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Structure of MMCs with SiC Particles after Gas-tungsten Arc Welding

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Abstract

The gas-tungsten arc (GTA) welding behaviors of a magnesium matrix composite reinforced with SiC particles were examined in terms of microstructure characteristics and process efficiencies. This study focused on the effects of the GTAW process parameters (like welding current in the range of 100/200 A) on the size of the fusion zone (FZ). The analyses revealed the strong influence of the GTA welding process on the width and depth of the fusion zone and also on the refinement of the microstructure in the fusion zone. Additionally, the results of dendrite arm size (DAS) measurements were presented.

Keywords: Composite, Gas-tungsten arc welding, Mg-Al-Mn alloy, SiC particles, Microstructure

1. Introduction

Magnesium-based metal matrix composites (MMCs) because of their low density and higher mechanical properties by the addition of reinforcements are attractive materials in the aerospace and automobile industries. Ceramic particles (like BN, SiC, TiC, Al_2O_3) are the most widely studied reinforcing materials for magnesium matrix composites, especially for use in grinding and polishing applications because of the high levels of hardness, strength and thermal stability. SiC particles compared to other ceramics are characterized by good wettability and stability in magnesium melt [1-6]. Casting methods are the most frequently used routes for the production of particulate reinforced magnesium-based composites [7].

One of the ways to improve the properties of casts is the treatment of the surface using a concentrated heat flux like laser or electron-beam or gas-tungsten arc (GTA) welding, which is the most economical [8-11]. The influence of gas tungsten arc welding on the structure of magnesium alloys has been widely investigated [12-17]. Recently, the welding technology of magnesium matrix composite has been the subject of studies [18-21]. However, these surface-modified processes were used to fabricate a composite layer on the surface of magnesium alloys. In the present work, the influence of the gas tungsten arc welding process on a magnesium matrix composite reinforced with an SiC_p microstructure was investigated.

2. Experimental procedures

The commercial AM50 magnesium alloy fabricated by Hydro Magnesium Ltd., with the nominal composition given in Table 1 was chosen as the matrix alloy in this study. SiC particles with an average diameter of 50 μm with the chemical composition listed in Table 2 were chosen as the reinforcement.

The experimental composite was fabricated by a casting method involving introducing 20 vol.% SiC particles to the molten magnesium alloy under the argon atmosphere and gravity casting the prepared composite suspension into a metal mould.

Table 1.
Chemical composition of AM50 alloy according to standard ASTM B93-94

Chemical composition [wt.%]*)						
Alloy	**Al**	**Mn**	**Zn**	**Si**	**Fe**	**Cu**
AM50	4.5÷5.3	0.28÷0.5	max 0.02	max 0.05	max 0.004	max 0.008

*) Mg rest

Table 2.
Chemical composition of reinforced particles – SiC according to manufacturer certificate, 98C no 240

SiC	**$Si+SiO_2$**	**$Al_2O_3+CaO+MnO_2$**	**$C_{(graphite)}$**	**Fe_2O_3**
95.90	2.80	0.50	0.42	0.38

The prepared composites were used as the starting material for the gas-tungsten arc (GTA) welding process. The GTAW method which was described in [6], was conducted by using a Falting 315 AC/DC instrument. In accordance with the DIN Standard a set of tungsten electrodes with a diameter of 2.4 mm was used. As the shielding gas helium with a flow rate of 20 l/min was applied. The GTAW process parameters were as follows: voltage (U) 12-15 V, current (I) 100 and 200 A, welding speed of electric arc (v) 13.3 mm/s.

The samples for microstructure examinations were prepared perpendicular to the direction of welding by standard metallographic procedures. The specimens were etched in a solution of 1% nitric acid in alcohol. Microstructural examinations of the fabricated composites after the GTA welding process were carried out by means of light microscopy (LM) – Axiovert 25 (Carl-Zeiss Jena) and a scanning electron microscope (SEM) – Phenom ProX (Phenom-World). In order to determine the influence of the GTAW process on microstructure changes, the dendrite arm size (DAS) of the base material and the fusion zone was obtained using the linear method as a quotient of the mean distance between the dendrite cross-section centers by the numbers of arms. Results were obtained from about 50 measurements for each sample.

3. Results

Fig 1 shows a typical as-cast microstructure of the fabricated AM50-SiC_p composite which is characterized by uniform distribution of the SiC particles within the matrix. The matrix has a dendritic structure typical for magnesium alloys, which is comprised mainly of an α solid solution of the alloying elements in magnesium and divorced eutectic α+γ in the interdentritic spaces (where γ is the $Mg_{17}Al_{12}$ intermetallic compound).

