INVESTIGATION OF MICROSTRUCTURE AND MECHANICAL PROPERTIES OF GTAW AND GMAW JOINTS OF AA7075 ALUMINUM ALLOY

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Abstract

Aluminum and its alloys have been used in recent times due to their light weight, moderate strength and good corrosion resistance. Aluminum alloy 7075 has been researched upon especially as a potential candidate for aircraft material. This alloy is difficult to weld using conventional welding techniques like GMAW and GTAW. An attempt has been made in this paper to weld 7075 alloy using GTAW and GMAW with argon as a shielding gas. Mechanical properties of the joint like tensile strength, Hardness and impact strength have been reported.Microstructural characterization has been done using standard metallography.SEM micrographs have also been taken to study the fracture characteristics.

Keywords: AA 7075 aluminum alloy, Gas tungsten arc welding, Gas metal arc welding, Mechanical properties, Microstructural characterization

I. INTRODUCTION

High strength precipitation hardening 7xxx series aluminum alloys, such as 7075 are used extensively in aerospace industry. 7xxx series alloys are Heat treatable with ultimate tensile strength of 32 to 88 psi. These are the highest strength aluminum alloys. These alloys are often used in high performance applications such as aircraft, aerospace and competitive sport equipment like the 2xxx series of alloys, this series incorporates alloys which are considered unsuitable for arc welding and others, which are often arc welded successfully. The commonly welded alloys in this series such as 7075 are predominantly welded with the 5xxx series filler alloys.

Today's aluminum alloys together with their various tempers, comprise a wide welding procedure development, It is important to understand the differences between the many alloys available and their various performances and weldability characteristics. When developing arc weld procedures for these alloys, consideration must be given to the specific alloy being welded. It is often said that arc 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

Commonly used aluminum alloys for aircraft industries

The most commonly used materials in aircraft construction are 2024 and 7075 alloys because of the good materials properties. The former has good fatigue characteristics. the later has a high yield stress Applications of AA7075 Al alloy ,[5] Applications of AA7075 Al alloy The following industries are use the 7075 aluminum alloy Aircraft and aviation Space shuttle, Rocket propulsion for missiles Automotive industries (alloy – wheel),Marine engine components. External throwaway tanks for military aircrafts

The traditional method of joining components in many structural applications is through the use of mechanical fasteners, which makes assembling primary structures extremely time consuming. Riveted joints are replaced by fusion welds, in Considerable reduction in time consumption in the manufacturing process can be achieved, as well as weight reduction and conception improvement in mechanical performance. In recent years significant attention has been focused on manufacturing cost in aerospace industry. The new techniques in aircraft components manufacture are being developed to provide simultaneous weight saving and cost saving. AA 7075 –T6 (70,000 psi yield strength) and Al – Zn –Mg – Cu alloy was introduced in 1943. Since then most aircraft structures have been specified in alloys of this type. The first aircraft design in 7075-T6 was the Navy's P2V patrol bomber.[7]

Aluminum alloy castings traditionally have been used in constructional airplane, hardware such as pulley brackets, quadrants doubless chips, ducts and wave guides . They also have been employed extensively in complex valve bodies of hydraulic control system. Many materials are available to the structure engineer, and some of the most commonly used one in aerospace structures are listed.The most commonly used materials in aircraft construction are 2024 and 7075 alloys because of the good materials properties. The former has good fatigue characteristics. The later has a high yield stress.

A. Heat-treatable and Non-heat-treatable alloys

Heat-treatable alloys:2000,6000,7000 & 8000

Non-heat-treatable alloys:1000,3000,4000 &5000

B. Non-heat-treatable alloys

The initial strength of alloys in this group depends upon the hardening effect of elements such as manganese, silicon, iron, and magnesium, alone or in various combinations. The non-heat-treatable alloys are usually designated as, in 1,000, 3,000, 4,000 or 5,000 series. Since these alloys are work-harden able, further strengthening is made possible by various degrees of cold working, denoted by the _H_series of tempers. Alloys containing appreciable amounts of magnesium when supplied in strain-hardened tempers are usually given a final elevated temperature treatment called normalizing to insure stability of properties.[7]

