Journal of Manufacturing Engineering, December 2019, Vol. 14, Issue. 4, pp 139-143

INVESTIGATION OF WELDING SPEED ON FUSION ZONE CHARACTERISTICS OF GTA WELDED AZ31B MAGNESIUM ALLOY JOINTS

https://doi.org/10.37255/jme.v4i4pp139-143

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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., [7] studied the influences of pulsed current parameters on mechanical and metallurgical properties of gas tungsten arc welded AZ31B magnesium 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 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.

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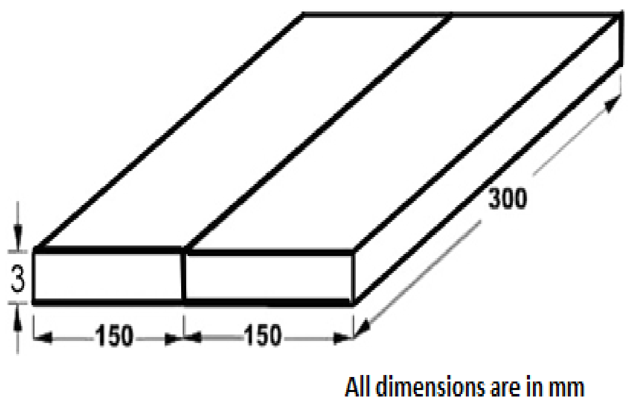


Fig. 1 Joint configuration

Table 1. Effect of welding speed on fusion zone characteristics

Joint No.	Welding speed (mm/min)	Heat Input (J/mm)	0.2% Yield Strength (MPa)	Ultimate tensile strength (MPa)	Joint efficiency (%)
1	105	415	143	183	66
4	135	369	165	214	78
5	145	323	189	193	70

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/mi. 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

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 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 of2.25 mm/s was used in this investigation. A Vickers'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 welding speeds are presented in Fig. 3. At low heat input levels (i.e., welding speeds of greater than 135 mm/min), a partial penetration was observed in the welded joints. At higher heat input levels (i.e., welding speeds of less than 135 mm/min), a burn through of the weld and the surface breaking defects were observed, it is noticed that whenever welding speeds increases from lower level to higher level heat input is decreases 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.

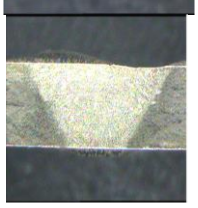
weld speed mm/min	Cross – sectional macrostructure	Observations
105		Fusion zone width = 9mm Fusion zone depth = 3 mm Remarks = = Burn through with surface breaking
135		Fusion zone width = 5 mm Fusion zone depth = 3 mm Remarks = Full penetration
145		Fusion zone width = 4 mm Fusion zone depth = 1.5 mm Remarks Lack of penetration

Fig. 3 Effect of welding speed on bead geometry

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 pulsed current is known.

From the Fig 4b and 5b, it is noticed that whenever welding speed increases from lower level to higher level heat input is decrease linearly.

