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EFFECT OF CONSTANT AND PULSED CURRENT GAS TUNGSTEN ARC WELDING ON TENSILE PROPERTIES AND MICRO STRUCTURAL CHARACTERISTICS OF AZ31B MAGNESIUM ALLOY

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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. Gas tungsten arc welding (GTAW) is widely used material joining process, especially used to weld the non ferrous metals such as magnesium. Hence, in this investigation it is planned to study the effect of constant and pulsed current welding on tensile and microstructure properties of AZ31B magnesium alloy. From this investigation, it is found that the joints fabricated with pulsed current having the superior tensile properties compared to constant current welding.

Keywords: *Magnesium alloy; GTA welding; Tensile properties; Microstructure.*

1. Introduction

Today, decreasing weight in ground vehicles and aircraft is considered one of the most effective approaches to improve fuel economy and reduce anthropogenic environment-damaging emissions [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]. Most magnesium alloys are readily weldable using gas tungsten arc (GTA), gas metal arc (GMA), electron beam, laser beam welding processes [3]. However, there is no information available on the effect of constant and pulsed current welding of Keeping this in mind, an investigation has been carried out to study the effect of constant and pulsed current welding processes on tensile and microstructure properties of AZ31B magnesium alloy joints, and the results are revealed in this article.

2. Experimental Work

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

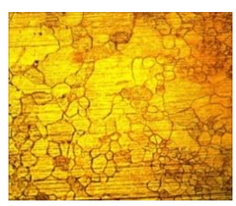

Fig. 1. Microstructure of Base metal

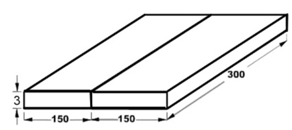

Fig. 2. Joint configuration

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

Al	2.60
Ni	0.01
Zn	0.67
C	0.008
Mn	0.27
Mg	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. Square butt joints were fabricated using autogenous arc welding processes (without filler metal), such as, constant current gas tungsten arc welding (CCGTAW) and pulsed current

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gas tungsten arc welding (PCGTAW). Argon gas was used as a shielding gas with a constant flow rate of 20 l/min. The process parameters used to fabricate the joints are presented in Table.2.

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

Yield Strength (MPa)	160
Ultimate tensile strength (MPa)	275
Elongation in gauge length of 50mm(%)	14.7
Reduction in cross section area (%)	14.3
Notch tensile strength (MPa)	253
Notch strength ratio (NSR)	0.92
Hardness at 0.05kg load (Hv)	69

Table.2. Process parameters used for GTA Welding.

Sl No	Parameters	CCGTAW	PCGTAW
1.	Peak current (A)	80	110
2.	Base current (A)	-	50
3.	Pulse Frequency (Hz)	-	5
4.	Pulse on Time (%)	-	50
5.	Voltage (V)	18	19
6.	Welding Speed (mm/min)	125	135

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 table.3. this study. The heat input per unit length is proportional to voltage and current and inversely proportional to the welding speed.

Heat input (HI) is calculated using Eq. 1 [10]:

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

Where
I Arc current, amps
V mean voltage, V
S welding speed, mm/s
η efficiency of the welding process

The welded joints were sliced and then machined to the required dimensions according to the ASTM E8M-04 standard for sheet type material (i.e., 50 mm gauge length and 12.5 mm gauge width). Two different tensile specimens were prepared to evaluate the transverse tensile properties of the welded joints. The smooth (unnotched) tensile specimens were prepared to evaluate yield strength, tensile strength and elongation of the joints. The notched specimens were prepared to evaluate notch tensile strength and the notch strength ratio of the weld. The tensile test was carried out in a 100 kN, electro mechanical controlled universal testing machine (Make: FIE-Bluestar, India; Model: UNITEK-94100). The 0.2 % offset yield strength was derived from the load-displacement diagram. The percentage of elongation was also evaluated and the values are presented in Tables 2. The photographs of GTA welded joints and tensile specimens are shown in Fig.3. The photographs of tensile specimensare shown in Fig.4.

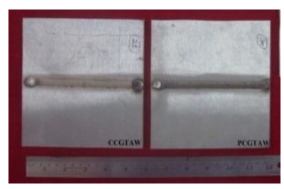


Fig.3. Photograph of GTA Welds

Fig.4. Photograph of Tensile specimens

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 image analyzing software (Metal Vision).

3. Results

3.1 Tensile properties

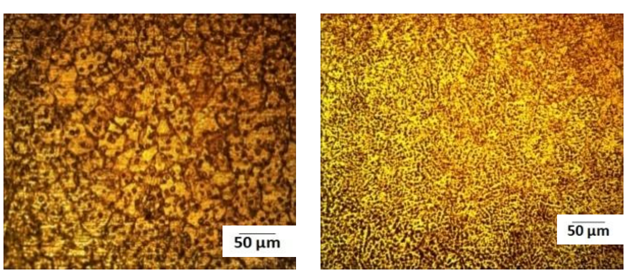
The transverse tensile properties such as yield strength, tensile strength, percentage of elongation, percentage of reduction in cross-sectional area, notch tensile strength, notch strength ratio and joint efficiency of the constant current and pulsed current welded AZ31B magnesium alloy joints were evaluated. In each condition, three specimens were tested and the average of three results are presented in Table 2. Of the two joints fabricated, the joint fabricated with a PCGTA welding yielded superior tensile properties compared to CCGTA welding.

