Study on Newer Techniques of TIG Welding and Microstructure of Welded Parts of Aluminium Composites and Alloys: A Review

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Abstract - Over the years, alloys and metal matrix composites (MMC) has developed into an essential material for modern manufacturing processes. Especially, aluminium based MMCs have a widespread importance due to their physical and chemical properties making them applicable for aviation and aerospace industries. Also, lightness and high strength-to-weight ratio are two important factors for their widespread usage. Manufacturing in these industries involve joining processes, wherein welding plays primary role. In welding of aluminium, Tungsten Inert Gas (TIG) welding process is highly preferred. Although, aluminium welding confronts a major problem due to formation of alumina (Al_2O_3), however this is overcome due to usage of pulsed TIG welding. In this process, one half of the pulse breaks the alumina layer to aid in welding. This paper investigates various modern techniques of welding aluminium alloys and metal matrix composites. Also, the findings regarding microstructure and mechanical properties of the welded parts are studied.

***Key Words*:** Aluminium, Welding, Tungsten Inert Gas welding, Microstructure, Mechanical properties.

1. Introduction

Welding of aluminium alloys and composites have been a challenge for several reasons. Especially TIG welding has yielded several interesting results. Numerous researchers have attempted the same over the years. Some of them are discussed here.

Wang Xi-he et. al [1] peformed TIG welding of SiCp/6061 Al composites using He–Ar mixed gas as shielding gas with and without using Al–Si filler. Welded joints were subjected to tensile test and also microstructure of the same was studied. The results revealed that addition of 50 volume % of helium as shielding gas improved the arc stability and weld beads of high quality were produced using filler materials.

In an investigative work, Gao and Wu [2] studied on weld penetration through weld pool morphology. This was achieved by using a three-layer neural network, a new method to establish such a model. Several tests were performed and results suggested that the model was accurate in predicting weld penetrations.

In an interesting work by Chen et. al [3], intelligent techniques for fulfilling quality control of bead-on-plate welding was performed. A new image sensing system was designed which was capable of capturing images of topside and backside of weld beads simultaneously. Influences of welding parameters were analysed. Results of simulation hinted at the accuracy of the system.

Pichumani et. al [4] attempted to optimize pulsed TIG welding parameters while welding Al-SiC metal matrix composite. The objective was to maximize bending strength. Welding parameters considered were peak current, base current, pulse on time and pulse frequency. Optimal combination was at 160A, 60A, 50% and 5Hz of the mentioned parameters respectively. Regression equation and empirical models were utilized.

Urena et. al [5] experimented on the effect of interfacial reaction on fracture behavior due to reaction between matrix and reinforcement of aluminium alloy reinforced with SiC particles during arc welding. TIG welding was performed on AA2014/SiC/Xp (X = 6, 13 and 20 vol%, respectively) and then tensile tested. It was observed that failures was located in weld material and was 50% less than strength of parent metal. Fracture studies of weld metals were performed and compared with parent composites. It was concluded that proportion of interfacial failure increased due to formation of Al4C3, which reduced strength of matrix.

In an interesting experimental investigation, Parshin et. al [6] tried to find the impact on productivity by addition of ultrafine particles of activating flux during TIG welding of aluminium and steel alloys. Also, welded joint formed during welding was studied with direct in alternating current to increase the productivity of automatic argon-shielded arc welding.

2. Newer techniques in TIG welding of aluminium

Over the years, welding of aluminium has witnessed great advancement. Especially TIG welding process has improved rapidly and several newer techniques have been introduced. Some of them are discussed.

Yasuda et. al [7] attempted a hybrid TIG welding process to join thin aluminium sheets. This process was compared with plug welding method. In plug welding, good quality weld was obtained upto a certain range of He-AC TIG welding. However, with hybrid welding process, consistent weld was produced.

TIG welding of ultra thin aluminium sheets of 0.3 mm or less was performed by Ukita et. al [8]. It is a well known fact that butt welding very thin aluminium sheet is difficult. Also, usage of high speed during welding is a major constraint. Thus, the experimental investigation was an important one. It was reported that ultra thin aluminium sheets could be butt welded at weld speed of 1000 mm/min using a single electrode. The weld speed could be increased to 2000 mm/min using two electrodes.

TIG welding process is depicted in Fig. 1.

Fig-1: TIG welding process

Stano et. al [9] experimented to find the difficulties in welding of aluminium alloys and composites. Newer techniques of joining these materials were explored. Different welding processes such as low heat input arc welding methods, plasma arc welding and hybrid laser and MIG welding for joining thin aluminium sheets were attempted.

Wang et. al [10] reviewed on fast frequency pulsed TIG welding technique. The advantages of the process w.r.t. conventional pulsed TIG welding process were studied. It was observed that several problems associated like insufficient depth of penetration, large heat affected zone and many weld defects were overcome. Also, characteristics of the process were analyzed and reasons found regarding the wide usage of the process in modern manufacturing process.

3. **Microstructure study of weld parts**

Post weld microstructure study of weld bead is an important area of research. Numerous important findings have evolved through microstructure analysis.