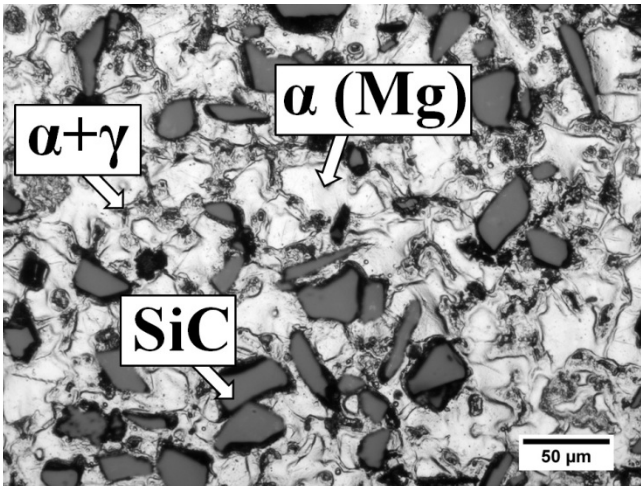

Fig. 1. Microstructure of as-cast AM50-SiC_p composite

The values of the depth and width of the fusion zone obtained using different welding current are presented in Table 3. As might be expected, raising the welding current causes changes in fusion zone geometry. When the welding current is raised from 100 A to 200 A. Both the depth and the width of the fusion zone increase.

Table 3.
Applied GTAW parameters with obtained results of width and depth of FZ

Welding current, I [A]	Welding speed, v [mm/s]	Width of FZ [mm]	Depth of FZ [mm]
100	13.3	5.78	1.11
200	13.3	9.92	2.58

The microstructure of the composite after the gas-tungsten arc welding process is presented in Fig. 2. The fusion zone is clearly visible. It should be noted that the GTAW process did not have an influence on the silicon carbide particle distribution. The reinforced particles were uniformly distributed within the matrix alloy (in the fusion zone). No sedimentation or flotation phenomena were observed. As should be expected, significant refinement of the matrix microstructure in the fusion zone was obtained. For the base materials the DAS parameter was equal to 90.95±33, whereas for the fusion zone it was only 8.85±4 (at a welding current of 200 A) and 8.56±4 (at a welding current of 100 A). It is well known that the DAS parameter depends on the solidification conditions, especially the cooling rate. In the presented cases, the differences in the cooling rate between the used GTAW parameters were too small to exert an influence on DAS.

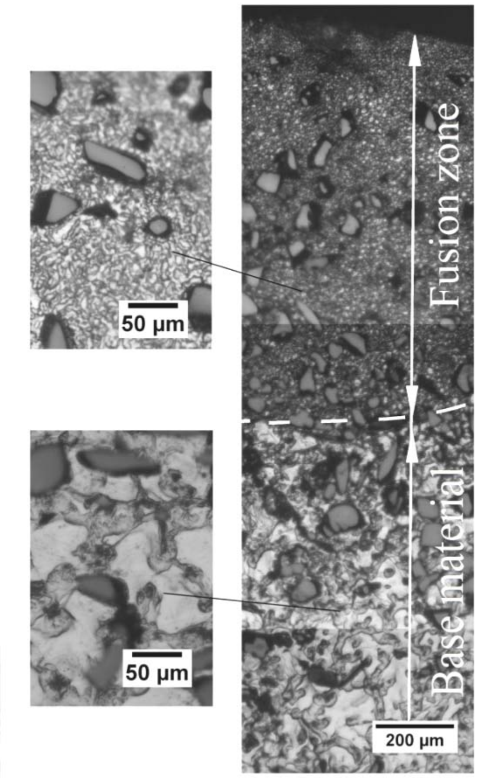

Fig. 2. Microstructure of AM50-SiC_p composite after GTAW at 100 A current and 13.3 mm/s welding speed

Figs. 3 and 4 show SEM images of the investigated materials. No changes in the morphology of the boundary between the components after the GTAW process were observed. In Figure 4, detailed microphotographs of the microstructure changes in the area from the fusion zone to the base material are presented. It should be noted that no damage of the reinforcing material that could result from exposure to high temperatures during the GTAW process or the conditions of rapid cooling (thermal shock) was observed either.