The initial strength of alloys in this group is enhanced by the addition of alloying elements such as copper, magnesium, zinc and silicon. Since these elements singly or in various combinations show increasing solid solubility in aluminum with increasing temperature, it is possible to subject them to thermal treatments which will impart pronounced strengthening. Precipitation hardening is commonly used to process copper alloys and other non-ferrous metals for commercial use .The examples of aluminum –copper alloys , copper-beryllium , copper –tin ,magnesium- aluminum and some ferrous alloys. An appreciable maximum solubility of one component in the other, on the order of several percent. A solubility limit that rapidly decreases in concentration of the major component with temperature reduction. Increase strength and stiffness and / or reduce density whilst maintaining other properties. The AA7075 al-alloys chemical composition were tabulated:

Table 1. Chemical composition of AA 7075 aluminum alloy

Parameters	Results (%)	Procedure
Copper	1.43	
Silicon	0.07	
Magnesium	2.80	
Manganese	0.03	
Iron	0.18	
Titanium	0.029	Optical emission spectrometry
Nickel	0.029	ASTM E 1251-04
Zinc	5.832	
Chromium	0.18	
Strontium	í 0.0005	
Vanadium	0.005	
Zirconium	0.009	

The above sample confirms to AA7075 Aluminum alloy grade for the above chemical parameters tested.

Table 2. Typical Physical Properties of AA 7075

Characteristic	English	Metric
Nominal Density (68 °F/20 °C)	0.101 lbs./in.3	2.80 Mg/m3
Melting Range	990 °F - 1175 °F	532 °C - 635 °C
Specific Heat (212 °F/100 °C)	0.23 BTU/lb. - °F	960 J/kg - °K

II. EXPERIMENTAL PROCEDURE

Gas Metal arc welding GMAW welding is widely used for welding aluminum and it produces welds of good appearance and quality. A constant current AC power [5] Source with a continuous high frequency is used with water or air-cooled GMAW torch and an externally supplied inert shielding gas. The AC process is used to provide a degree of cleaning of the aluminum surface during the electrode positive cycle though this is not a substitute for proper cleaning of the base material. The tungsten electrode diameter is usually about 2,4 mm and the method can be used with or without filler metal. The filler material is fed into the weld bead from outside. GMAW Welding gives the welder very good control, but welding speed is normally slower than for MIG and requires higher welder competence. The choice of torch cooling depends upon welding parameters and duty cycle. They are usually water-cooled. Air-cooled torches can be used at up to about 100 amps, and of the correct diameter for the current, are used The end of the electrode is prepared by reducing the tip diameter to 2/3 of the original diameter and then striking an arc on a piece of scrap material. This creates a ball on the end of the electrode. The ball must not be larger than 11/2 times the electrode diameter.[10] A good indication that the electrode diameter is suitable for the welding current is to observe the ball diameter and the ease with which it forms. An electrode that is too small for the welding current will form an excessively large ball, whereas too large an electrode will not form a satisfactory ball at all. The torch must be maintained at an angle of close to 90° to the work piece surface and the filler material must enter the weld pool at an angle of typically 5°. As well as the work piece being properly clean it is important that the filler rod is also clean. If the rod has been exposed to air for a long time it is advisable to clean it by pulling the rod through a 'Scotchbrite' type of abrasive pad or through stainless steel wool in order to remove the oxide layer.

The GMAW welding process is best suited for thin gauge materials up to about 6 mm thick, but preferably only up to 4mm for best economy. Thicker material can be GMAW welded, but this would require many more weld passes and results in high heat inputs, leading to distortion and reduction in mechanical properties of the base metal. High quality welds with good appearance can be achieved due to the very high degree of control available - the heat input and filler additions are controlled separately. GMAW welding can be carried out in all positions and the process is always preferred for tube and pipe work and small, thin components.

