



COMPARISON STUDY ON PULSED AND ARC OSCILLATION TECHNIQUES OF GTA WELDED AZ31B MAGNESIUM ALLOY JOINTS

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ABSTRACT

The challenges of achieving significant weight reduction in the automobile industry in the context of fuel savings, recyclability and emission reduction has promoted focus on lightweight metals such as magnesium. GTA welding technology is the main welding method adopted for magnesium alloys because of its advantages of utility and economy. Both magnetic arc oscillation and current pulsing techniques resulted in significant microstructural refinement in weld fusion zone. Hence in this investigation an attempt has been made to study the arc pulsing and arc oscillation on tensile and microstructural characteristics of pulsed current gas tungsten arc welded AZ31B magnesium alloy joints. From this investigation, it is found that the joints fabricated with magnetic arc oscillation having the superior tensile properties compared to pulsed current welding. The formation of fine grains and higher hardness in fusion zone are the main reasons for the superior tensile properties of these joints.

Keywords: *Magnesium alloy, GTA welding, Tensile Properties and Microstructure*

1. Introduction

Magnesium alloys arouse the interest of the materials field because of good features such as low density, good damping characteristics, dimensional stability, machinability and low casting costs [1]. Magnesium alloys have high stiffness-to-weight ratio, and these applications include automotive, industrial, materials handling and aerospace equipment where there is an obvious need for lightweight materials [2,3] most magnesium alloys are readily weldable using gas tungsten arc (GTA), gas metal arc (GMA), electron beam, laser beam welding processes [4]. GTAW process is a widely used material joining process. The quality of GTA welds ranks higher than that of any of the arc-welding processes, due to the reliability, clearance and strength of the weld. However, some processing problems and welding defects such as oxide films, crack, and porosity could easily be caused by the physical properties of magnesium, such as its strong tendency to oxidize, high thermal conductivity, low melting and boiling temperatures, high solidification Shrinkage, and tendency to form low melting point constituents, low viscosity, and high solubility for hydrogen in the liquid state [5].

In general, the severity of a number of weld defects can be reduced if the solidification structure is refined [8]. Magnetic arc oscillation (MAO)

is one of the effective techniques for refining the grain structure in the fusion zone of welds. Arc oscillation produces mechanical agitation in the weld fusion zone and breaks down the growing dendrite columns. As the broken dendrites act as nucleating sites and increase the cooling rate, microstructure is refined [9]. In case of pulsed current technique, the welding current is pulsed between two levels. The background current (I_b) used is not enough to melt the base metal but to maintain the arc stable. Peak current (I_p) instantaneously melts the base plate in a small region for which the surrounding base metal acts as a chill and increases the cooling rate of the spot. A reasonable amount of research has been performed on this process and the reported advantages include improved bead contour, greater tolerance to heat sink variations, lower heat input requirements, reduced residual stresses, and distortion. Metallurgical advantages of pulsed current welding frequently reported in literature include refinement of weld metal grain size and substructure [11]. Current pulsing has been used by several investigators to obtain grain refinement in weld fusion zones and improvement in weld mechanical properties [13].

Fusion zone grain refinement in aluminum alloy welds through magnetic arc oscillation and its effect on tensile behavior was studied by Janaki Ram et al. [12]. Sivaprasad et al. [13] studied the influence of

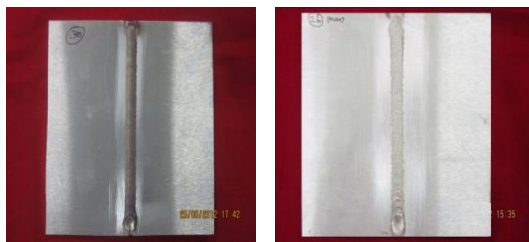
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magnetic arc oscillation and current pulsing on microstructure and high temperature tensile strength of alloy 718 alloy TIG weldments [11]. Effect of mechanical arc oscillation on the grain structure of mild steel weld metal was examined by Mahajan et al. [14]. Grain refinement in magnetically stirred GTA pulsed current and magnetic arc oscillation on magnesium alloys. Keeping this in mind, an investigation has been carried out to study the effect of pulsed and MAO welding processes on tensile and microstructure properties of AZ31B magnesium alloy joints, and the results are revealed in this article.

2. Experimental work

The plates were mechanically and chemically cleaned by acetone before welding to eliminate surface contamination. The initial joint configuration was obtained by securing the plates in position using mechanical clamps. The direction of welding was normal to the rolling direction. The Magnetic arc oscillation equipment is mounted and surrounded with GTAW Torch and interfaced with controller, which monitors the arc oscillation frequency and amplitude. The MAO equipment and controller unit is shown in Fig.1. The photographs of fabricated joints are shown in Fig.2. Argon gas was used as a shielding gas with a constant flow rate of 20 l/min.

Two joints were fabricated using different levels of Pulsed current and Magnetic arc oscillation. The photographs of fabricated joints are shown in Fig.2



PC

MAO

Fig. 2 Photographs of Fabricated joints

Heat input is a very important factor, which affects the bead geometry, mechanical properties and metallurgical properties of weld. Hence, heat input was also calculated and included in the study. In continuous current GTAW process, the heat input per unit length is proportional to voltage and current and inversely proportional to the welding speed. Whereas in

the pulsed GTAW process, the heat input is calculated from the mean current. The equation for the Heat Input is given as:

$$\text{Heat Input} = \frac{I_m \times V \times \eta}{S}$$

Where

I_m - Mean Current

S - Welding speed, mm/s

V - Mean voltage, volts

η - Efficiency of the welding process.

