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Refining whisker size of 2024Al/$Al_{18}B_4O_{33}$w composite through extrusion and its effects on the material's micro-structures and mechanical properties

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ABSTRACT

Hot extrusion is used to improve the distribution of whiskers and refine the whisker sizes of 2024Al/$Al_{18}B_4O_{33}$w composite. The grain size and the ultimate tensile strength of the extruded 2024Al/$Al_{18}B_4O_{33}$w composite are analyzed. The results show that the average length of whiskers decreases due to the whisker breakage. The nonuniform distributions of stress and velocity along the whisker lead to whisker breakage. The microcrack between the broken whiskers can propagate into the interface or the matrix, related to the wedge angle of the broken whisker. The extrusion is beneficial to the whisker staggered and makes it easy for the microcracks filled with matrix. The whisker breakage and the whisker staggered result in the decreasing distance between the neighboring whiskers. Due to the dislocation motion constrained by matrix and the overlap of the deformation areas, the decreasing distance between the neighboring whiskers promoting the recrystallization results in the smaller grain size. During tensile tests, due to the smaller resistance with the smaller distance between the neighboring whiskers, the cracks between the progressive broken whiskers are easy to coalesce resulting in the lower ultimate tensile strength of the extruded composite.

1. Introduction

Whisker (such as $Al_{18}B_4O_{33}$ whisker) reinforced aluminum matrix composites with low density and high mechanical properties have been used for automotive components and aircraft structures [1]. However, some cast defects (such as clusters and the poor distribution of whiskers) in the as-cast whisker reinforced aluminum matrix composites limit the extensive application of the composites [2]. To improve the distribution of reinforcement, secondary processing such as extrusion is used. Hot extrusion can break up the clusters and has been generally used to control microstructure and the distribution of reinforcement [3,4].

During extrusion, the average length of the whiskers decreases due to the plastic mismatch between the matrix and whiskers, which is dependent on the distribution of whiskers and the processing parameters [5,6]. Meantime, the extrusion has the effect on the distance between the neighboring whiskers. For the particle reinforced aluminum matrix composites, S. Scudino et al. [7] and S. Amirkhanlou et al. [8] have indicated that the yield strength with the lower particle space is higher. However, for the whisker reinforced aluminum matrix composites, the effect of the distance between the neighboring whiskers on strength response has not been considered. Also, it is necessary to investigate the relationship between grain size and the distance between the neighboring whiskers, which has the significant effect on the strength of the extruded whisker reinforced aluminum matrix composite.

In the present work, the main objective is to study the relationship between the whisker breakage and whisker sizes of the whisker reinforced aluminum matrix composite, consisting of 2024 matrix reinforced with 25 vol% of $Al_{18}B_4O_{33}$. The influence of the distance between the neighboring whiskers on the grain size and the ultimate tensile strength of the extruded 2024Al/$Al_{18}B_4O_{33}$w composite is also analyzed.

2. Materials and Methods

25 vol% $Al_{18}B_4O_{33}$ with a diameter of 0.5-1um and a length of 10–20 μm was used as the reinforcement. The 2024Al/$Al_{18}B_4O_{33}$w composite was fabricated by squeeze casting technique followed by hot extrusion with different extrusion ratios of 9:1, 16:1 and 25:1 at 350 °C, 400 °C, 450 °C and 500 °C. Microstructural investigations were carried out in the as-cast composite and the extruded composite using

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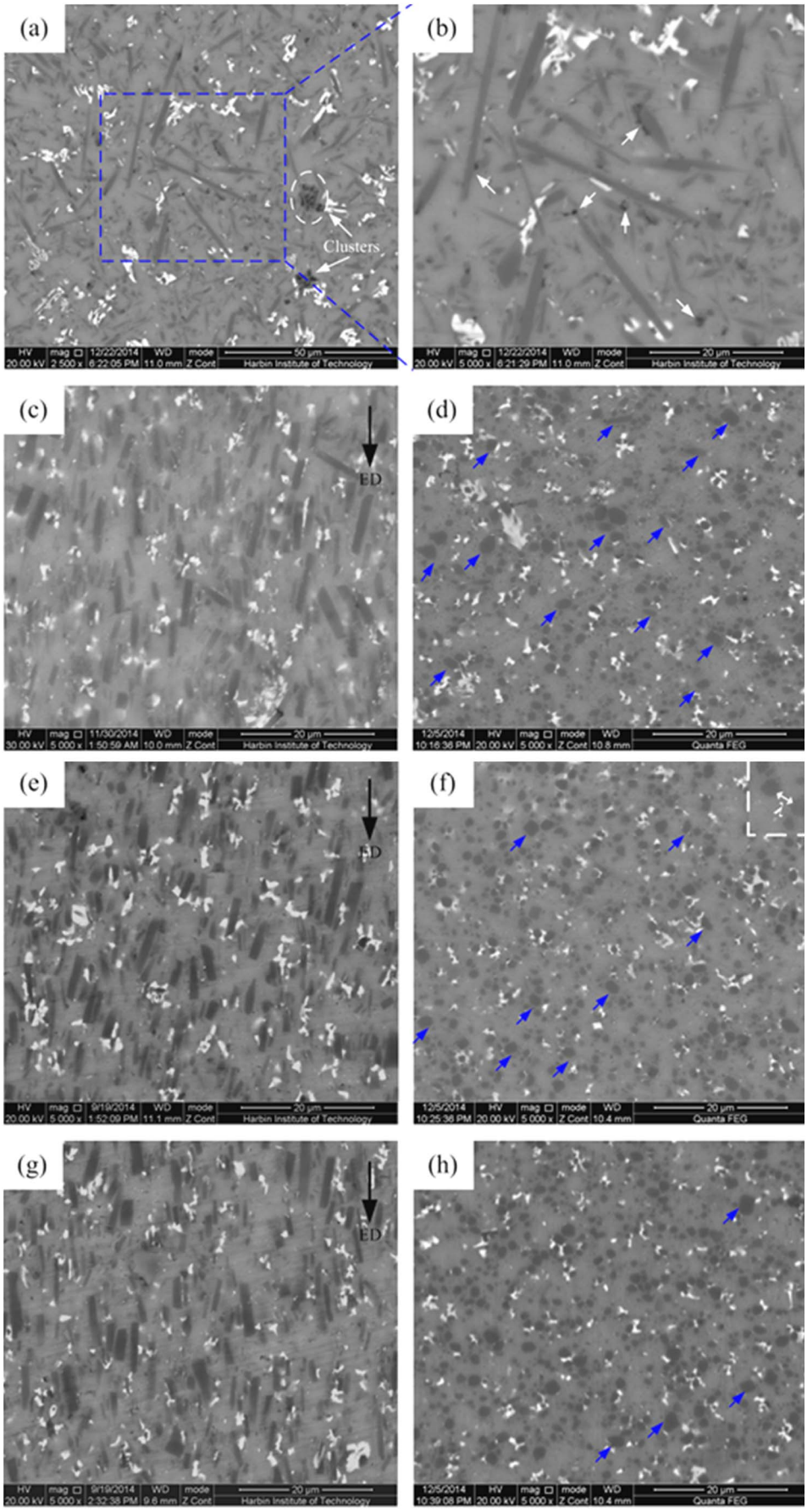

Fig. 1. SEM micrographs of: (a) and (b) the as-cast composite; the longitudinal sections of the composites extruded at 450 °C with different extrusion ratios (c) 9:1, (e) 16:1 and (g) 25:1; the cross sections of the composites extruded at 450 °C with different extrusion ratios (d) 9:1, (f) 16:1 and (h) 25:1.