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INVESTIGATION OF PULSE FREQUENCY ON FUSION ZONE CHARACTERISTICS OF GTA WELDED AZ31B MAGNESIUM ALLOY JOINTS

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ABSTRACT

In this investigation an attempt has been made to study the effect of welding on fusion characteristics of pulsed current gas tungsten arc welded AZ31B magnesium alloy joints. Five joints were fabricated using different levels of welding speed (105 mm/min –145 mm/min). From this investigation, it is found that the joints fabricated using a welding speed of 135 mm/min yielded superior tensile properties compared to other joints. The formation of finer grains and higher hardness in fusion zone and uniformly distributed precipitates are the main reasons for the higher tensile properties of these joints.

Keywords: *Magnesium alloy, GTA welding, tensile properties and Microstructure*

1. Introduction

Magnesium alloys have exceptional specific strength, stiffness, damping capacity, machinability, castability and weldability making it attractive for use in the different applications including automobile and computer parts, aerospace components, mobile phones, sporting goods, and household equipment because of their some advantageous properties [1&2] As a general means of material manufacturing, welding can be used to optimize product design and minimize the costs of production. Presently, gas tungsten arc (GTA) welding process is a well established process for reactive materials like magnesium alloy due to its comparatively easier applicability and better economy of industrial use but also produces the best quality welds amongst the arc welding processes [3&4] 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. Pulsed current gas tungsten arc welding (PCGTAW) is a variant of GTA welding which involves cycling of the welding current from a high level to a low level at a selected regular frequency. In pulsed GTA process, the current is supplied in pulses rather than at a constant magnitude. The aim of pulsing is mainly to achieve maximum penetration without excessive heat build-up, using the high current pulses to penetrate deeply and then allowing the weld pool to dissipate some of the heat during relatively longer arc period at a low current [5].

Recently, few studies were carried out to evaluate the tensile properties and metallurgical characteristics of GTA welded magnesium alloys. Padmanaban et al. [6] revealed the influences of pulsed current parameters on mechanical and metallurgical properties of gas tungsten arc welded AZ31B magnesium alloy. Liming Liu et al. [7] examined the microstructure and fracture of AZ31 magnesium alloy joint welded by automatic gas tungsten-arc filler (GTAF) welding process. Munitz et al. [8] examined mechanical properties and microstructure of GTA welded magnesium AZ91D plates. Kishore babu et al. [9] investigated the influence of alternating current pulsing on the structure and mechanical properties of AZ31 magnesium alloy weldments. Reddy et al. [10]. studied the effect of ratio of peak and background current durations on the fusion zone microstructure of PCGTA welded Al-Li alloy.

The available literatures are mainly focused on evaluating mechanical and metallurgical properties of PCGTA welded magnesium alloys. However very little information available on the effect of pulsed current GTAW parameters such as peak current, base current, pulse frequency and pulse-on- time on mechanical and metallurgical properties of magnesium alloys. Since these pulsed current parameters have significant influence on fusion zone microstructure and related mechanical properties, understanding the effect of these pulse current parameters is very essential. Hence, the present investigation was carried out to study the effect

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of peak current to base current ratio on tensile properties and microstructural characteristics of pulsed current GTA welded AZ31B magnesium alloy.

2. Experimental work

The rolled AZ31B magnesium alloy sheets of 3 mm thickness were cut into the required size (150 × 150 mm) by machining process. The chemical composition and mechanical properties of AZ31B magnesium alloy sheet are presented in Table 1 and 2, respectively. A square butt joint configuration, as shown in Fig. 1, was prepared to fabricate the joints.