Table2. Transverse tensile properties of welded joints

Process	CCGTAW	PCGTAW
Heat Input (J/mm)	423	369
Yield strength (MPa)	156	165
Ultimate tensile Strength (MPa)	192	214
Elongation in gauge length of 50mm(%)	4.7	7.2
Notch tensile Strength (MPa)	148	167
Notch strength Ratio (NSR)	0.75	0.72
Joint efficiency (%)	70	78

3.2 Microstructure

The optical micrographs of CCGTAW and PCGTAW are presented in Fig. 5. From the micrographs, it is understood that there is an appreciable difference in grain size (average grain diameter) in the weld metal regions. Hence, an attempt has been made to measure the average grain diameter in the fusion zone of all the joints were taken by image analyzing software. The measured average grain diameter of CCGTAW joints is 42 μm, but the average grain diameter of PCGTAW joints is 30 μm. This indicates that the reduction in grain diameter is 12 μm due to the pulsed current welding process. Of the two techniques, the PCGTAW process produces fine grains in the weld metal region compared with the CCGTAW.



CCGTAW **PCGTAW**

Fig.5. Fusion zone microstructures of GTA welds

3.3 Microhardness

Microhardness survey was done across the weld direction from weld centre to base metal. The regions of base metal, heat affected zone and fusion zone, marked on Fig.8 were identified based on changes in microstructure. The fusion zone hardness of the CCGTAW and PCGTAW joint is 61 Hv and 65 Hv, respectively. However, the hardness of the PCGTAW joints in the weld metal region is higher compared to the CCGTAW joints.

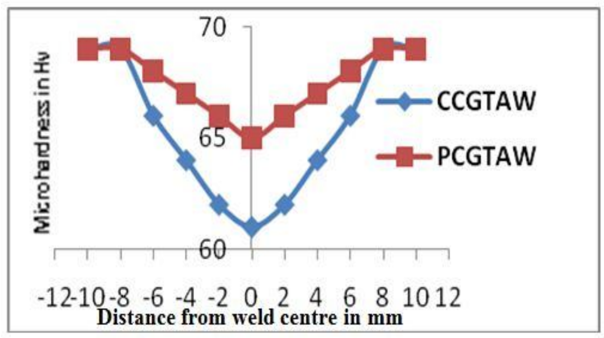


Fig.6. Fusion zone microharnness of GTA welds

4. Discussion

In autogenous arc welds, the CCGTAW process produces coarser grains compared to PCGTAW processes. The heat input supplied by the CCGTAW process is relatively higher than that supplied by the PCGTAW processes. 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 PCGTAW process is a variation of the GTAW process, which involves cycling of the welding current from a high level to a low level at a selected regular frequency. The high level of the peak current is generally selected to give adequate penetration and bead contour, where as the low level of the back ground current is set at a level sufficient to maintain a stable arc [7]. In contrast to constant current welding, the fact that the heat energy required to melt the base material is supplied only during peak current pulses for brief intervals of time allows the heat to dissipate into the base material [8]. The microstructure of the weld centre reveals coarse grains in the constant current weld while in the pulsed current process the grains are fine, the dendrite spacing in the constant current is wider but the pulsed current process reveals narrower spacing. It is also seen that the area of grain boundary is much less in the constant current process compared with the pulsed current process. The effect of faster cooling rate is seen in the microstructure of the pulsed current specimen with domination of smaller grains. The morphology of the constant current one predominates with the columnar grain structure due to the lower cooling rate (due to higher peak current). Due to lower heat input supplied by the PCGTAW produces finer grains in the fusion zone which leads to higher tensile properties of the welded joint compared with CCGTAW [9].

Hardness surveys revealed that the joint made with CCGTAW and PCGTA welding resulted in reduction of hardness in the fusion zone, the heat supplied by the CCGTAW process higher, which leads to slower cooling of the weld metal and results in coarser grains and PCGTAW welds were found to have better hardness (65VHN) compared to those made on CCGTAW joints [10].

5. Conclusions

The effect of autogeneous arc welding processes on tensile properties compared to CCGTAW Joints of magnesium alloy joints was investigated. From this investigation, the important conclusions are as follows:

1) Of the two welded joints, the joints fabricated by PCGTAW exhibited higher.
2) The lower heat input, finer fusion zone grain size, and higher fusion zone hardness are the reasons for superior tensile properties of PCGTAW joints compared to CCGTAW joints.

Acknowledgments

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