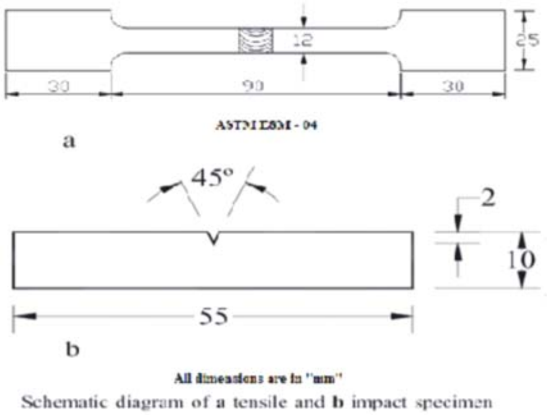

Fig. 1. (a) Dimensions of flat tensile specimen (ASTM E8M-04). (b) Dimensions of flat impact specimen.

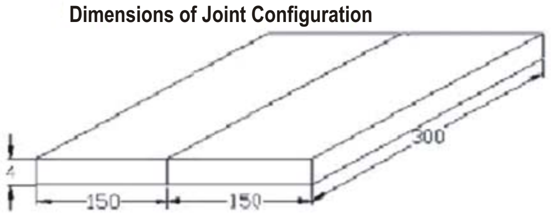

Fig. 2. Scheme of welding with respect to rolling direction and extraction of tensile specimen.

Tensile testing

The rolled plates of AA7075 aluminum alloy were machined to the required dimensions (300 mm×150 mm).Single 'V' butt joint configuration, as shown in Fig. 2a, was prepared to fabricate GMAW welded joints. The initial joint configuration was obtained by securing the plates in position using tack welding for GMAW welds. The direction of welding was normal to the rolling direction. All necessary care was taken to avoid joint distortion, and the joints were made with suitable clamps Single pass welding was used to fabricate the joints.AA (Al-5%Si) grade filler rod and wire were used for GMAW welding processes, respectively. High purity (99.99%) argon gas was the shielding gas. Square butt joint configuration as shown in Fig.1b was prepared to fabricate GMAW Butt joints. After the GMAW Weld Butt joint model were completed on AA7075 aluminum Base weld metal was metal were prepared for the tensile specimen according to ASTM E8M-04 standard ,AA7075 aluminum alloy the tensile specimen were prepared for as per Fig. 2b, ASTM E8M-04 standard for the tensile test was carried out using universal testing machine(UTM). The results are noted that Tensile strength is 549.86N/mm2, yield strength 413.66 N/mm and the elongation on 5.65 mm $\sqrt{A}$ GL

Hardness testing

Hardness was measured under 40x objective and an applied load of 300gms using Vickers microhardness tester. Three readings were taken and the average value has been reported in Tables 4 and 5.

Measurement were taken along a line at half of the depth of fusion zone across the entire weld region at an interval of four times the indenter's size to avoid the effects of localized strain hardening in the vicinity of the indentation attributed to the dissolution of precipitates' into solution and subsequently .

Impact testing

Impact testing was done using Charpy impact testing method IS 1757 AND 1599 .Results are shown in Table.6

III. RESULT AND DISCUSSION

A. Tensile properties

The transverse tensile properties such as yield strength, tensile strength, percentage of elongation, notch tensile strength, and notch strength ratio of AA7075 aluminum alloy joints were evaluated. In each condition, three specimens were tested, and the average of the three results is presented in Table 4. The yield strength and tensile strength of unwelded parent metal are 537 MPa and 570 MPa, respectively. However, the yield strength and tensile strength of GMAW joints are 110 MPa and 118 MPa, respectively.

Table.3. Tensile Strength, Yield and % Elongation Value of Samples

Sample	Tensile Strength N/mm2,	Yield N/mm2,	%Elongation mm
1	551.22	413.66	13.61
2	570.19	445.61	13.33
3	537.58	404.37	13.61
4	540.47	409.52	11.60
	Average value		
	549.86	413.66	

