Semi-Solid Casting Preparation Technology for Graphene-Reinforced Magnesium Matrix Composites

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Abstract: Traditional magnesium alloy materials have problems such as low strength and elongation, low elastic modulus and poor wear resistance, which limit their further application. How to effectively improve the comprehensive properties of magnesium alloy to meet the development needs has become the development goal of new materials. Graphene with excellent mechanical, thermal and electrical properties, has been considered as an ideal reinforcement of magnesium matrix composites. However, due to the uniform dispersion of graphene in the metal matrix, the interface bonding and complex preparation processes, the progress of graphene-reinforced magnesium matrix composites has not achieved the expected results. In this paper, semi-solid thixomolding process was used to prepare graphene nanoplatelets (GNPs) reinforced magnesium matrix composites. The preparation technology was studied to reveal the GNPs uniform dispersion mechanism, fracture mechanism and strengthening mechanism. The effects of process parameters on the properties of the composites were studied. The developed technology is expected to realize mass production and application of graphene-reinforced magnesium matrix composites.

Keywords: Graphene nanoplatelets, Magnesium matrix Composites, Semi-solid thixomolding process

1 Introduction

Semi-solid processing (SSP) has received considerable interests as a promising technology for processing of magnesium matrix composites (MMCs) relies on the thixotropic behavior of alloys in the semi-solid state [1]. It is expected that the low processing temperature of SSP can prevent the problem of Mg oxidation and GNPs structural damage effectively. Furthermore, the semisolid-state mixing might facilitate the engulfment of GNPs into the semi-solid slurry by reducing their buoyancy. Several recent reports have described the synthesis of MMCs base on SSP [2]. However, there is limited data in the literature on the SSP preparing methods of GNPs/Mg composites in addition to thixomolding process. Even more important, although most of work focused on the preparing methods and the effects of GNPs on the microstructure, little work has been reported on the microstructure evolution of MMCs in the semi-solid state.

2 Experimental procedure

The AZ91D-chips and GNPs (0.6 wt% content) were mixed and stirred in the V-pattern mixer to obtain AZ91D-chips fixed GNPs (AZ91D-chips-GNPs). After extruding and shearing by the screw of Mg thixomolding machine (JLM220-MG), the AZ91D-chips-GNPs were processed into semi-solid mixed slurry in the end of barrel. The barrel temperature and the screw rotate rate were 600℃ and 140 r/min, respectively. When the quantity reaches a fixed value, the semi-solid mixed slurry was injected into the mold with injection velocity of 1.5 m/s to mold for AZ91D-GNPs composites. The semi-solid mixed slurry and AZ91D-GNPs composites, respectively named as SSM@0.6GNPs and AZ@0.6GNPs, were collected individually to assess microstructural evolution in AZ91D-GNPs composites fabricated by thixomolding process, as shown in Fig. 1 [3-5].

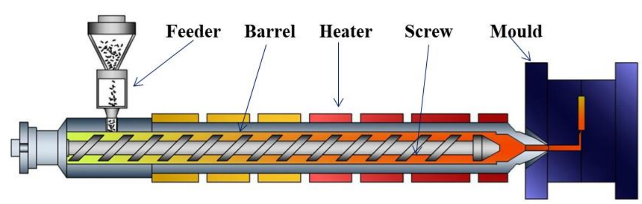

Fig. 1 Semi-solid Thixomolding Process

3 Result and discussion

As can be observed in Fig. 2, the *UTS* and δ of AZ@0GNPs were dropped slightly compared with SS@0GNPs. Although grain structure became much finer after injection process, the high porosity would lead to a significant decline of the performance for AZ@0GNPs. However, the *UTS* and δ of AZ@0.6GNPs had achieved 247.1 MPa and 4.3%, showing a significant increase in mechanical properties by adding GNPs to AZ91D alloy. According to the above results, the strength improvement should be attributed to grain refinement, porosity decline and special GNPs distribution characteristic. More importantly, the uniformly dispersed intragranular GNPs with anchoring MgO particles were supposed to be the main reason for the higher performance of AZ@0.6GNPs.

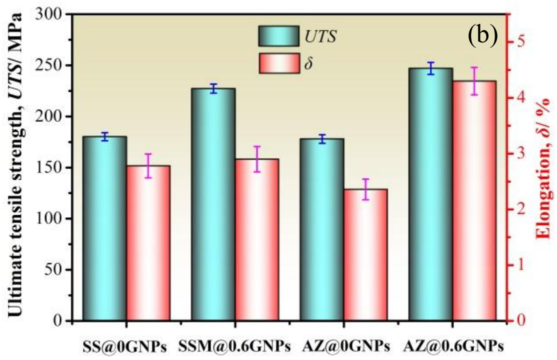

Fig. 2 The mechanical properties analysis

The mechanical properties of the composites strongly depend on the interfacial load transfer efficiency between the matrix and reinforcement. The GNPs/MgO interface was intimate and thus the compressive stress might be initiated at the interface, leading to the formation of a stress contrast. The appropriate amounts of MgO particles could contribute to enhance the anchor effect of GNPs from the AZ91D alloy matrix and enhance the load transfer efficiency at the interface. The MgO particles could be bonded to the outer layer of GNPs and share the applied load from the AZ91D alloy matrix to all GNPs layers, which is expected to increase the load-bearing capacity of GNPs. Furthermore, the anchor effect of GNPs would contribute to the improvement of effective interfacial shear strength. Consequently, due to the increased load-bearing capability and the effective interfacial shear strength, the appropriate amounts of MgO particles could effectively improve the interfacial load transfer, leading to the enhancement of mechanical properties for AZ@0.6GNPs. However, what would the best size, morphology and content of MgO particles in strengthening the interfacial bonding is still unclear, which will be highlighted in the following work.

4 Conclusion

The GNPs reinforced MMCs were fabricated by Semi-solid thixomolding process, which could enable reference for the practical application of SSP in GNPs reinforced MMCs. The strength improvement of AZ@0.6GNPs can be attributed to grain refinement, porosity decline and special GNPs distribution characteristic. The appropriate amounts of MgO particles were anchored around the GNPs, which could effectively improve the interfacial load transfer.

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