the fabrication of lightweight structures. The Extruded form of aluminum alloys AA1100 and AA3003 is used in the present investigation. It was in sheet form having a thickness of 5.5 mm and a width of 50 mm.

AA1100 is an alloy of Aluminum which is further classified within the AA1000 series (commercially pure wrought aluminum). It is the first modification of AA1000 alloy. It is a commercially 99.00% pure aluminum alloy. A1100 has excellent Workability, Weldability, Corrosion resistance, and good Machinability.

Table 1. Chemical composition of aluminum alloy AA1100 in percentage

Si	Fe	Cu	Mn	Zn	Al	Others
0.95	0.03	0.05-0.2	0.05	0.10	99.00	0.15

Table 2. Physical properties of aluminum alloy AA1100

Density (g/cm3)	Melting point (°C)	Modulus of Elasticity (GPa)	Poisson's ratio
2.71	646	70-80	0.33

Table 3 Mechanical properties of aluminum alloy AA1100

Yield Strength (MPa)	Ultimate Strength (MPa)	Elongation	Hardness
105	110	12 %	28

The 3xxx-series alloys are used in applications where added strength and formability are needed, in addition to excellent corrosion resistance. This is the most widely used of all aluminum alloys. A3003 has excellent corrosion resistance and workability it can be deep drawn or spun welded or brazed.

Table 4. Chemical composition of aluminum alloy AA3003 in percentage

Si	Fe	Cu	Mn	Zn	Al	Others
0.6	0.7	0.05-0.2	1.0-1.5	0.10	Bal	0.15

Table 5. Physical properties of aluminum alloy AA3003

Density (g/cm3)	Melting point (°C)	Modulus of Elasticity (GPa)	Poisson's ratio
2.71	644	70-80	0.33

Table 6. Mechanical properties of aluminum alloy AA3003

Yield Strength (MPa)	Ultimate Strength (MPa)	Elongation	Hardness
125	130	10 %	35

In this investigation hardness test, impact test (Izod), tensile test has been done on the welding joint of AA1100 and AA3003 joined by TIG welding. The actual joined material is shown below.

Fig 2. TIG welded joint of AA1100 and AA3003

Filler metal ER4043 commonly referred to as AlSi5 is a 5% Silicon aluminum filler metal that is available for TIG welding processes. This alloy is recommended for welding 1080,1100,3003,6061 6063 and 5052. In some cases, other aluminum alloys are also welded with this type.

Table 7. Chemical composition of filler metal ER 4043 in percentage

Si	Fe	Cu	Mn	Zn	Al	Ti	Mg
4.5-6.0	0.8	0.3	0.05	0.10	Bal	0.2	0.05

III. EXPERIMENTAL PROCEDURE

Materials and Mix design

AA1100 and AA3003 with a thickness of 5.5mm were cut by using a shearing machine to dimensions of 150 × 40 mm then being welded by single pass welding with butt joint configuration. The chemical compositions of AA1100 and AA3003 and filler metal ER4043 are shown in the above tables. The operations were performed by using an automated table and TIG welding machine type of ESAB Se69601. The parameters used in this operation were welding current, filler wire diameter, and gas flow rate.

Experimental Test

For the tensile test, the welded AA1100 and AA3003 were cut by using Electron Discharge Machine (EDM) model sodick AQ535L following American Standard Testing Material. The tensile test of the weld was measured by FIE/UTN 40-type Universal testing machine which was shown in fig. The schematic diagram of Tensile test specimens was shown in Fig. 3

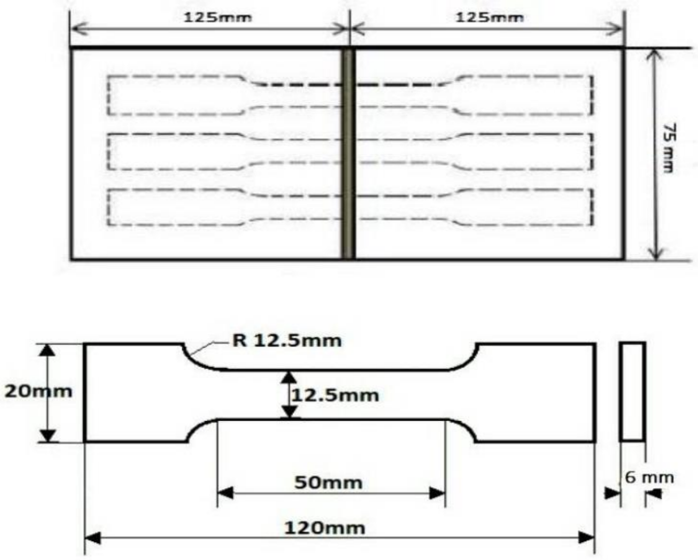


Fig. 3 Schematic diagrams for dimensions of specimen for tensile test

For the hardness test, the specimens were cut into 10mm. The specimen was then hot-mounted, grinded, and polished. The hardness of the weld was measured by the RAB-250 Brinell hardness test. The schematic diagram of Hardness test specimens was shown in Fig .4

