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Effects of YAl_2 particulates on microstructure and mechanical properties of β-Mg–Li alloy

G. X. Luo · G. Q. Wu · S. J. Wang · R. H. Li · Z. Huang

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Abstract A new β-Mg-12 wt%Li matrix composite reinforced with 15 wt%YAl_2 particulates is produced. Microstructures and mechanical properties of the YAl_2p/β-Mg-Li composite were investigated. The results show that a clean interface is formed between YAl_2 particulate and magnesium-lithium matrix; YAl_2 particulates are dispersively distributed in Mg-12 wt%Li alloy matrix; and mechanical properties of the β-Mg-Li alloy are effectively improved by the addition of YAl_2 particulates.

Magnesium–lithium alloys have potential for use in aerospace applications because of their low specific gravity and high specific stiffness. However, magnesium–lithium alloys have the intrinsic problems concerning the age hardening stability, low creep strength and poor corrosion resistance, which would prevent their wider applications [1]. Recently, some interests [2–5] have been reported on the enhancement of the strength and stiffness of magnesium–lithium alloys by using second stiffness phase reinforcement. Researches [3] on ceramic phase-reinforced magnesium–lithium matrix composites indicate that ceramic phases considerably enhance the yield strength and modulus of magnesium–lithium matrix alloys. However, the chemical incompatibility between ceramic reinforcements and the magnesium–lithium matrix remains as the most critical problem, and it would therefore, induce undesired degradation in the mechanical properties of the composite. Since the high specific strength, specific stiffness and high modulus, advanced intermetallic compounds have been utilized as one of the most promising reinforcements [6, 7]. Among intermetallics of Aluminum, YAl_2 compound has low density (3.93 g/cm^3). When compared to β-Mg–Li alloy, YAl_2 compound presents interesting properties: high melting temperature (1,731 K), high Young's modulus (158 GPa) [8], high hardness ($HV = 648$), low coefficient of thermal expansion (about 10×10^{-6}/K [9]). It can be supposed, therefore, that the combination of β-Mg–Li alloy and YAl_2 properties can result in a composite with favorable properties. In the present work, the possibility of using YAl_2 particulates as a reinforcement candidate of Mg–Li alloy will be evaluated.

The β-Mg-12 wt%Li matrix composite containing 15 wt% YAl_2 particulates was produced in a vacuum non-consumable arc-melting furnace under an argon atmosphere. Magnesium ingots and lithium rods used in the present study had the purity of 99.9% and 99.95%, respectively. YAl_2 particulates were prepared using planetary ball milling equipped with agate ball. YAl_2 intermetallic compound particulates with a size range of 5~30 μm were selected as reinforcement. By comparison, the monolithic β-Mg-12 wt%Li alloy was produced by the same technique.

Microstructures of the YAl_2p/β-Mg–Li composite were examined by optical microscope (OM), scanning electron microscope (SEM) and transmission electron microscope (TEM). To characterize the mechanical properties of the composite, hardness, compression yield strength and shear strength of the composite were assessed. Hardness tests were conducted on the HXZ-1000 micro-hardness tester and HBE-3000 Brinell hardness (HB) tester, respectively. Shear strengths and compression yield strengths of the YAl_2p/β-Mg–Li composite and β-Mg–Li alloy were tested, respectively, in the Material Test System (MTS880). Fig. 1 shows the schematic diagram of the shear test. Compression samples were 10 mm tall and 5 mm in diameter.

