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Effect of high temperature annealing and subsequent hot rolling on microstructural evolution at the bond-interface of Al/Mg/Al alloy laminated composites

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ABSTRACT

Using a two-pass hot rolling process, Al(5052)/Mg(AZ31)/Al(5052) alloy laminated composite plates were fabricated. The first pass was performed at relatively low temperatures, and the second pass was performed at higher temperatures. No new phases formed at the bond interface after the first hot rolling pass. High temperature annealing with the annealing temperature at or above 300 °C caused the formation of continuous layers of the intermetallics Mg17Al12 and Al3Mg2 at the bond interface of Al(5052)/Mg(AZ31). The growth rate of the intermetallic layers increased with increasing the annealing temperature, while the incubation time decreased with increasing the temperature. A kinetic equation was developed to describe the growth of the intermetallic compound layers. The second hot rolling pass caused the break of the continuous intermetallic layers into fragments, which were intermittently dispersed at the bond interface.

1. Introduction

Magnesium and magnesium alloys have great potential in the applications of aerospace, automotives and electronics [1–5] due to low density, high specific strength, excellent castability, damping ability, and ease in machining [2,6]. However, the poor corrosion resistance of magnesium has limited the practical applications of magnesium alloys [6–8]. It is known that aluminum and aluminum alloys have better corrosion resistance and are extensively used as lightweight materials [5]. One expects that Al–Mg composite plates formed by coating or cladding magnesium alloys with aluminum alloys can limit the corrosion of the magnesium alloys and improve the corrosion resistance of the composite plates.

Recently, researches have been made to coat magnesium alloys with aluminum or aluminum alloys. Aluminum-rich coatings were obtained on pure magnesium via the vacuum pack treatment [9] and on magnesium alloy AZ31 via cold spray method [10]. Various techniques of fabricating Al/Mg alloy composite plates have been developed, such as hot

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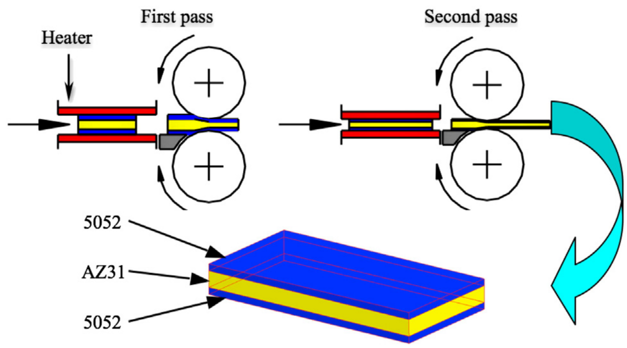

Fig. 1 – Schematic diagram for the hot rolling of the Al/Mg/Al alloy laminated composites.

pressing [11,12], explosive welding [13], hot rolling [14,15] and twin-roll casting [16]. For the rolling processing, a large reduction in thickness is needed to bond a magnesium alloy plate and an aluminum alloy plate by rolling, which results in plastic deformation. The limited ductility of most magnesium alloys has made it difficult to fabricate Al/Mg composite plates at room temperature. An exception is the laminated composite of Mg–Li alloy/Al plates, which can be fabricated by rolling at room temperature due to good ductility of the Mg–Li alloy [17]. Therefore, hot rolling has been used to form Al/Mg alloy composite plates at temperatures above 400 °C. Zhang et al. [15] used the rolling process to bond magnesium and aluminum alloy plates at 400 °C, 450 °C, 465 °C and 475 °C. It is known that a clean surface on the base metal plate is preferred in order to form a strong bond after hot rolling. Thus, it is desirable to perform the rolling at low temperatures to ensure clean surfaces and to achieve a strong bond with the aluminum plate.

Here, a two-pass hot rolling process is proposed for fabricating Al/Mg alloy composite plates. The first pass is performed at low temperatures, and the second pass is performed at high temperatures. The first pass is to form a

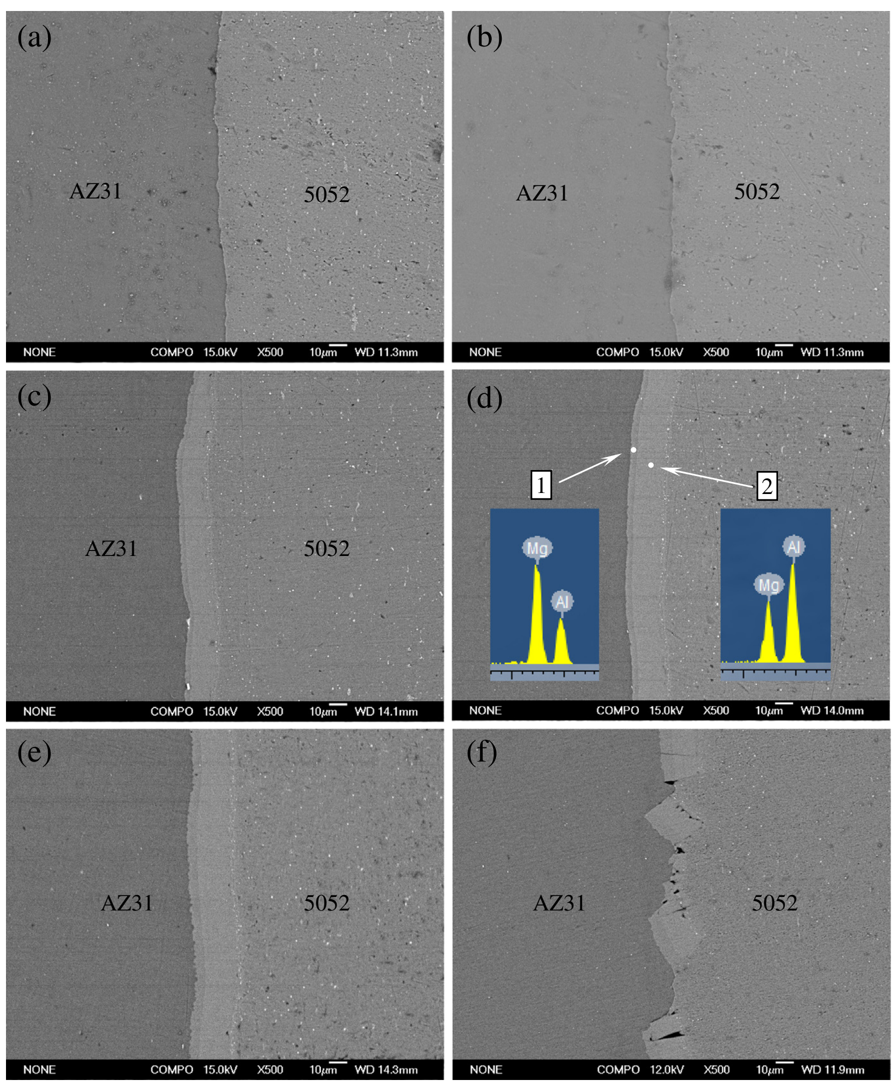

Fig. 2 – Cross-sectional images of the bond interfaces at different states. (a) After first rolling pass, transverse direction; (b) after first rolling pass, rolling direction; (c) after annealing at 400 °C for 10 min, transverse direction; (d) after annealing at 400 °C for 10 min, rolling direction. EDS results from dot 1: Mg—59.07%, Al—40.93%; EDS results from dot 2: Mg—39.95%, Al—60.05%. (e) After second rolling pass, transverse direction; (f) after second rolling pass, rolling direction.