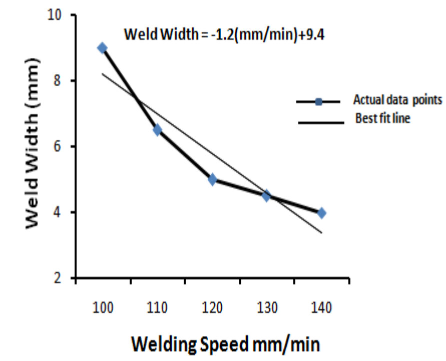


Fig. 4a Fusion Zone Profile

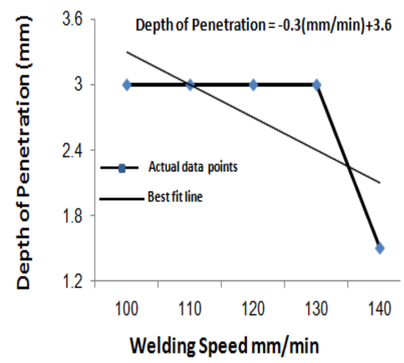


Fig. 4b Fusion Zone Profile

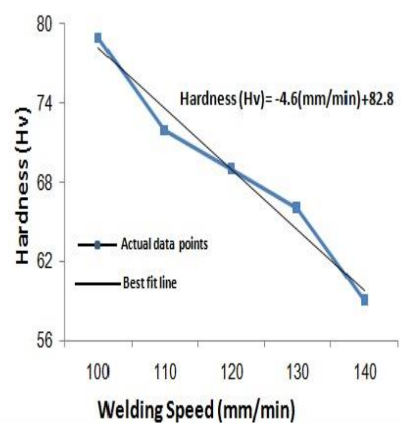


Fig. 4c Fusion Zone Profile

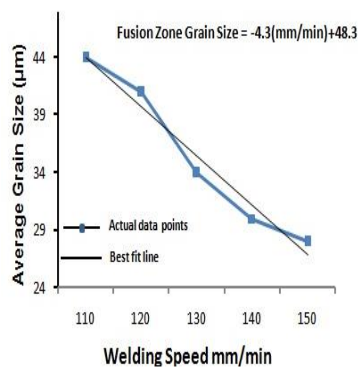


Fig. 4d Fusion Zone Profile

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 welding speed is known.

From the Fig. 5a, 5c and 5d when the welding speeding increased from lower level to higher level, hardness decreased linearly up to certain level and starts to increased, but depth of penetration is maintained at constant level. 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.

In the case of grain size (Fig. 5a) decreasing welding speed starts to decrease the grain size then gradually increases. However, increasing welding speed from lower level to higher level up to an optimum level, weld region grain size starts increasing and then decreased linearly due to formation of coarser grains.

Though, the above represented curves show the trend of input welding speed on weld characteristics, it is important to identify the weld region to set an optimum quality of welding. Fig.5b shows the optimum welding conditions that satisfying all the weld quality characteristics.

From this figure one can easily find the optimum conditions to weld to magnesium alloys with proper depth of penetration. It was achieved at welding speed of 135 mm/min. It is observed that when the welding speed increase from 135 mm/min leads to incomplete penetration of the weld region and increases beyond that region is called burn through region.

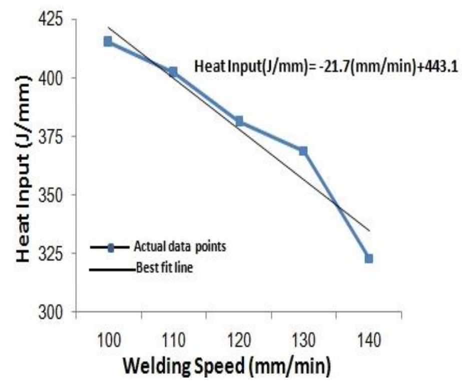


Fig. 5a Fusion Zone Characteristics

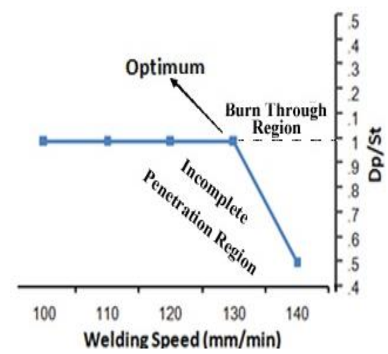


Fig. 5b Fusion Zone Characteristics

4. Conclusions

From this investigation, the following important conclusions are derived:

The welding speed has significant influence on the grain size and hardness of fusion zone and subsequently on the tensile properties of PCGTAW joints of AZ31B Magnesium alloy.

Of the five welded joints, the joint fabricated with welding speed of 135 mm/min, showed superior tensile properties than their counterparts. The formation of finer grains in the fusion zone, higher hardness in fusion zone, is the main reasons for the superior tensile properties of the above joint.

Acknowledgments

The authors wish to place their sincere thanks to University Grant commission (UGC), New Delhi for financial support rendered through Major Research Project No: 39-864/2010.

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