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Investigation of Microstructure and Mechanical Properties of TIG and MIG Welding Using Aluminium Alloy

Yatender Gupta[1], Dr. Amit Tanwar[1], Raunak Gupta[2]
[1](*Department of Mechanical Engineering, Roorkee Institute of Technology, Roorkee (Uttarakhand), India)*
[2](*Department of Mechanical Engineering, Quantum School of Technology, Roorkee (Uttarakhand), India)*

Abstract: *TIG (Tungsten Inert Gas) welding and MIG (Metal Inert Gas) welding are well known welding techniques, that are being used in industries in the current age. Aluminium is the most commonly used material in all industries. Aluminium is the second material in case of annual consumption after steel. Pure aluminium melts at 660^{0}C and its alloys melts at slightly lower temperature. The crystal structure of aluminium is FCC and it is very ductile material. In this paper, the study is done to find out the best welding technique (TIG or MIG) for the aluminium alloy. The comparison is done on the basis of microstructure and mechanical properties of the welded joint of TIG and MIG welding on aluminium alloy 6062. It was observed that MIG welding has better tensile strength, hardness, impact strength and microstructure compared to TIG welding for the used aluminium alloy.*
Keywords: *Aluminium alloy, AA-6062, Microstructure, MIG, TIG.*

I. Introduction

Welding is a process where coalescence is produced by the application of heat. There are many types of welding techniques used to weld different metals. Aluminium is on second number in terms of annual consumption however steel is having the first position. The market value of aluminium is increasing at very fast rate which is causing the welding of aluminium a major consideration in industries. There are a number of techniques for joining the aluminium alloys. The selection of welding process depends on various factors affecting the joining of the material. These factors are material and geometry of the parts to be joined, requirement of joint strength, type of joint, number of parts to be joined, aesthetic property of the joint and service conditions like moisture, temperature, inert atmosphere and corrosion.

The products of aluminum and aluminum alloys can be cast, extruded, forged and machined. The different manufacturing processes are used to make a single component of a product, but welding is used to assemble the different parts to make a single complex structure/product.

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 [1].

II. Literature Review

2.1 Tungsten Inert Gas (TIG) Welding:

In the tungsten inert gas welding process, the arc is maintained between a non-consumable tungsten electrode and a work piece in a protective inert gas atmosphere. Figure 1 shows the real processes.

Filler material is used externally for the joining of the work pieces. Normally, a DC arc is used with tungsten as the negative pole (DCEN). This is not possible for metals, such as aluminum and magnesium, where the oxide layer persists if the work piece is used as the anode. This layer prevents the formation of the weld pool. The mobile cathode spot can disperse the oxide layer but excessive heat is generated at the tungsten electrode if this is used as the anode.

Hence, AC arc is used for such materials. To avoid the melting of the electrode, thorium or zirconium is added to the tungsten (to increase the melting point). Argon is most commonly used to provide the inert atmosphere. Nitrogen is sometimes used for welding copper. To prevent the possible little contamination, an argon DE oxidant is added to the filler **[2].**

Direct polarity is the most commonly employed in GTAW. In this case, the electrode is connected to the negative pole of the heat source and the electrons are emitted from the electrode and they are accelerated as they travel through the arc (plasma). This effect produces a high heat in the work piece and therefore gives a good penetration and a relatively narrow weld shape.

When alternating current is used, is possible to obtain a good combination of oxides elimination (cleanliness) and penetration. This polarity is the most employed to weld aluminum alloys **[3]**. The polarity system used in the TIG welding process is shown in Figure 2.