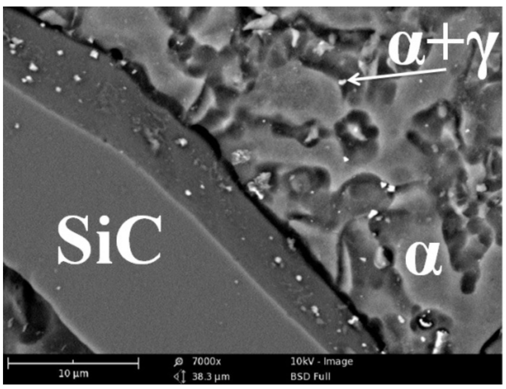

Fig. 3. Separation boundary between the particle and the matrix in fusion zone after GTA welding of AM50-SiC_p composite at 13.3 mm/s welding speed and 200 A current, SEM

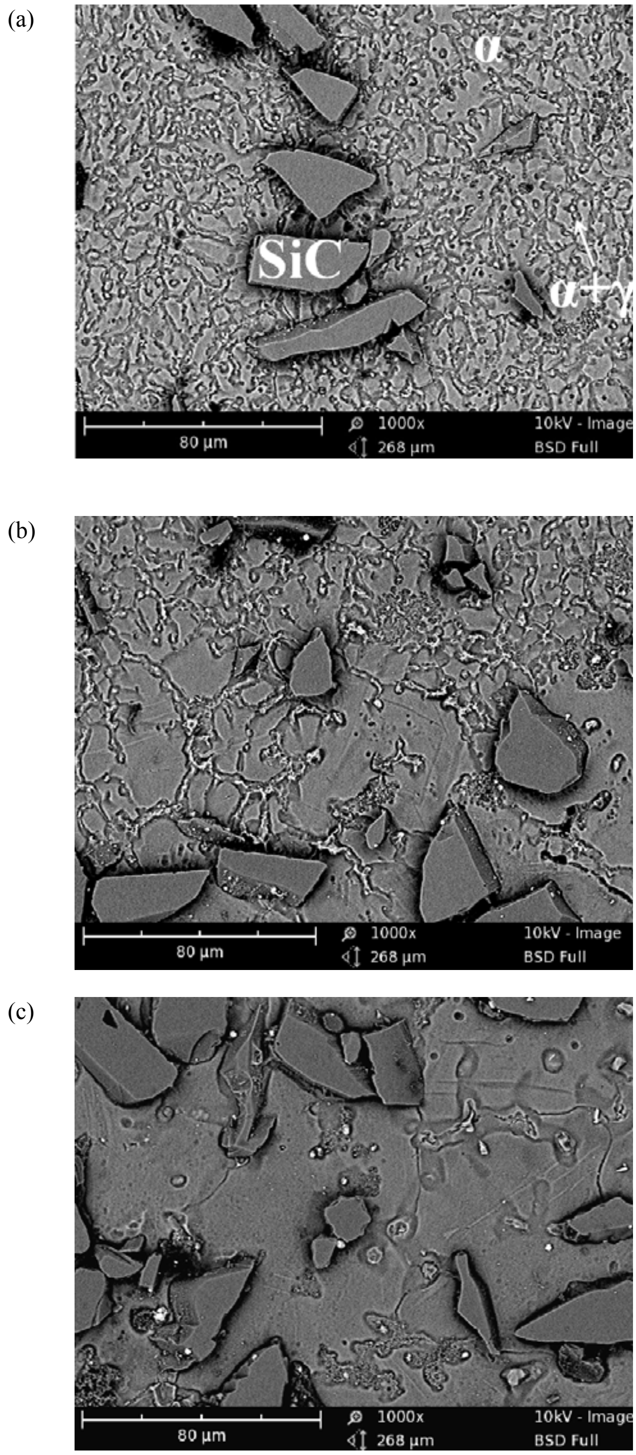

Fig. 4. Microstructure of fusion zone (a), boundary of fusion zone (b) and base material (c) after GTA welding of AM50-SiC_p composite at 13.3 mm/s welding speed and 200 A current, SEM

4. Summary

The presented results indicate the feasibility of using the GTAW process to modify the surface layer structure of the metal-ceramic particle composite which causes refinement of the matrix structure. No unfavorable influence of the GTAW process on the distribution, size or morphology of the reinforcement particles or on the boundary between the components was observed. Furthermore, no damage of the SiC particles that could result from exposure to high temperatures during the GTAW process or the conditions of rapid cooling (thermal shock) was observed.

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