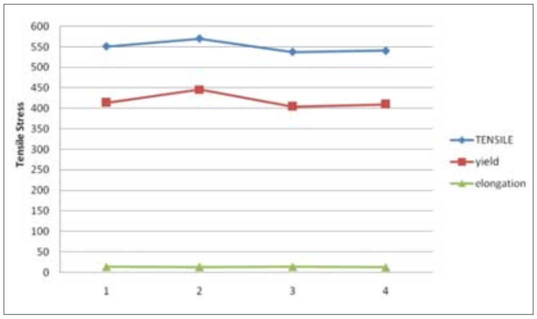

Fig. 3. Tensile Test

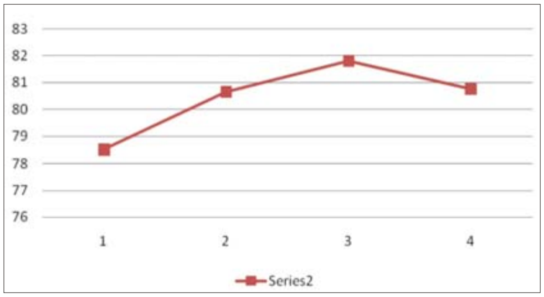

Fig.4. Tensile Strength for MIG Weld

B. Hardness results

Hardness profile indicates a decrease in the weld hardness in the weld region as shown fig4 , and this has been a Hardness measurement of the various weld regions were performed using a Vickers diamond indenter. favor nucleation and growth of all precipitates .The transition region indicates a reduction in hardness because of coarsening precipitates. The average hardness at different areas of the welded work piece are as given below

Table 4. Hardness Profile for TIG Welds

WELD TYPE	WM (Hv)	HAZ (Hv)	BM (Hv)
GTMAW	96	157	153

Table 5. Hardness Profile for MIG Welds

WELD TYPE	WM (Hv)	HAZ (Hv)	BM (Hv)
GMAW	73	133	100.5

The results of hardness tests show that hardness values are lesser for MIG welds compared to TIG welds due to the filler metal used in TIG welding.The filler metal used in TIG welding is 5356 electrode which contains Magnesium,Manganese and chromium as principal alloying elements.These alloying elements may precipitate carbides which may contribute to the higher hardness levels.

C. Impact testing results

Table 6. Impact Test

IMPACT TEST	IMPACT (CHARPY METHOD STRENGTH (JOULES)
BASEMETAL	12J
GTAW	6J
GMAW	4J

Results of impact tests show that the weld is able to absorb only 4J in GMAW and 6J in GTAW as compared to 12 J absorbed by the base metal.

D. Microstructure of TIG welds

Microstructure of the parent metal has revealed spheroidal particles of MgZn (black precipitates) and light grey particles of FeAl3 present in the Aluminium soild solution as shown in Figure 6.We can also see the grains elongated along one direction

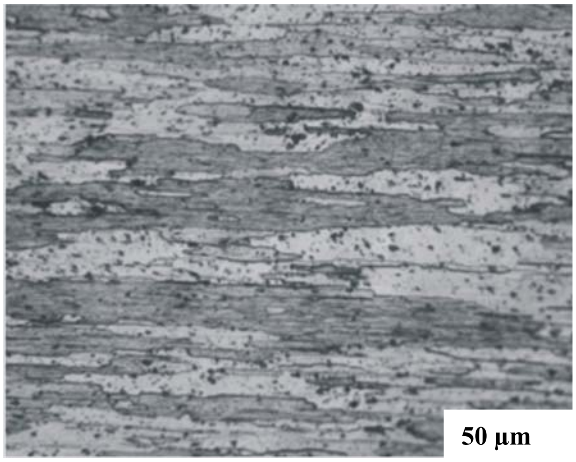

Fig. 5. Base metal microstructure-TIG welding

Microstructure of the weld metal has revealed interdendritic eutectic with light grey particles of FeAl3 present in the Al solid solution as shown in Figure 7

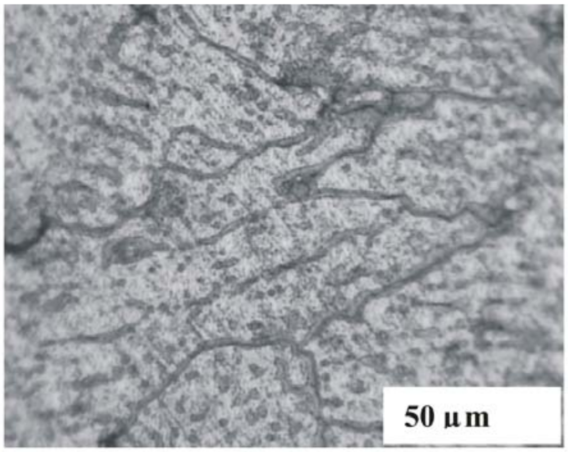

Fig. 6. Weld metal microstructure-TIG welding

The microstructure of the HAZ has revealed elongated grains with grain boundary eutectic and light grey particles of Fe3Al present in the Aluminium solid solution as shown in Figure 8