Table 1

Property	Purity				
	99.999%	99.99%	99.8%	99.5%	99.0%
Melting point, ^{0}C		660.2			657
Boiling point, ^{0}C		2480			
Latent heat of fusion, Cal/g		94.6			93.0
Specific heat at 100^{0}C, Cal/g		0.2226			0.2297
Density at 20^{0}C	2.70	2.70	2.70	2.71	2.71
Electrical resistivity Ω-cm at 20^{0}C	2.63	2.68	2.74	2.80	2.87
Temp. coefficient of resistivity		0.0042	0.0042	0.0041	0.0040
Coefficient of thermal expansion × 10^6 (20^0-100^{0}C)		23.86	23.5	23.5	23.5
Thermal conductivity, CGS units at 100^{0}C		0.57	0.56	0.55	0.54
Reflectivity (total)		90%	89%	86%	
Modulus of elasticity, lb./in^2 × 10^{-6}		9.9			10.0
Tensile strength, tons/in^2		3.8	4.4	5.2	5.8
Brinell hardness, P/D^2=5		15	19	21	22

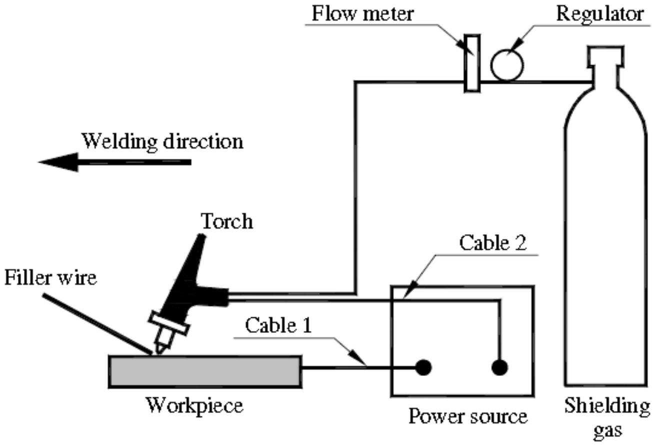

Fig. 1: TIG welding process

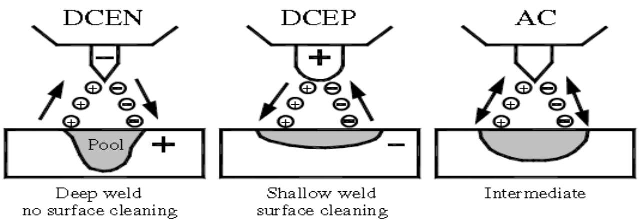

Fig. 2: Polarity in TIG welding process

2.2 Metal Inert Gas (MIG) Welding:

In MIG welding process the arc is maintained between a consumable electrode and the work piece in an inert gas atmosphere. The coiled electrode wire is fed by drive rolls as it melts away at the tip. Except for aluminum, a DC source is used with the consumable electrode as the positive terminal. For welding steel, a shielding is provided by CO_2 for lowest cost. Normally, a high current density in the electrode (of the order of 10,000 amp/cm^2) is used so that projected types of metal transfer results. The welding current is in the range 100-300 amp. The process is primarily meant for thick plates and fillet welds. Fig. 3 shows the main process **[2]**. MIG welding process is one of the most employed to weld aluminum alloys.

There are three basics metal transfer in MIG welding process: Globular transfer, Spray transfer and Short-circuiting transfer. In the globular transfer, metal drops are larger than the diameter of the electrode, they travel through the plasma gas and are highly influenced by the gravity force. One characteristic of the globular transfer is that this tends to present, spatter and an erratic arc. This type of metal transfer is present at low level currents, independently of the shielding gas. However, when using CO2 and He, globular transfer can be obtained at all current levels.

