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Effect of welding speed on microstructural characteristics and tensile properties of GTA welded AZ31B magnesium alloy

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Abstract: The effect of welding speed on tensile and microstructural characteristics of pulsed current gas tungsten arc welded (PCGTAW) AZ31B magnesium alloy joints was studied. Five joints were fabricated using different levels of welding speeds (105−145 mm/min). It was found that the joints fabricated using a welding speed of 135 mm/min yielded superior tensile properties compared to other joints. The formation of fine grains and uniformly distributed precipitates in the fusion zone are the main reasons for the superior tensile properties of these joints.

Key words: AZ31B magnesium alloy; GTA welding; welding speed; tensile properties; microstructure

1 Introduction

Magnesium alloys exhibit the attractive combination of low density and high specific strength (comparable or greater than that of precipitation strengthened Al alloys), along with good damping capacity, castability, weldability, and machinability. Of the various commercial magnesium alloys, those developed from the Al−Zn ternary system (i.e. the as-named AZ alloys) have found the largest number of industrial applications [1,2]. These applications include automotive, industrial, materials handling and aerospace equipment where lightweight materials are needed [3,4]. Presently, gas tungsten arc (GTA) welding process is one of the most well established processes for reactive materials like magnesium alloy due to its comparatively easier applicability and better economy of industrial use, but it also produces the best quality welds amongst the arc welding processes [5,6]. 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. The welding speed is an important parameter in GTA welding, which is used to achieve maximum penetration without excessive heat build-up, and produces a greater extent of constitutional supercooling at the solidification front and this in turn helps heterogeneous nucleation, which is responsible for grain refining in the welds [7,8].

Recently, few studies have been carried out to evaluate the tensile properties and metallurgical properties of gas tungsten arc welded magnesium alloys. PADMANABAN and BALASUBRMANIAN [9] studied the influences of welding processes on microstructure, hardness, and tensile properties of AZ31B magnesium alloy. They successfully joined AZ31B magnesium alloy by gas tungsten arc welding process, without any macro level defects. DONG et al [10] studied the microstructure and mechanical properties of AZ31B magnesium alloy gas metal arc weld, and they suggested that the tensile strength of the magnesium joints was close to or even higher than that of the base metal despite the existence of pores in the weld. They also argued that the microhardness in the weld was higher than that of the base metal due to the second phase strengthening effect of the β-$Mg_{17}(Al,Zn)_{12}$ phases formed in the weld. LIU and DONG [11] examined the microstructure and fracture of AZ31 magnesium alloy joint welded by automatic gas tungsten-arc filler (GTAF) welding process. In their study, the microstructure of gas tungsten-arc welded joint (without filler wire) revealed a HAZ with coarse grains. Because of the coarse grains in

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HAZ, GTA welded joint always leads to fracture in HAZ during tensile test.

MUNITZ et al [12] investigated the mechanical properties and microstructure of gas tungsten arc welded magnesium AZ91D plates. They suggested that backing plates need to be used to prevent melt flow from the weld pool through the molten grain boundaries and might reduce the HAZ. Available literatures are mainly focused on evaluating mechanical and metallurgical properties of PCGTA welded magnesium alloys. However, very little information is available on the effect of welding speed on mechanical and metallurgical properties of GTA welded AZ31B magnesium alloy. Since welding speed has significant influence on fusion zone microstructure and related mechanical properties, understanding the effect of welding speed is very essential. Hence, the present investigation is carried out to study the effect of welding speed on tensile properties and microstructural characteristics of pulsed current GTA welded AZ31B magnesium alloy.

2 Experimental

The rolled AZ31B magnesium alloy plates with a thickness of 3 mm were cut into the required size (150 mm × 150 mm) by machining process. The chemical composition and mechanical properties of AZ31B magnesium alloy sheet are presented in Tables 1 and 2, 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 welding speed. The other parameters such as peak current to base current ratio, pulse frequency, pulse on time 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 the weld. Hence, heat input was also calculated and included in this 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 I_m [9] is given as

Table 1 Chemical composition of AZ31B magnesium alloy (mass fraction, %)

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

Table 2 Mechanical properties of AZ31B magnesium alloy

Property	Value
0.2% offset yield strength/MPa	160
Ultimate tensile strength/MPa	275
Elongation in 50 mm gauge length/%	14.7
Reduction in cross section area/%	14.3
Notch tensile strength/MPa	253
Notch strength ratio (NSR)	0.92
$HV_{0.49N}$	69

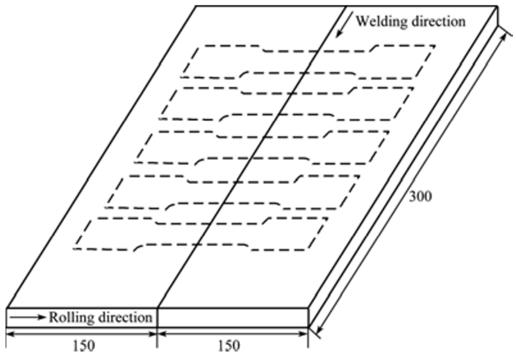

Fig. 1 Joint configuration and scheme of extraction (unit: mm)

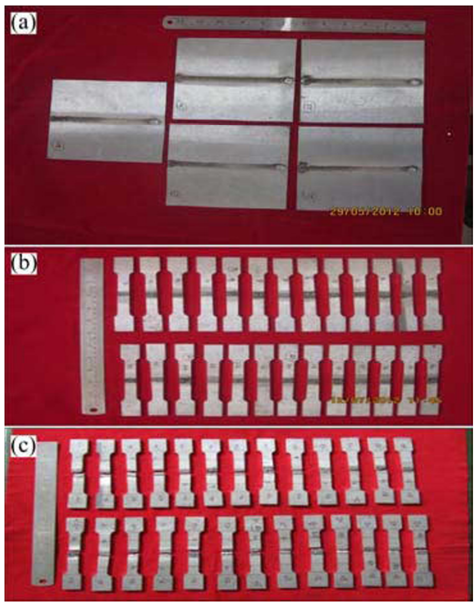

Fig. 2 Photographs of welded joints and tensile specimen: (a) Fabricated joints; (b) Tensile specimens before tensile test; (c) Tensile specimens after tensile test

$$I_m=(I_p \times t_p+I_b \times t_b)/(t_p+t_b) \quad (1)$$

Heat input (Q) is calculated using [10]

$$Q=(I_m \times V \times \eta)/S \quad (2)$$

where I_p is the pulse current, A; I_b is the base current, A;