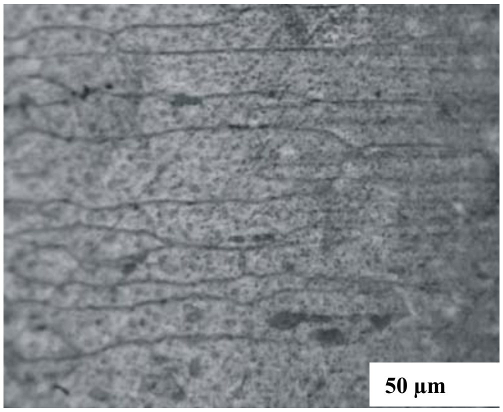

Fig. 7. HAZ Microstructure-TIG welding

The microstructure of the composite zone,that is parent metal + HAZ +Weld is shown in Figure 9.We can see the three distinct zones clearly.

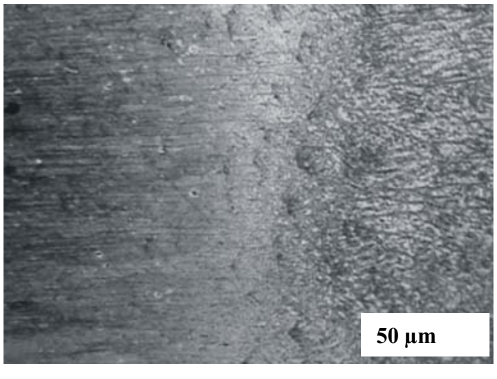

Fig. 8. Parent metal + HAZ +weld microstructure-TIG Welding

E. Microstructure of MIG

The microstructure of parent metal is similar to that of TIG welding.

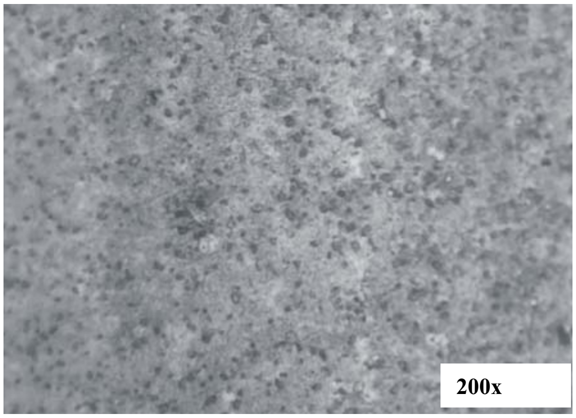

Fig. 9. Parent metal Microstructure-MIG welding

The weld microstructure consists of slightly elongated grains.Some porosity can also be seen in the weld.

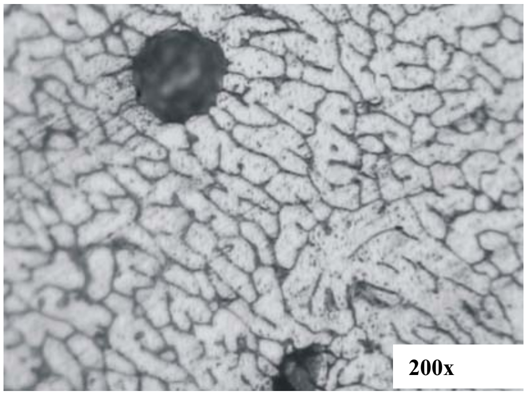

Fig. 10. Weld metal microstructure-MIG welding

The HAZ consists of grain boundary eutectic and a coarse grain structure can be seen.