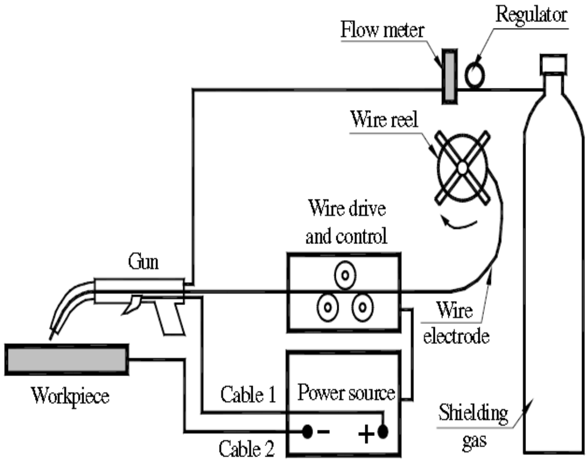

Fig. 3: MIG welding process

On the other hand, spray transfer occurs at higher current levels, the metal droplets travel through the arc under the influence of an electromagnetic force at a higher frequency than in the globular transfer mode. In this transfer mode, the metal is fed in stable manner and the spatter tends to be eliminated. The critical current level depends of the material, the diameter of the electrode and the type of shielding gas.

In short-circuiting transfer, the molten metal at the electrode tip is transferred from the electrode to the weld pool when it touches the pool surface, that is, when short-circuiting occurs. The short-circuiting is associated with lower levels of current and small electrode diameters. This transfer mode produces a small and fast-freezing weld pool that is desirable for welding thin sections, out-of-position welding and bridging large root openings. Figure 4, shows the typical range of current for some wire diameters **[3]**.

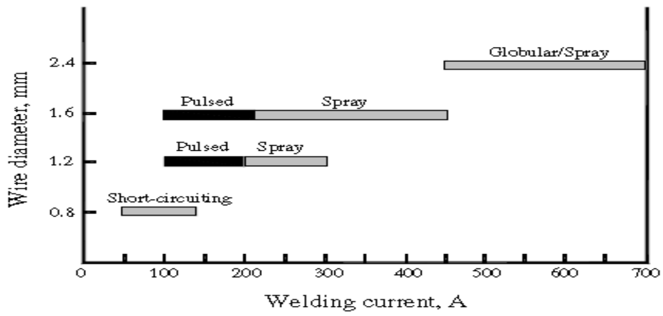

Fig. 4: Typical welding current ranges for wire diameter and welding current

III. Materials And Methodology

This section mainly deals with experimental details and material used in this investigation work, like welding technique, specimen size and testing conditions etc. Aluminium alloy AA6062 (Al-Mg-Si) is the most widely used medium strength aluminium alloy, and has gathered wide acceptance in the fabrication of light weight structures **[4]**.

The Extruded form of aluminium alloy AA6062 is used in the present investigation. It is heat treated up to 3000C. It was in the sheet form having thickness 6 mm and width 50 mm. Chemical compositions and physical properties are given in Table 2 and 3 respectively.

Table 2: Chemical composition of aluminium alloy AA6062

Mg	**Si**	**Fe**	**Cu**	**Cr**	**Mn**	**Zn**	**Ti**	**Al**
0.65	0.45	0.42	0.12	0.19	0.05	0.08	0.02	Bal.

Table 3: Physical properties of aluminium alloy AA6062

Density(g/cm^3)	**Melting Point(^{0}C)**	**Modulus of Elasticity(GPa)**	**Poison Ratio**
2.7	595	72-85	0.34

The principle alloying elements in AA6062 are Magnesium and Silicon. Magnesium is introduced in aluminium alloys to increase strength, and recrystallization temperature, allowing the alloy to maintain its strength at high temperatures.

Table 4: Mechanical properties of aluminum alloy AA6062

Yield Strength (MPa)	Ultimate Strength (MPa)	Elongation (%)	Reduction in cross sectional area (%)	Hardness (HRB)
275	360	25	65	70

In this investigation hardness test, impact test (Izod), tensile test and SEM tests has been done on the welding joint joined by TIG and MIG. The actual joined material is shown in figure 5:

Fig. 5: Actual representation of TIG and MIG weld joint

IV. Result And Discussion

In this investigation tensile testing has been done on UTM, hardness testing has been done on Brinell hardness tester, impact testing (Izod) has been done on impact testing machine.

Impact strength is the measurement of energy absorbing capacity of the material. Impact is a sudden load, which is applied on the work piece having a V notch. Two types of impact tests are performed here to know the impact strength of the welds made by TIG and MIG.

