Study on Interfacial Strengthening of Al/Mg Bimetal Prepared by the Lost Foam Compound Casting

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Abstract: Al/Mg bimetal combines the advantages of both aluminum and magnesium and has broad application prospects in automotive, aerospace, weapons, digital products and so on. The compound casting has the characteristics of low cost, easy to achieve metallurgical combination and suitable for the preparation of complex Al/Mg bimetallic parts. However, bimetallic joint strength is low due to the differences of physical properties between Al and Mg, oxide film on the metallic surface and interfacial Al-Mg IMCs, which is closely related to the interfacial microstructure and properties. Therefore, how to control the interface of the bimetal to achieve the performance enhancement is the focus and difficulty in this field. To solve the above problems, we put forward the following solutions. Firstly, the undesirable Al-Mg IMCs were reduced or eliminated by adding the interlayers (Zn, Ni and Ni-Cu). Secondly, the evolution process of interfacial microstructure was changed and fine strengthening phases were formed by adding Si element to Al alloy or rare earth element to Mg alloy. Thirdly, mechanical vibration and ultrasonic vibration were applied in the process of the filling and solidification to refine and homogenize the interfacial structure. Finally, some other methods, including heat treatment and constructing exterior 3D morphology, also can be used to regulate the interfacial microstructure and compositions. The above strengthening methods can be used alone or in combination to achieve bimetallic strengthening. The highest shear strength (69.8 MPa) was obtained by adding plasma sprayed Ni coating on the surface of A356 alloy in the lost foam compound casting so far. Finally, the future development direction of the Al/Mg bimetal is prospected, which provides some new ideas for the development and application of the Al/Mg bimetal.

Keywords: Al/Mg bimetal; Compound casting; Interfacial regulation; Interface strengthening

1 Introduction

Al/Mg bimetal combines the performance characteristics of aluminum alloy and magnesium alloy, and maintains excellent comprehensive performance while achieving lightweight, which has broad application prospects in aerospace, automotive, weapons and other fields [1-2]. According to the state of bimetal preparation, the preparation methods can be divided into solid-solid composite, solid-liquid composite and liquid-liquid composite, each of which has its own characteristics and application fields. Among them, solid-liquid composite is also known as composite casting, which has the advantage of low-cost preparation of complex parts. However, the use of composite casting to prepare bimetals also has problems such as too thick interfacial layer, oxidation inclusion, cracks, etc. These problems lead to the bimetal performance cannot meet the requirements of use, therefore, limiting the development of bimetals. These problems are mainly related to the interface, so how to regulate the interface of bimetal is the focus and difficulty of this field. At present, researchers have proposed many methods to regulate the Al-Mg bimetallic interface, including removing oxide film, adding intermediate layer, applying external field, alloying and so on [3-4].

Our research team has more than ten years of research experience in the field of composite casting Al/Mg bimetal. In this paper, the research results on the interface regulation and strengthening of composite casting bimetal are reviewed, and the future development direction is prospected to provide theoretical basis and practical experience for the application of bimetal.

2 Experimental procedure

Al/Mg bimetal is prepared by the lost foam compound casting, the principle of which is shown in Fig. 1. The microstructures and properties of the bimetals were analyzed by SEM, EDS, TEM, EBSD, XRD and material property testing machine.

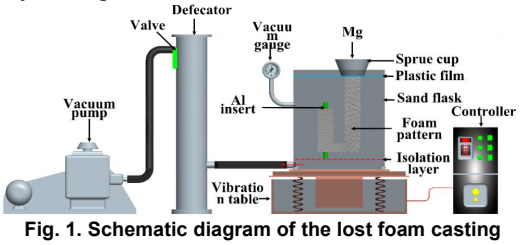

Fig. 1. Schematic diagram of the lost foam casting

3 Result and discussion

ADDING INTERLAYER

The effects of the Ni coatings prepared by different methods, namely, electro nickeling (EN), electroless nickel plating (ENP), plasma sprayed nickel (PSN), on the microstructure and properties of the Al/Mg bimetal were compared, as exhibited in Fig. 2. There is metallurgical bonding between Ni coating and Al matrix but no metallurgical bonding between Ni coating and Mg matrix at the bimetallic interface of EN and ENP, and the interfacial layers are mainly composed of Ni solid solution (Ni SS) and Al_3Ni, as exhibited in Fig. 2(a) and (b). For the bimetal containing PSN coating, metallurgical reaction layers occur between the Ni coating with Al substrate and Mg substrate, and the interfacial layer is mainly composed of Mg_2Ni, Ni SS and Al_3Ni, because the rough coating is more conducive to the metallurgical bonding, as displayed in Fig. 2(c). EBSD results verify the existence of these phases, and these phases have small grain size and random orientation, as exhibited in Fig. 2(d) and (e). Only the shear strength of the bimetal with PSN coating is improved, with a shear strength of 69.8 MPa, which is 69% higher than that of the bimetal without coatings.

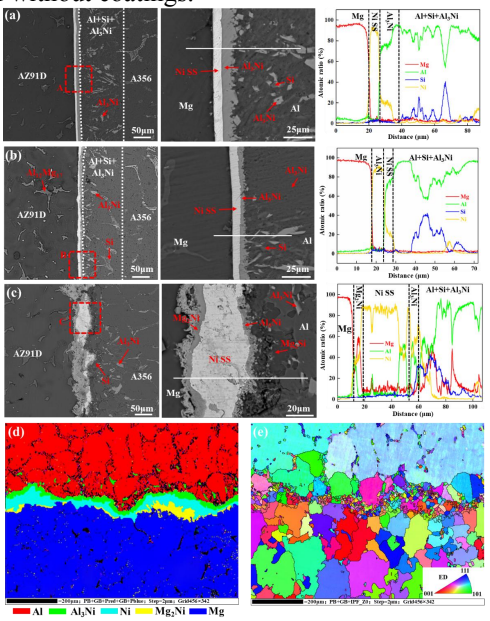

Fig. 2 Microstructure and EBSD results of the bimetal with different Ni coatings

Alloying

It is well known that if the bimetallic matrix is pure magnesium and pure aluminum, the phase composition of the interface layer must be Al-Mg intermetallic compound. However, we know that Al-Mg IMCs are brittle and hard phase, accompanied by coarse grains, uneven composition, stress concentration, preferred orientation and other problems. In practice, the matrix alloy usually contains other elements, and the presence of these elements will also affect the interface structure of the bimetal. Therefore, alloying is also an effective method to improve the structure and properties of the interface by adjusting the element type or content of the matrix alloy. At present, the elements used in the study of alloying in compound casting can be divided into two categories: one is Si element; the other is rare earth alloy, including La, Ce, Nd, Y and Gd, as listed in Table 1.

Table 1. Alloying element used in compound casting

Material	Alloying element	Improvement of shear strength/MPa (Content)
Al-Si/AZ91D	Si	6.0→58.6 (15 wt.%)
A356/AZ91D	La	39.36→51.54 (1 wt. %)
	Ce	37.22→53.29 (1 wt. %)
	Nd	36.8→52.2 (0.7 wt. %)
	Y	36.51→50.98 (0.2 wt. %)
	Gd	33.1→46.0 (0.6 wt. %)

4 Conclusion

The above strengthening methods can be used alone or in combination to achieve bimetallic strengthening. The highest shear strength (69.8 MPa) was obtained by adding plasma sprayed Ni coating on the surface of A356 alloy in the lost foam compound casting so far.

Acknowledgments

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