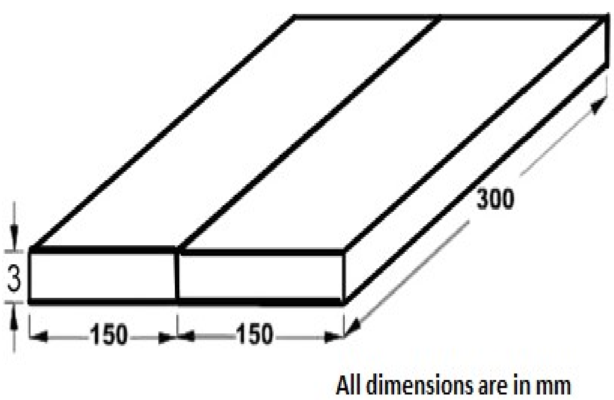


Fig. 1 Joint configuration

Table 1Chemical composition (wt.%) of AZ31B magnesium alloy

Al	Zn	Mn	Ni	Cr	Cu	Mg
2.60	0.67	0.27	0.012	0.008	0.017	Bal

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. A single pass welding procedure was used to fabricate the joints with the pulsed current gas tungsten arc welding machine (Make: Lincoln, USA). Argon gas was used as a shielding gas with a constant flow rate of 20 l/min. Five joints were fabricated using different levels of pulse frequencies. The other parameters such as Current Ratio, pulses on time, welding speed were kept constant.

Table 2 mechanical properties of AZ31B magnesium alloy

0.2 % offset Yield Strength (MPa)	Ultimate tensile strength (MPa)	Reduct ion in cross section area (%)	Notch tensile strength (MPa)	Hardnes s at 0.05kg load (Hv)
160	275	14.3	253	69

Table 3. Effect of welding speed on fusion zone characteristics of the joints

(current ratio (I_p/I_b) = 2.2; Pulse on time = 50%; welding speed = 135 mm/min)

Joint No.	Pulse Frequency (Hz)	0.2% Yield Strength (MPa)	Ultimate tensile strength (MPa)	Joint efficiency (%)
1	2	160	209	76
4	5	165	214	78
5	6	141	181	68

The photographs of fabricated joints are shown in Fig.2

Fig. 2 Photographs of fabricated joints

For the pulsed GTAW process, arc efficiency is taken as 60 % based on the literature [6]. 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 135 mm/min 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).

3. Results and Discussion

The macrostructure of the joints made with different pulse frequency are presented in Fig. 3. At low pulse frequency levels (i.e., 2 Hz), a partial penetration was observed in the welded joints. At higher pulse frequency levels (i.e., 6 Hz), Excess penetration with concave upper bead surface were observed, it is noticed that whenever pulse frequencies increase from lower level to higher level complete penetration was achieved. In order to simplify this work, we developed a linear equation based upon the experimental results, to calculate the pulse frequency for welding of AZ31B magnesium alloy.

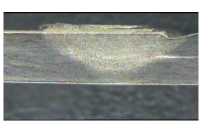
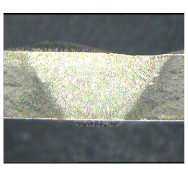
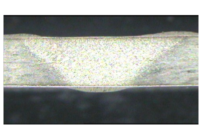
weld speed mm/ min	Cross – sectional macrostructure	Observations
105		Fusion zone width = 9mm Fusion zone depth = 1. mm Remarks = Lack of penetration
135		Fusion zone width = 5 mm Fusion zone depth = 3 mm Remarks = Full penetration
145		Fusion zone width = 8 mm Fusion zone depth = 3 mm Remarks Excess penetration with upper concave surface

Fig. 3. Effect of pulse frequency on bead geometry

From the Fig 4a, it is noticed that whenever pulse frequencies increase from lower level to higher level weld width is increased linearly.