Fig. 6: MIG weld specimen after Izod test

Fig. 6: TIG weld specimen after Izod test

Table 5: Summary of Impact Test

Welds/Material	Energy Absorbed (Joule) Izod	Effect
BM	24	BREAK
TIG	6.0	BREAK
MIG	14.0	BREAK

The hardness of the weld metal is measured with the help of the Rockwell hardness testing machine at B grade (HRB) and the values of the hardness in the weld region is shown in the following Table 6.

Table 6: Hardness of the weld region

Type of Welding	Hardness of weld region (HRB)
TIG	45
MIG	54

Different types of tensile properties of welded aluminium alloy AA6062 were evaluated such as yield strength, ultimate tensile strength, percentage elongation and joint efficiency. For each condition three specimens were tested and the average properties of the welded joints are taken, these properties are shown in the following Table 7.

Table 7: Tensile properties of weld joints

Type of Joint	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Elongation (%)	Joint Efficiency (%)
TIG	83.3	144.80	21	40.5
MIG	241	330.305	9.0	91.75

In this study the microstructure of each and every joint has been examined at different locations of the joint. But it is found the joint mainly break/failed at the fusion zone, hence only the microstructure of the weld fusion zone is studied. The weld fusion zone microstructures of different welding processes are shown in the Fig. 7.

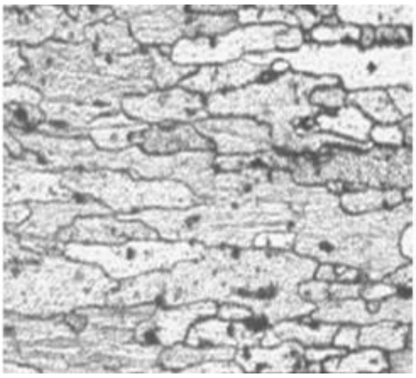

Fig. 7 (a) : Base Metal

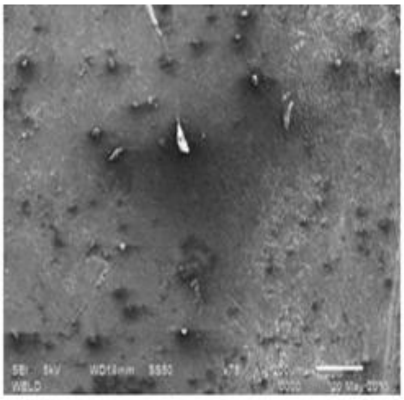

Fig. 7 (b) : MIG Weld metal

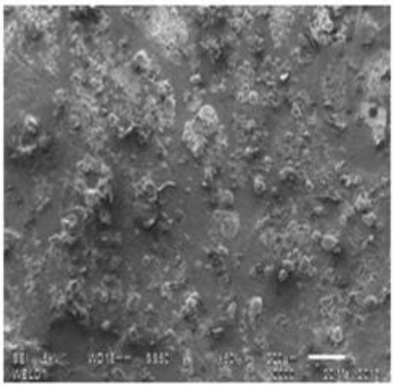

Fig. 7 (c) : TIG Weld metal

Fig. 7 : Microstructure of weld zone at 200µm scale

V. Conclusion

After the welding by TIG and MIG mechanical properties and microstructure of welds have been tested and following conclusions can be drawn:

1. The impact strength of MIG joints is higher than that of the TIG joints.
2. It is found that hardness in weld metal region is less than that of the BM. The maximum hardness is found in MIG and the minimum hardness is found in TIG welded joint. The hardness pattern in the weld region in two welding processes is like, MIG > TIG.
3. In case of MIG the microstructure is very fine and equiaxed, having uniformly distributed grains with strengthening precipitates as compared to TIG welding processes in which dendritic grain structures is found. Because of fine grain structure the MIG joint possesses good tensile and mechanical properties than that of the TIG welding processes.

On the basis of the above discussion it can be elaborate that the MIG is the best suitable welding process to join aluminium alloy AA6062 as compared to TIG welding processes.

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