For the pulsed GTAW process, arc efficiency is taken as 60 % based on the literature⁷. During the experiment, voltage was found to vary from 14 V to 18 V. Hence, a mean voltage of 16 V was taken for the heat input calculation. A constant welding speed of 2.25 mm/s was used in this investigation. A Vicker's microhardness testing machine (Make: SHIMADZU, Japan; Model: HMV-2T) was used to measure the hardness across the weld cross section with a 0.05 kg load for a 20 s dwell time. The specimens for metallographic examination were sectioned to the required size and then polished using different grades of emery paper. A standard reagent made of 4.2 g picric acid, 10 ml acetic acid, 10 ml diluted water and 70 ml ethanol was used to reveal the microstructure of the welded joints. Microstructural analysis was carried out using a light optical microscope (Make: MEIJI, Japan; Model: MIL-7100) incorporated with an image analyzing software (Metal Vision).



Fig. 1 MAO Equipment

3. Results and Discussion

The macrostructure of the joints made with different welding speeds are presented in Fig. 3 MAO joints exhibit higher yield strength and tensile strength than PCGTAW welded joints. This is influenced by the weld thermal cycles or in other words by the heat input supplied by the welding process involved. The heat input supplied by the PCGTAW process is relatively

higher than that supplied by the MAO processes [Table 1]. These variations of heat input in the welding processes influence the weld thermal cycle and subsequently cause variations in the microstructural features and hardness characteristics. The measured average grain diameter of PCGTAW joints is 30 μm . Similarly, the measured average grain diameter of MAO joints is 26 μm , and this also indicates that the reduction in grain diameter is 16 μm due to the MAO process. Of the two techniques, the MAO process produces fine grains in the weld metal region compared with PCGTAW processes.

PROCESS Cross – Sectional Macrostructure

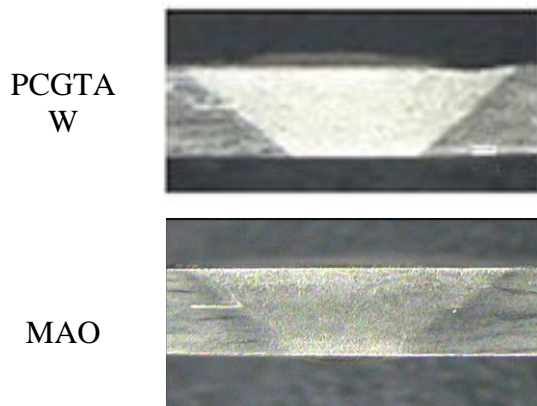


Fig. 3 Bead geometry

Fine grained microstructures obtained by these arc manipulation techniques on the autogenous have been presented in Fig. 4, along with the coarser grained microstructure that is generally observed in PCGTAW weld metals. Though there are many sets of oscillation that have resulted in fine equiaxed grains in the weld metal. It is observed that oscillation frequency plays an important role in generating the equiaxed grains [kou]. MAO welds were found to have better hardness (68VHN) compared to those made on PCGTAW joints. The reason for the higher hardness is the grain refinement and equiaxed grains in weld metal.

The tensile testing revealed that there is a marginal improvement in yield strength of the welded joints, due to the use of arc manipulation techniques produces mechanical agitation in the weld fusion zone and breaks down the growing dendritic columns formed during weld solidification. These broken dendrites can act as new nucleating sites leading to refined equiaxed

grain structure. The refinement of grain structure in the weld fusion zone should have an impact on the tensile properties of the welded joints.

Table. 1 Heat input supplied by the PCGTAW and MAO

Process	Heat Input J/mm	Yield strength (MPa)	Ultimate tensile strength (MPa)	Joint efficiency (%)
PCGTAW	369	165	214	78
MAO	355	192	248	91

Process Cross – Sectional Microstructure

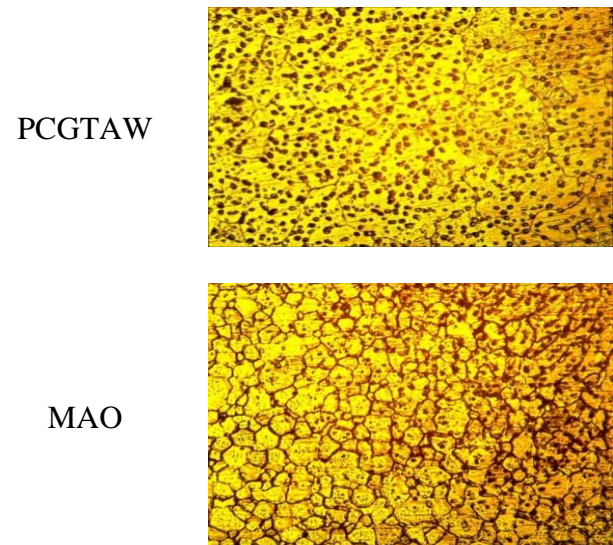


Fig. 4. Cross Sectional Microstructure for PCGTAW and MAO

4. Conclusions

From this investigation, the following important conclusions are derived:

(1) Of the two welded joints. The joints fabricated by MAO exhibited higher tensile strength and the enhancement in strength was approximately 13% when compared with PCGTAW joints.

(2) Lower heat input, finer fusion zone grain diameter, and higher fusion zone hardness may be the reasons for superior tensile properties of MAO joints compared to PCGTAW joints.

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