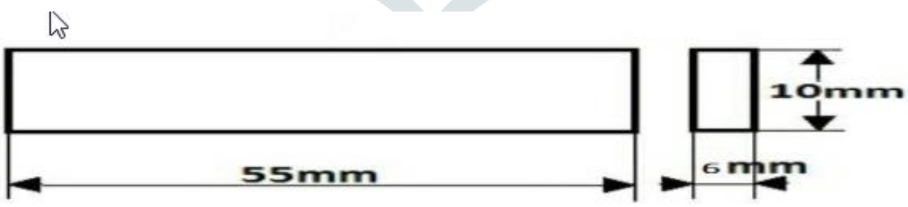


Fig. 4 Schematic diagrams for dimensions of specimen for Hardness test

For the impact test, the specimens were cut into 10mm. The specimen was then hot-mounted, grinded, and polished. The energy observed by the weld was measured by KRYSTAL ELMEC Charpy impact test machine. The schematic diagram of impact test specimens was shown in Fig 5.

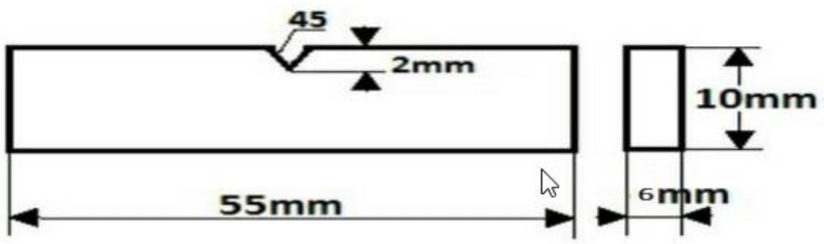


Fig 5. Schematic diagrams for dimensions of specimen for Impact test

After welding, the microstructure and mechanical properties conditions are the principal aspects that determine the appropriate performance in structures and components of aluminum alloys. It means that it is necessary to know exactly the mechanical behavior of the welded joint, including the global and local mechanical properties. This is necessary because the temperature susceptibility of some aluminum alloys tends to change in greatly manner the microstructure conditions in the fusion zone and in the HAZ.

IV. RESULTS AND DISCUSSIONS

Experimentations with a combination of different parameters of welding current, filler wire diameter, and shielding gas flow rate were performed. In this investigation tensile testing has been done on UTM, hardness testing has been done on the Brinell hardness tester, and impact testing (Charpy) has been done on the impact testing machine and microstructure.

Tensile test

Tensile tests were conducted by using a Universal Testing Machine type of FIE/UTN with different loads applied to the specimens. The crosshead speed to pull the specimen at 1 min/mm was used. A total of eight tensile tests were performed and the tensile stresses of these eight specimens were recorded. The result of the tensile testing shows that the weakest area is located in the heat-affected zone (HAZ), roughly 8-12 mm from the weld. Figure 6. shows samples after the tensile test and notices that the material has been deformed and necking occurs before fracture This is a typical ductile fracture. The ultimate load and ultimate tensile strength obtained from the test for 8 specimens with different parameters are presented in table 8 All samples have different tensile strengths but samples 6 and 8 are Higher compared to others.