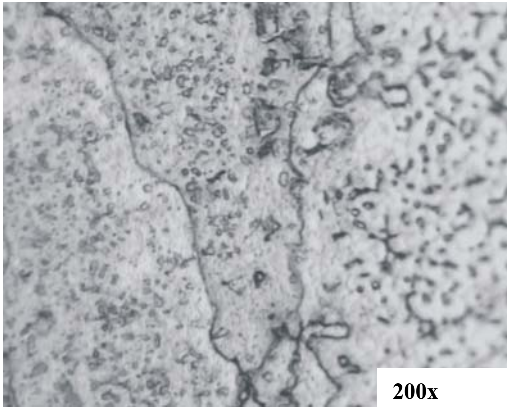

Fig. 11. HAZ microstructure-MIG welding

Figure 13 shows the composite microstructure of the prent metal,HAZ and weld metal

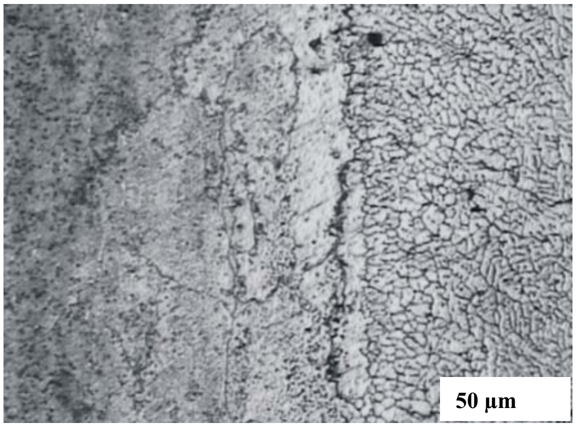

Fig. 12. Microstructure of Parent metal + HAZ +Weld

IV. FRACTOGRAPHY

SEM studies were done to identify the mode of fracture.It appears that the fracture is brittle in nature.

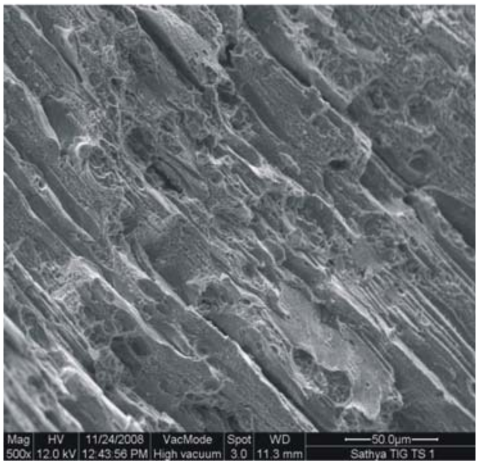

Fig. 13. SEM Fractograph of Tensile test specimen

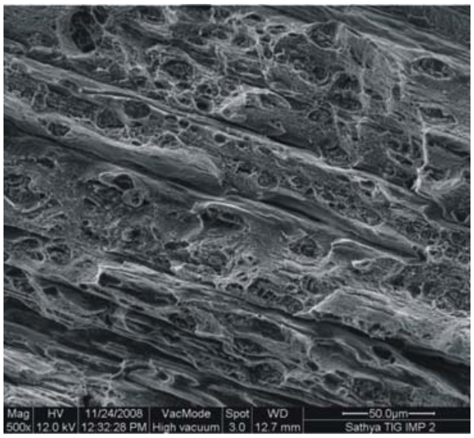

Fig. 14. SEM fractograph of Impact tested specimen

V. CONCLUSION

From this investigation, the following important conclusions have been arrived at

(I) Welded joints fabricated by GMAW process have lower strength comparatively GTAW values and the enhancement in strength value is approximately 28 %

(ii) Hardness islower in the weld metal (WM) region compared to the HAZ and BM regions. High hardness is recorded in the GTAW (HAZ) and the maximum Hardness of 157 VHN was observed in the HAZ. In the parent metal 153VHN is recorded. In GMAW (HAZ) also high Hardness of 133 VHN was observed. In the parent metal 100.5VHN is recorded.

(iii) The impact strength value observed by charphy method the value in base metal weld metal are tabulated.In GTAW 6J and GMAW 4J value was observed.

(iv) Fine, equiaxed grains were formed in the welding zone and they were uniformly distributed in the microstructure. The SEM image was studied to identify the mode of fracture. It appears that the fracture is brittle in nature.

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