G. X. Luo (✉) · G. Q. Wu · S. J. Wang · R. H. Li · Z. Huang
School of Materials Science and Engineering, Beijing University of Aeronautics and Astronautics, Beijing 100083, P.R. China
e-mail: luogenxiang@eyou.com

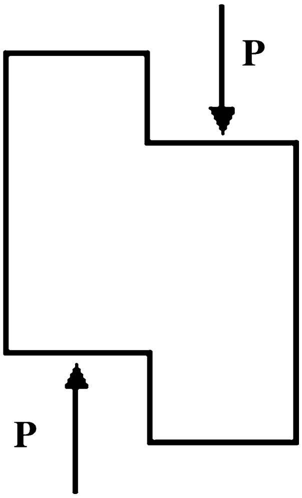

Fig. 1 The schematic diagram of the shear tests

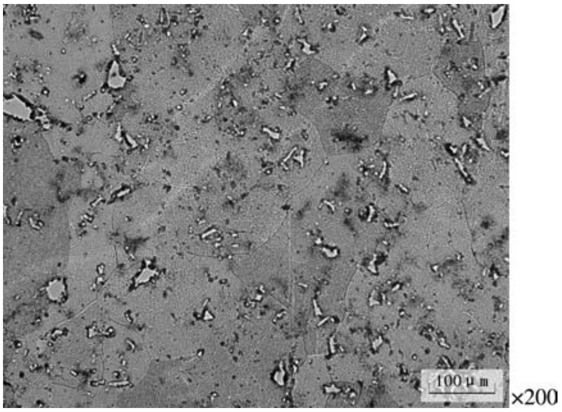

Fig. 2 Optical micrograph of the as-fabricated YAl_2p/β-Mg–Li composite

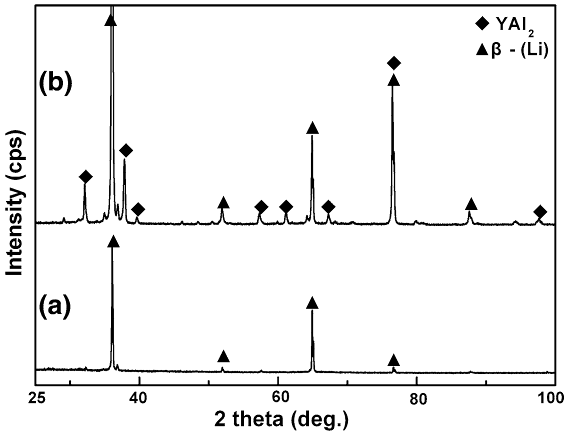

Fig. 3 X-ray diffraction patterns of (**a**) monolithic β-Mg–Li alloy and (**b**) YAl_2p/β-Mg–Li composite

Fig. 2 shows microstructure of the as-fabricated YAl_2p/β-Mg–Li composite. It displays that YAl_2 particulates dispersively distribute in the β-Mg–Li matrix alloy, and a large proportion of YAl_2 particulates present within the grains. X-ray diffraction pattern (Fig. 3) indicates that the YAl_2p/Mg–Li composite consists of YAl_2 intermetallic compound and β-(Li) phases. The YAl_2 particulates appear to be stable and suffer no chemical reaction on contact with the β-Mg–Li matrix during the manufacturing process, and clean and featureless interface is formed in YAl_2p/β-Mg–Li composite as shown in Figs. 4 and 5. The stability of YAl_2 intermetallic compound in the β-Mg–Li matrix as observed above would be of great significance in obtaining the YAl_2p/β-Mg–Li composite with good mechanical properties.

The results of hardness, compression and shear tests are listed in the Table 1. The results show that the micro-hardness and HB value of the composite is 1.7 and 2.5 times of those of β-Mg–Li alloy, respectively. The shear strength of YAl_2p/β-Mg–Li composite is 1.75 times of that of monolithic β-Mg–Li composite. Fig. 6 illustrates the stress-strain behavior of YAl_2p/β-Mg–Li composite and β-Mg–Li alloy obtained from the compression tests at room temperature. It can be seen that YAl_2p/β-Mg–Li composite show higher compression yield strength than

