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STUDY 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 peak current to base current ratio (I_p / I_b)on fusion zone characteristics of pulsed current gas tungsten arc welded AZ31B magnesium alloy joints. Five joints were fabricated using different levels of peak current to base current ratio (1.8 – 2.6). From this investigation, it is found that the joints fabricated using a peak current to base current ratio of 2.2 yielded superior tensile properties compared to other joints. The formation of finer grains and higher hardness in fusion zone are the main reasons for the superior tensile properties of these joint

Keywords: *Magnesium alloy, Current Ratio, Tensile properties*

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., (2011) studied the influences of pulsed current parameters on mechanical and metallurgical properties of gas tungsten arc welded AZ31B magnesium alloy. Kishore babu et al., (2012) investigated the influence of alternating current pulsing on the structure and mechanical properties of AZ31 magnesium alloy weldments. Liming Liu et al., (2006) examined the microstructure and fracture of AZ31 magnesium alloy joint welded by automatic gas tungsten-arc filler (GTAF) welding process. Mechanical properties and microstructure of GTA welded magnesium AZ91D plates were examined by Munitz et al., (2001). Reddy et al., (2002) 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

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pulse current parameters is very essential. Hence, the present investigation was carried out to study the effect 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 1a and 1b, respectively. A square butt joint configuration, as shown in Fig. 1, was prepared to fabricate the joints. 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 peak current to base current ratios. The other parameters such as pulse frequency, pulses on time, welding speed were kept constant. The photographs of fabricated joints are shown in Fig.2 Heat input is a very important factor, which affects the bead geometry, mechanical properties and metallurgical properties of weld.

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

Al	Zn	Mn	Ni	Mg
2.60	0.67	0.27	0.012	Bal

Fig 3 (a) Photographs of Fabricated joints

Fig 3 (b) before tensile test

Fig 3 (c) After tensile test

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 mean current is given as:

$$\text{Mean current } I_m = \frac{[I_p \times T_p] + [I_b \times T_b]}{[T_p + T_b]} \qquad (1)$$

Heat input (HI) is calculated using Eq. 2 [6]:

$$\text{Heat Input} = \frac{I \times V \times \eta}{S} \qquad (2)$$

Where

I_p is pulse current, amps
I_b is base current, amps
T_b is base current duration, milli seconds
T_p is pulse current duration, milli seconds
S is welding speed, mm/s
V is mean voltage, volts
η is efficiency of the welding process.

For the pulsed GTAW process, arc efficiency is taken as 60 % based on the literature [7]. 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.

Table 1. (b) Mechanical properties of base metal AZ31B magnesium alloy

Ultimate tensile strength (MPa)	**Notch tensile strength** (MPa)	**Hardness at 0.05kg load** (Hv)
275	253	69

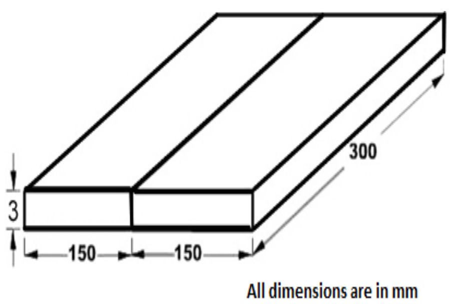

Fig. 1. Joint configuration

3. Results

3.1. Macrostructure

The macrostructure of the joints made with different peak to base current ratios are presented in Fig. 3. At lower heat input levels (i.e., lower peak to base current ratio of less than 2.2), a partial penetration was observed in the welded joints. At higher heat input levels (i.e., higher peak to base current ratio of greater than 2.2), a burn through of the weld and the surface breaking defects were observed. This may be the reason for the lower tensile properties of these joints. The joint fabricated using peak to base current ratio of 2.2 produced a defect free joint with full penetration. This may be due to the supply of required level of heat input (369 J/mm).

I_P/ I_b	**Macrostructure(cross section)**	**Observations**
1.8		FZW - 4 mm FZD -2 mm Partial penetration
2.2		FZW - 5 mm FZD - 3 mm Full penetration
2.6		FZW- 9 mm FZD - 3 mm Burn through With surface breaking

Fig.3 Effect of Ip / Ib on fusion zone macrostructure

3.2. Microstructure

The microstructures of fusion zone of all the joints are displayed in Fig.4. From the micrographs, it is understood that the peak to base current ratio have appreciable influence on average grain diameter of fusion zone region in AZ31B magnesium alloy. The joint fabricated with a peak to base current ratio of 2.2, contains finer grains (30 µm) in the fusion zone compared to other joints. Furthermore, evidence of a large number of precipitated particles is observed in the fusion zone and the concentration of precipitates is moderate. This is also one of the reasons for higher tensile properties of these joints compared to other joints. Coarse grains (45 µm) were observed in the joint fabricated using a peak to base current ratio of 2.6. This may be one of the reasons for the lower tensile properties of these joints.

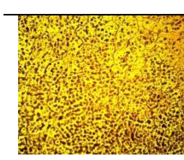	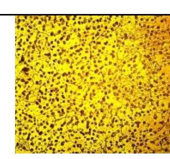	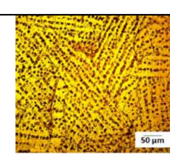
2.0 **Grain Size 24µm**	2.2 **Grain Size 26µm**	2.6 **Grain Size 46µm**

Fig.4 Effect of I_p / I_b on fusion zone microstructure.