Balasubramanian et. al [11] investigated on influences of pulsed current welding and post weld aging treatment on fatigue crack growth behaviour of AA7075 aluminium alloy joints. TIG welding and MIG welding were used due to their easiness of application. It was observed that weld fusion zones of this alloy displayed coarse columnar grains due to existing thermal conditions. In the study attempt was made to refine fusion zone grains. Filler material used was AA5356 (Al–5Mg (wt.%)) grade aluminium alloy. Four different welding techniques were applied. They were constant current and pulsed current TIG and MIG welding. Argon was used as shielding gas. It was observed that pulsing technique produced finer and equi-axed grain structure in GTA welds. Alongwith grain refinement, there was also increase in fatigue crack growth resistance and fatigue life.

The typical microstructure of an aluminium composite TIG welded component in shown in Fig.2.

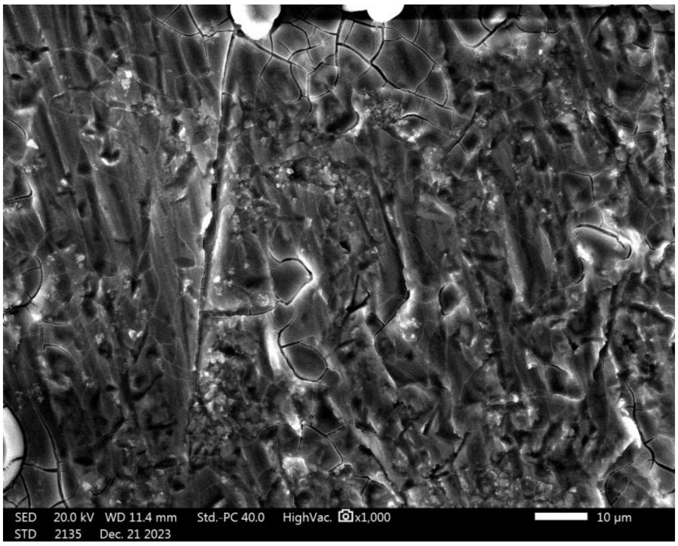

Fig-2: Typical microstructure of aluminium composite TIG welded component

Ahmadi et.al [12] experimented on a new type of nanocomposite tungsten inert gas (TIG) welding filler metals with a matrix of 4043 aluminum alloy and hybrid reinforcement of ZrC and TiC nanoparticles. After welding, microstructure analysis was performed using scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Furthermore, mechanical properties of nanocomposite welds were studied by tensile and microhardness tests.

Senthil Kumar et. al [13] investigated to study impact of pulsed current TIG welding parameters on tensile properties of AA 6061 aluminium alloy weldments. It was observed that medium strength aluminium alloy has wide application in manufacturing light weight parts. This is due to high strength to weight ratio.

In another investigation on microstructure of welded parts, Manti et. al [14] searched on effect of pulsed TIG welding process parameters, namely pulse duration, peak current, and pulse frequency on microstructure and microhardness of Al-0.8%Mg-0.5%Si (6061) alloys. Refined grains were produced by pulsed TIG welding compared to constant current TIG welding process. Increase in pulse frequency produced finer grains of aluminium and eutectic structures. It was concluded that pulsed duration influenced effect of pulse frequency on the grain structure.

Mosneaga et. al [15] investigated on the effect of manganese (Mn) addition on toughness of welded parts of Al–Mg–Si alloys. The microstructure of the weld beads were studied through scanning electron microscopy (SEM). Phenomenon like crack initiation and propagation behavior were examined. It was observed that addition of Mn completely prohibited formation of recrystallization, whereas non-addition resulted in fibrous structures.

4. **Conclusion**

Several new techniques of TIG welding were studied.

Wang Xi-he et. al peformed TIG welding of SiCp/6061 Al composites using He–Ar mixed gas as shielding gas with and without using Al–Si filler. Gao and Wu studied on weld penetration through weld pool morphology. This was achieved by using a three-layer neural network, a new method to establish such a model. Chen et. al tried intelligent techniques for fulfilling quality control of bead-on-plate welding. A new image sensing system was designed which was capable of capturing images of topside and backside of weld beads simultaneously. Effect of interfacial reaction on fracture behavior due to reaction between matrix and reinforcement of aluminium alloy reinforced with SiC particles during arc welding were investigated. Parshin et. al tried to find the impact on productivity by addition of ultrafine particles of activating flux during TIG welding of aluminium and steel alloys.

Also, the microstructural analysis yielded interesting results.
Investigations on influences of pulsed current welding and post weld aging treatment on fatigue crack growth behaviour of AA7075 aluminium alloy joints were performed. Experiments were performed on a new type of nanocomposite tungsten inert gas (TIG) welding filler metals with a matrix of 4043 aluminum alloy and hybrid reinforcement of ZrC and TiC nanoparticles. Effects of pulsed TIG welding process parameters, namely pulse duration, peak current, and pulse frequency on microstructure and microhardness of Al-0.8%Mg-0.5%Si (6061) alloys were analyzed. Refined grains were produced by pulsed TIG welding compared to constant current TIG welding process. The effects of manganese (Mn) addition on toughness of welded parts of Al–Mg–Si alloys were examined. The microstructure of the weld beads were studied through scanning electron microscopy (SEM). Phenomenon like crack initiation and propagation behavior were examined.

5. **References**

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