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Short Communication

Effects of anomalies on fracture processes of graphite fiber reinforced aluminum composite

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ABSTRACT

To determine the effects of anomalies on fracture processes of graphite fiber reinforced aluminum composite (Gr_f/Al), unidirectional Gr_f/Al specimens embedded with inclusions and aluminum-rich areas (Al-rich) were chosen for bending test. Fracture processes and fracture surfaces of anomaly-embedded specimens were analyzed by scanning electron microscopy in situ observation. The micromechanisms of fracture process are as following: interface layer between inclusions and composite is fractured by stress concentration in front of crack tip, and cracks connect voids in inclusions, resulting in failure of inclusion-embedded specimens immediately. However, Al-rich eases stress concentration in bending specimens and crack is blunted by Al-rich/composite interface debonding and friction during fracture process.

1. Introduction

The new generation of aerospace vehicles will require low density/high strength materials while retaining a high stiffness under relatively high loads. Continuous fiber, metal matrix composites (MMCs) are candidate materials for such applications [1–5]. However, due to the complex structure of composite materials, anomalies such as matrix rich areas, inclusions, and voids may be introduced during manufacturing process and service [6], especially for fiber reinforced metal matrix composites, which are fabricated at high temperature. Some anomalies greatly reduce the strength of the composite materials whereas others do not impose significant limitations on structural performance [7–9]. So, it is necessary to understand the effects of anomalies on the mechanical behavior of MMCs.

Many researchers have paid much attention to anomalies such as crack and delamination [10–14] in fiber reinforced composite. Models have been built on their growth [15–18]. While researchers [8] seldom paid attention to the effects of anomalies on fracture processes of graphite fiber reinforced aluminum composites (Gr_f/Al). As a direct way to investigate fracture process of composites, in situ scanning electron microscopy (SEM) observation has been widely used [19–22]. It helps us better understand the fracture process as a function of the applied stress other than fractographic.

In this paper, unidirectional Gr_f/Al embedded with inclusions and aluminum-rich areas (Al-rich) were fabricated by pressure infiltration method. Three-point bending tests were applied to Gr_f/Al specimens embedded with two anomalies. Anomaly-embedded in the center layer of specimens makes sure it is almost not subjected to bending stress before the crack initiation. The crack growth in three-points bending specimens embedded with anomaly was observed by in situ SEM. The interaction between crack and anomaly in Gr_f/Al specimens under three-point bending were also discussed.

2. Experimental procedure

2.1. Preparation of anomaly-embedded composite

Aluminum alloy 6061 (Northern Light Alloy Company Ltd, Harbin, China), which contained (in wt.%) 1.0 Mg, 0.8 Si, 0.7 Fe and 0.2 Mn, was used as the matrix, while the reinforcement consisted of continuous M40 J graphite fiber (Gr_f) of ~5 μm in diameter (Toray Industries, Inc., Japan). Tape of aluminum alloy 6061 and BN powder were used to be artificial anomalies (Al-rich and inclusions, respectively), and embedded in the central layer of fiber perform (16 layers in total). Gr_f/Al with Gr_f content of 65 vol.% was fabricated by pressure infiltration method.

2.2. Experimental methods

Both anomaly-embedded and anomaly-free specimens were cut from the same Gr_f/Al panel for comparison. The predefined anomalies were placed in the central layer of Gr_f/Al specimens, and the dimensions of specimens and anomalies are shown in the

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