Fig 6. The picture shows fractured tensile samples on the cross-section side

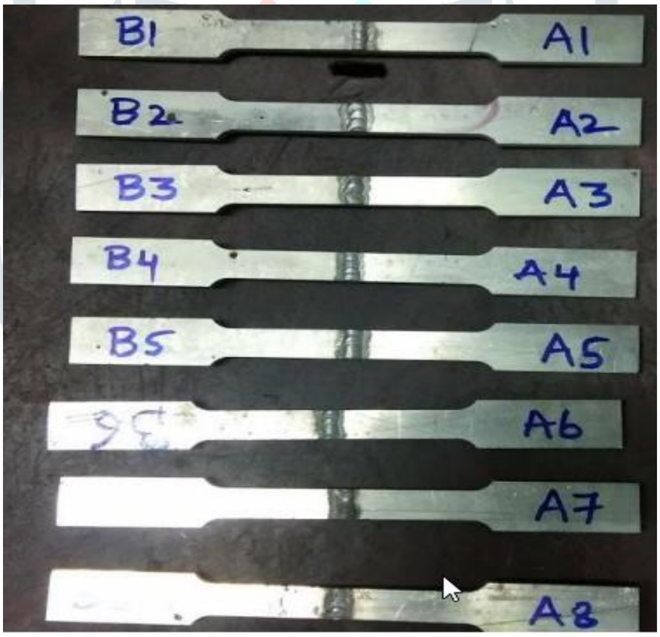


Fig 7. Tensile test specimens before Testing

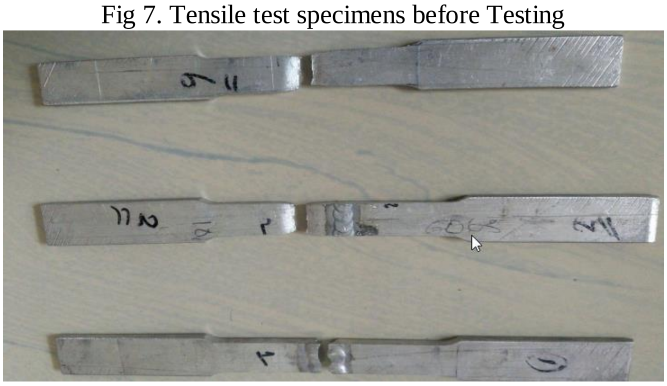


Fig 8. Tensile test specimens After Testing

Table 8. Ultimate load and ultimate tensile strength values of samples

Sample	Current (A)	Gas flow rate (Lit/min)	Filler rod dia (mm)	Ultimate load(KN)	Ultimate tensile strength (N/mm2)
1	210	12	1.6	8.98	130.45
2	210	12	2.4	9.12	134.53
3	265	12	1.6	7.23	109.9
4	265	12	2.4	8.92	131.9
5	210	14	1.6	9.21	141.9
6	210	14	2.4	10.51	159.5
7	265	14	1.6	8.32	125.9
8	265	14	2.4	9.31	146.23

Hardness test

The hardness of the weld metal is measured with the help of the Brinell hardness testing machine at B grade (BHN) and The average hardness at different areas of the welded regions are as given below table .

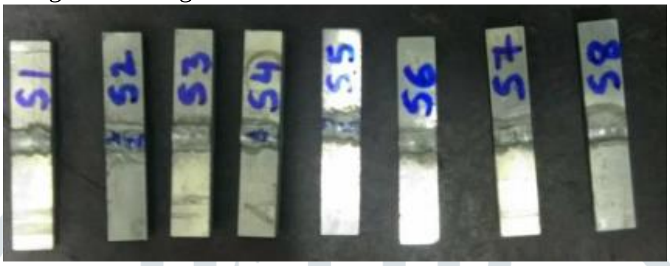


Fig 9. Hardness test specimens before Testing

Fig 10. Hardness test specimens After Testing

Table 9. Hardness Test values of samples

Current (A)	Filler wire dia (mm)	Gas flow rate (lit/min)	Observed values in BHN, Trial 1	Observed values in BHN, Trial 2	Observed values in BHN, Trial 3	Average
210	1.6	12	46.81	46.83	45.70	46.27
210	2.4	12	49.01	49.89	47.60	48.75
265	1.6	12	49.21	50.80	48.50	49.65
265	2.4	12	45.23	46.78	44.40	45.59
210	1.6	14	51.47	52.56	50.70	51.63
210	2.4	14	52.11	52.90	51.60	52.25
265	1.6	14	47.63	48.60	47.93	48.27
265	2.4	14	46.23	47.83	45.86	46.85

The filler metal used in TIG welding is ER4043 electrode which contains Magnesium, Manganese, and chromium as principal alloying elements. These alloying elements may precipitate carbides which may contribute to higher hardness levels.

Impact test

Impact strength is the measurement of the energy-absorbing capacity of the material. The impact is a sudden load, which is applied on the workpiece having a V notch. The Energy observed by the weld metal is measured with the help of the Charpy impact testing machine. The energy absorbed by the different samples with an average value was shown in table 10.