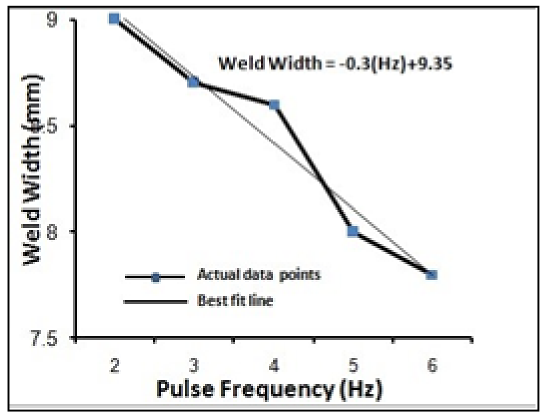


Fig.4a Fusion Zone Profile

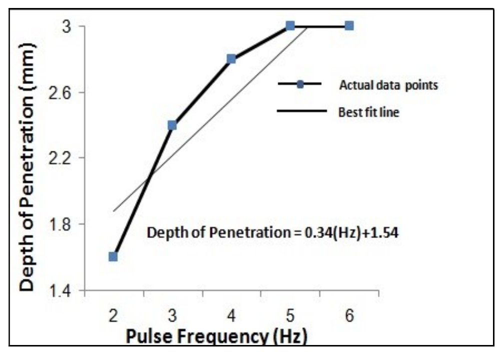


Fig.4b Fusion Zone Profile

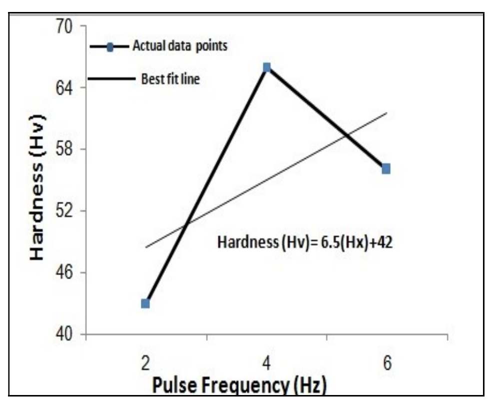


Fig.4c Fusion Zone Profile

From the Fig, 4b and 4c when the pulse frequencies increased from lower level to higher level, hardness increased up to certain level and starts to decreased, but depth of penetration is increased linearly. The reason for this behavior in the weld region is purely based upon the heat input. When the heat input is low improper melting was observed. At a higher heat input over melting higher heat input and slow cooling rate leads to formation of coarser grains. This will reduce the hardness and increases the depth of penetration.

Though, the above represented curves show the trend of input pulse frequencies on weld characteristics, it is important to identify the weld region to set an optimum quality of welding. Fig.4d shows the optimum welding conditions that satisfying all the weld quality characteristics.

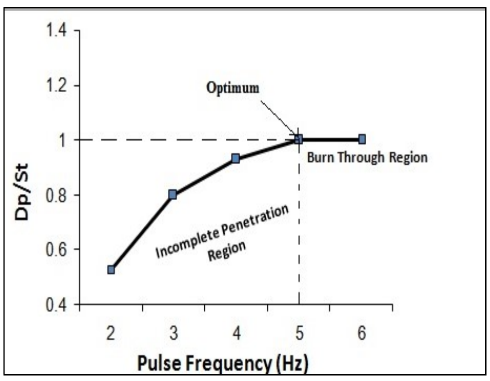


Fig.4d Fusion Zone Characteristics

From these figures one can easily find the optimum conditions to weld to magnesium alloys with proper depth of penetration. It was achieved at pulse frequencies of 5Hz. It is observed that when the pulse frequencies decrease from 5 Hz leads to incomplete penetration of the weld region and increases beyond that region is called excess penetration concave upper bead surface region.

4. Conclusions

From this investigation, the following important conclusions are derived:

i. The pulse frequencies have significant influence on the hardness of fusion zone and subsequently on the tensile properties of PCGTAW joints of AZ31B Magnesium alloy.

ii. Among the five welded joints, the joint fabricated with welding speed of 5 Hz, showed superior tensile properties than their counterparts. The formation of higher hardness in fusion zone, is the main reasons for the superior tensile properties of the above joint.

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