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A novel weld-bonding hybrid process for joining Mg alloy and Al alloy

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ABSTRACT

A novel weld-bonding hybrid process is carried out to join Mg alloy and Al alloy, and the technology combines a modified metal inert gas (MIG) spot welding process with adhesive bonding. The Mg base metal and the fusion zone are metallurgical connected by an Al–Mg transition layer with the thickness of 30–60 μm. Single nugget of spot welded joint can offer high shear strength of 130 MPa, which reach 81% of that of Mg base metal. The increased strength is due to the intermetallic layer being formed at the region with low stress, so the joint fractures in an Al-rich dendritic region. Superior mechanical properties can be obtained by weld bonded joint, benefiting from the advantages of both welding and adhesive bonding.

1. Introduction

As the potential structural and mechanical application materials, magnesium alloys have been welded by many welding technologies, such as laser welding [1], TIG welding [2], friction stir welding [3], electron beam welding [4] and laser-TIG welding [5,6]. Aluminum alloys have been widely used in the ground transportation and aerospace industries. Therefore, the issue of joining Mg alloys and Al alloys cannot be avoided if these alloys are applied in the same structures.

The main problem of fusion welding Mg and Al is that the very brittle intermetallic compounds of $Mg_{17}Al_{12}$ and Mg_2Al_3 are formed in the fusion zone and they can lead to unacceptable mechanical properties. As reported, the maximum shear strength obtained was 48 MPa by laser welding as a fusion welding process [7], and a maximum tensile strength of about 132 MPa was obtained by friction stir welding as a solid state welding process [8]. Cold metal transfer MIG welding was also used to weld Mg and Al [9]. Some methods were used to eliminate or to reduce the formation of intermetallic phases. For example, electromagnetic impact welding was used to join Mg and Al sheets [10], and diffusion bonding of Mg–Al with Zn alloy interlayer was investigated with the maximum shear strength of 83 MPa [11]. Therefore, the strength of Mg–Al welded joint cannot meet the needs of application, and the strength need to be further improved.

Stress concentration is crucial for the intermetallic in Mg–Al welded joint. If the intermetallic interlayer is formed at the region with low stress, the strength would be improved in mechanical property test. Based on this opinion, a modified MIG spot welding (MSW) technology is carried out to weld Mg and Al, and this process is different from traditional method. During the traditional MIG spot welding, the sheets can be spot welded directly if the sheets are thin, or be welded through the hole in the upper sheet if the sheets are thick. In this modified MIG spot welding technology, both of the sheets are drilled through before welding. MIG spot welding is firstly used through the hole from Al side and a backing block is set for arc staring, as shown in Fig. 1. Then, the joint is overturned to be spot MIG welded from the Mg side. This is a new technology to weld Mg and Al, and has not been reported before. The reason of double-side spot welding procedure is to avoid the intermetallic compounds at the interface between the sheets, where Mg–Al overlap joints usually fracture.

Adhesive bonding can offer many advantages including excellent strength in shear, uniform distribution of loads, softening of stress concentrations, good fatigue resistance and energy absorption. Weld bonding is a hybrid technology which combines fusion welding with adhesive bonding. In the papers reported, resistance spot weld bonding of dissimilar alloys was analyzed [12], and laser weld bonding was carried out to join Mg alloy and Al alloy [13]. If the adhesive bonding can be combined with the modified MIG spot weld bonding, the mechanical properties of the joint would be further improved. Therefore, a novel process of MIG spot weld bonding (MSWB) is applied to joining Mg and Al, and the schematic diagram is shown in Fig. 1. This technology mainly includes three steps: adhesive bonding, drilling and MIG spot welding. In the drilling step, the adhesive bonded sheets are drilled through.

The present work investigates on the weldability of Mg and Al sheets by this novel technology. By analyzing the typical microstructures in the joint, the connection and fracture mechanism are discussed, and the effect of intermetallic phase to the Mg–Al joint strength is represented.

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