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Superplasticity and texture of SiC whiskers in a magnesium-based composite

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Abstract

Superplastic deformation behaviors in a β-SiCw/ZK60 composite were investigated. The samples were tested at temperatures ranging from 613 to 723 K and at initial strain rates ranging from 8.3×10^{-4} to $8.3 \times 10^{-2}\ s^{-1}$. A maximum elongation of 200% was obtained at 613 K and at $1.67 \times 10^{-2}\ s^{-1}$ with a *m*-value of 0.35. The activation energy (98 kJ/mol) approximates to that for grain boundary diffusion (92 KJ/mol) in magnesium. A strong ⟨1 1 1⟩ fiber texture was formed in SiC whiskers during superplastic deformation, resulting from the matrix flow and interface sliding. The alignment of SiC whiskers restrains the grain boundary sliding of matrix alloy, and thus facilitates the growth and linkage of cavities, leading to a premature fracture of the composite.

Keywords: Superplasticity; Texture; Cavitation; Magnesium matrix composite

1. Introduction

Discontinuously reinforced magnesium matrix composites have been used in aerospace and automobile structures [1–5], owing to their low density, high specific strength, high specific stiffness and high damping capacity. However, magnesium matrix composites normally exhibit limited ductility (~1%) at room temperature. Therefore, it is necessary to improve the ductility of these composites in order to manufacture structural components. Superplastic forming is a viable technique to fabricate hard-to-form materials, such as magnesium matrix composites, into complex shapes. Much progress has been made on superplasticity of particulate-reinforced magnesium matrix composites [6–10]. In contrast, only a limited amount of research has focused on whisker-reinforced magnesium matrix composites.

In the present article, the superplastic behavior of 19.7 vol.% β-SiC whisker-reinforced ZK60 magnesium based composite is investigated, and the deformation mechanism discussed. Furthermore, the texture of SiC whiskers during superplastic deformation was examined, and its influence on cavitation investigated.

2. Materials and experimental procedure

The composite investigated was 19.7 vol.% β-SiC whisker-reinforced ZK60 magnesium matrix composite fabricated by a squeeze casting method. The chemical composition of the matrix is Mg–6 wt.%Zn–0.5 wt.%Zr. The dimensions of the β-SiC whiskers were 0.1–1 μm diameter and 30–100 μm initial length. Further extrusion was performed in order to homogenize the microstructure of SiCw/ZK60 composite. The extrusion process was conducted at 673 K in air with a reduction ratio of 24:1. The average value of matrix grain size was 2.3 μm. Tensile specimens with a 6 mm gage width and a

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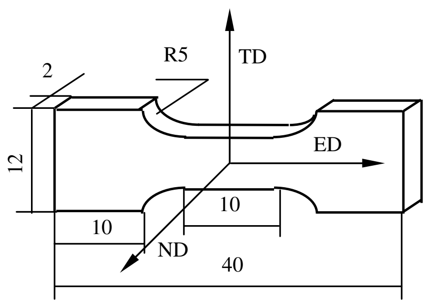

Fig. 1. Geometry of tensile specimens (mm).

10 mm gage length were machined from the as extruded composites with the tensile axis parallel to the extrusion direction. The geometry of the tensile specimens is shown in Fig. 1. Tensile tests were carried out in air at temperatures ranging from 613 to 723 K (0.68–0.80 T_m; T_m = 908 K for ZK60), and at the initial strain rates ranging from 8.3×10^{-4} to $8.3 \times 10^{-2}\ s^{-1}$. The texture data for the SiC whiskers were obtained by electron backscatter diffraction (EBSD) patterns using a LEO1530 field emission scanning electron microscope (SEM). Automated scans were carried out using stage control with a 0.5 μm step size. The microstructure of the composites and cavities formed in the process of superplastic deformation were observed with LEO1530 field emission SEM.

3. Results and discussion

3.1. Initial microstructure and superplastic deformation behavior

A photomicrograph of the composite in the as-extruded condition is shown in Fig. 2. The unetched micrograph reveals the alignment and fairly uniform distribution of SiC whiskers.

The variation of flow stress at a fixed strain of 0.1 as a function of strain rate is shown in Fig. 3(a). The reason

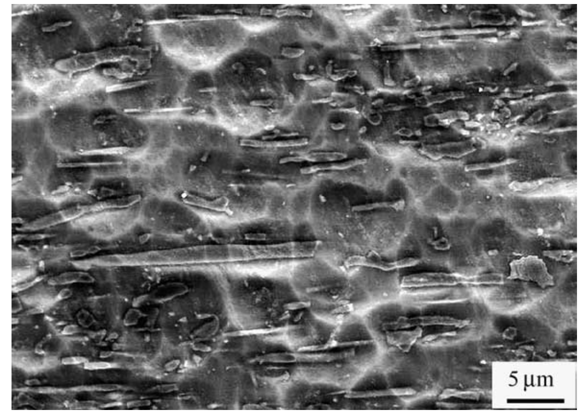

Fig. 2. SEM micrograph of as-extruded SiCw/ZK60.

that the strain of 0.1 was selected is that grain growing at $\varepsilon = 0.1$ during superplastic flow is negligible. It can be noted from Fig. 3(a) that, generally, the flow stress increases with increasing strain rate and decreases with raising temperature. The strain rate sensitivity exponent, *m*, defined as the slope of double logarithmic plot of flow stress versus strain rate, is calculated to be 0.14–0.35 in the studied temperature regime. At low temperatures (613 K), the *m*-value increases with strain rate at the beginning and then decreases gradually since the flow stress vs strain rate exhibits a sigmoid shape. At 613 K and at $1.67 \times 10^{-2}\ s^{-1}$, the composite exhibits a maximum *m*-value of 0.35. As for relatively high temperatures (>613 K), though the *m*-value increases monotonically with the strain rate, the maximum value of *m* is less than 0.25.

The variation of elongation-to-failure as a function of strain rate is shown in Fig. 3(b). It is evident that the elongation depends on both the strain rate and temperature. Furthermore, large elongation corresponds well with a large *m*-value. At 613 K and at $1.67 \times 10^{-2}\ s^{-1}$, a maximum elongation of 200% is obtained with an *m*-value of 0.35.

The constitutive equation to describe the superplasticity is usually expressed by

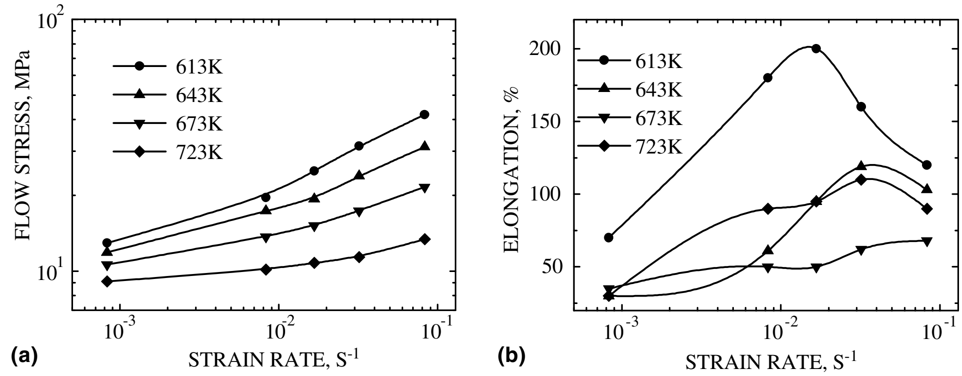

Fig. 3. The variation in (a) flow stress and (b) elongation-to-failure as a function of strain rate in 19.7 vol.% SiCw/ZK60.