4. Discussion

From the Fig. 5 it is noticed that whenever current ratio increases from lower level to higher level heat input is increase linearly. In order to simplify this work we developed a linear equation based upon the experimental results, to calculate the heat input for welding of AZ31B magnesium alloy. This equation is simple and one can easily find the heat input by extrapolating this curve and enables the good quality welding by referring the above depicted diagram, and also it will use the heat input for any condition when current ratio is known.

From the Fig. 5 and 6, the following welding characteristics can be inferred. Wherever, when

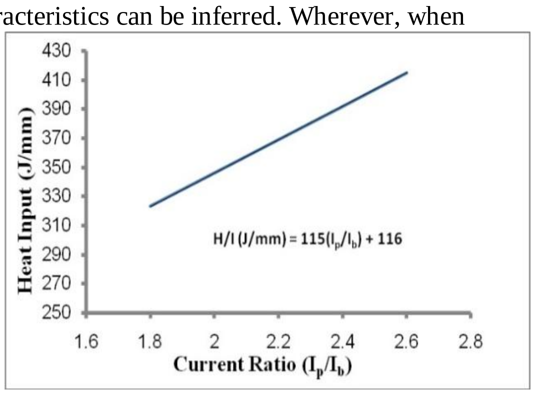

Fig. 5 Interaction plot between current and heat input.

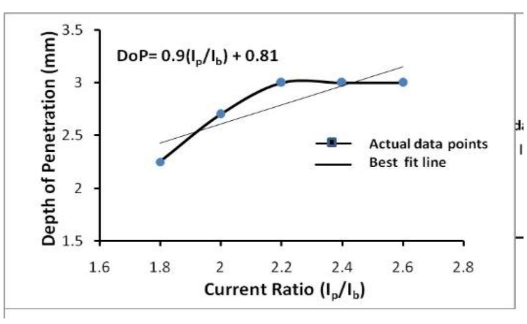

Fig. 6 Interaction plot between current and depth of pentration.

It is inferred from the evaporation of Zn from the weld region is purely dependent on the heat input supplied to the weld region. Higher the input current promotes the Zn evaporation previous studies also confirm this kind of evaporation in the magnesium alloys. From the Fig. 8, it is observed that increasing current ratio increases the fusion zone area..

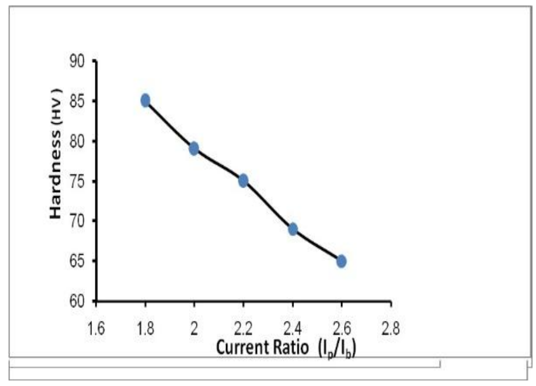

Fig. 7 A graphical plot between current and hardness.

However increasing fusion zone in the welding leads to reduction of the current ratio increased from lower level to higher level, hardness also increased up to certain level and starts to decreased, but depth of penetration is maintained at constant level.

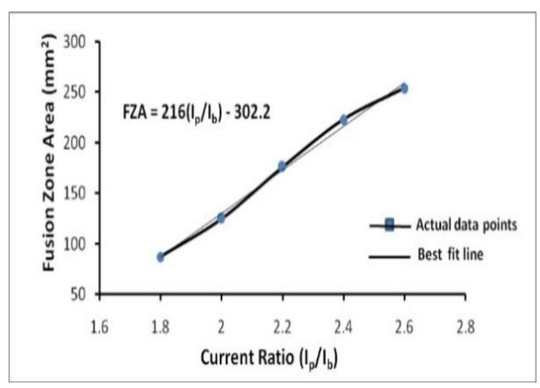

Fig. 8 Interaction plot between current and fusion zone area.

The reason for this behaviour 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. Tensile properties changes due to the larger heat affected zone in the weld region.

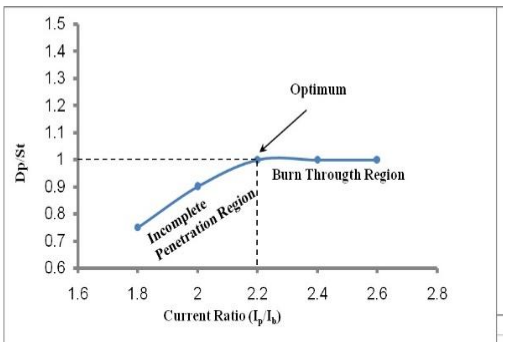

Fig. 9 Interaction plot between current and depth of pentration.

Though, the above represented curves show the trend of input current ratio on weld characteristics, it is important to identify the weld region to set an optimum quality of welding. Fig. 9 shows the optimum welding conditions that satisfying all the weld quality characteristics. From this Fig. 9 one can easily find the optimum conditions to weld to magnesium alloys with proper depth of penetration. And it was achieved at ratio of 2.2. It is observed that when the current ratio decrease from 2.2 leads to incomplete penetration of the weld region and increases beyond that region is called burn through region.

5. Conclusions

Of the five welded joints, A heat input level of 370 J/mm is found to be optimum for joining 3 mm thick rolled sheets of AZ31B Magnesium alloy. This optimum level of heat input is achieved when the Ip/Ib ratio is maintained at 2.2.

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