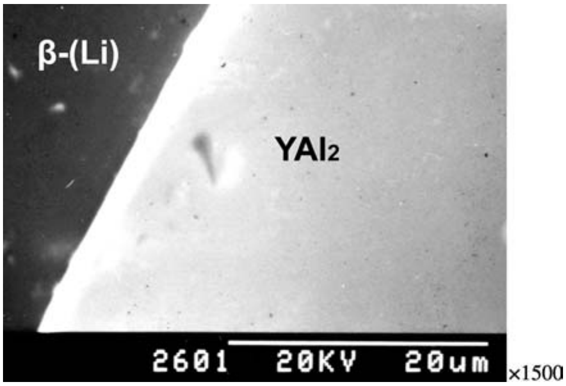

Fig. 4 SEM micrograph of the interface between YAl_2 particulate and β-Mg–Li matrix

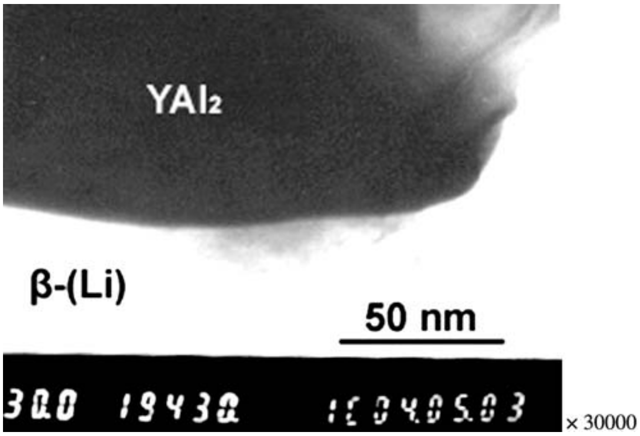

Fig. 5 TEM observation of the interface between YAl_2 particulate and β-Mg–Li matrix

Table 1 Results of the mechanical property tests

Material	Hardness		Shear strength (MPa)	Compression yield strength (MPa)
	Micro (HV) (gf/mm^2)	Macro (HB) (gf/mm^2)		
β-Mg–Li alloy	38	35	95	68
YAl$_2$p/β-Mg–Li composite	70	90	167	195

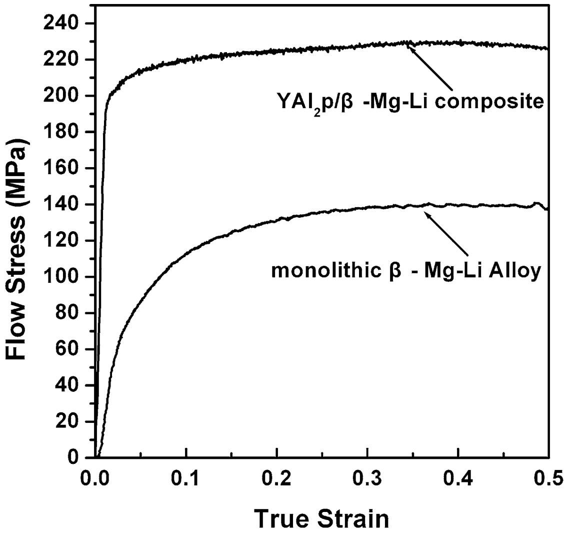

Fig. 6 Representative compression true stress–strain curves of YAl$_2$p/β-Mg–Li composite and the monolithic β-Mg–Li alloy

observed in the monolithic β-Mg–Li alloy. YAl$_2$p/β-Mg–Li composite exhibits no evidence of crack up to the maximum strain (ϵ = –0.5). The good compression ductility achieved in YAl$_2$p/β-Mg–Li composite can be attributed to the good ductility of magnesium–lithium alloy matrix with bcc lattice structure.

Therefore, YAl$_2$ particulates appear to the favorable reinforcement of Mg–Li alloys.

It is concluded that a new β-Mg-12 wt%Li matrix composite reinforced with 15 wt%YAl$_2$ particulates is produced. YAl$_2$ particulates dispersively distribute in the β-Mg–Li matrix, and a clean interface is formed between YAl$_2$ particulate and β-Mg–Li matrix. Mechanical properties of the β-Mg–Li alloy are significantly improved by the addition of YAl$_2$ particulates, and the hardness, shear strength and compression strength of the composite exceed those of the monolithic alloy by 150%, 75% and 186%, respectively.

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