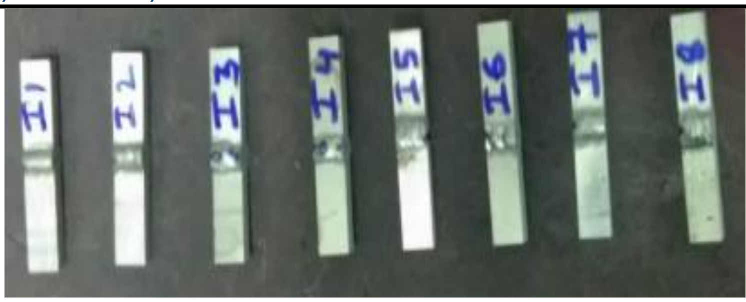


Fig 11. Impact test specimens before Testing

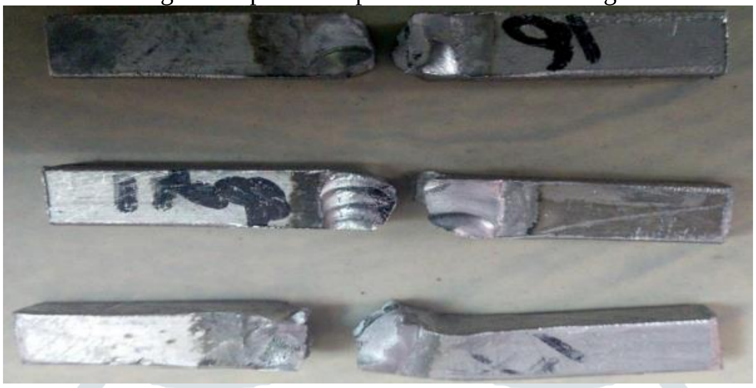


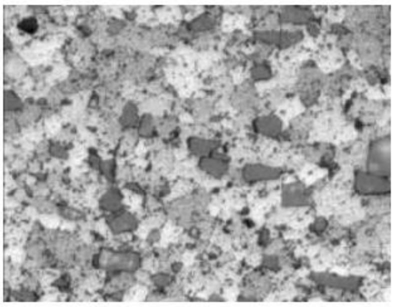
Fig 12. Impact test specimens before Testing

Table 10. Impact Test values of samples

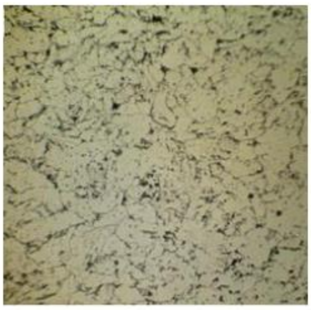
Current (A)	Filler wire dia (mm)	Gas flow rate(lit/min)	Observed values (joules)
210	1.6	12	8.88
210	2.4	12	10.88
265	1.6	12	10.86
265	2.4	12	10.84
210	1.6	14	10.88
210	2.4	14	8.85
265	1.6	14	6.90
265	2.4	14	12.85

Microstructure

The microstructure of the weld metal is measured with the help of the lapex FE PRO 900 Computerized metallurgical microscope. The given samples had microstructure of fine grains and script-like structures. The micro test report of the base metal and weld zone is shown below in Fig 13.

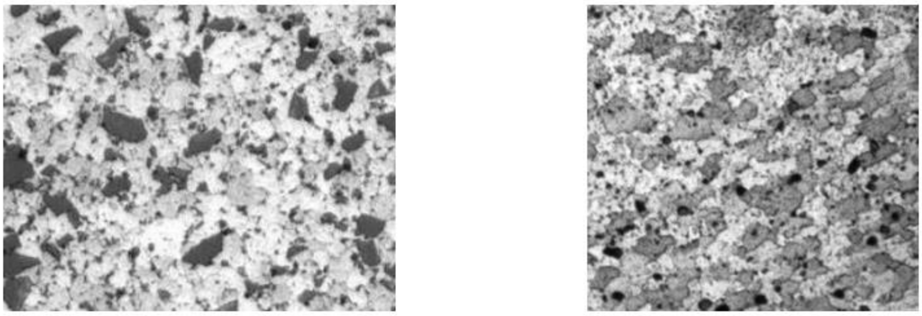


Weld zone microstructure ofAA1100



Base metal microstructure of AA1100

Fig 13. Microstructure image of sample A



Weld zone microstructure of AA3003 Base metal microstructure of AA3003

Fig 14. Microstructure image of sample B.

V. CONCLUSIONS

- AA1100 and AA3003 metals of 5.5mm thickness are successfully connected by GTAW with Aluminium ER4043 filler metal.
- It is observed that at different parameters were welding current of 231A, filler rod diameter is 1.6, and gas flow rate is 14lit/min, tensile strength, hardness, and impact were near to the base metal (in terms of %).
- The hardness in both sides of HAZ is close to the base metal i.e 93% and at the fusion zone 91% which is near to aluminum alloy.
- The microstructure of equiaxed grains and script-like structures with grain sizes are visible.
- The impact strength of AA welded joints is 12.85 joules at specimen 8. It is almost close to base metal strength.
- The ultimate tensile strength of AA welded joints is at specimen 3 of 220 amps current is 135.369N/mm2 about 94% of base metal.
- By the above results, it is concluded that with the parameters of current 231A, filler wire dia of 1.6mm and gas flow rate of 14lit/mm weldments values are observed nearer to the base metal.

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