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Materials Science and Engineering A 486 (2008) 413–420

MATERIALS SCIENCE & ENGINEERING A

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The effects of volume percent and aspect ratio of carbon fiber on fracture toughness of reinforced aluminum matrix composites

H. Naji, S.M. Zebarjad*, S.A. Sajjadi

Department of Materials and Metallurgical Engineering, Engineering Faculty, Ferdowsi University of Mashhad, Azadi Square, P.O. Box 91775-1111, Iran

Received 14 January 2007; received in revised form 7 September 2007; accepted 10 September 2007

Abstract

Carbon fiber reinforced aluminum matrix composites are used as advanced materials in aerospace and electronic industries. In order to investigate role of aspect ratio of carbon fiber on fracture toughness of aluminum matrix composite, the composite was produced using stir casting. Al–8.5%Si–5%Mg selected as a matrix. The samples were prepared with three volume fractions (1, 2 and 3) and three aspect ratios (300, 500 and 800). Three-point bending test was performed on the specimens to evaluate the fracture toughness of the materials. The results showed that the fracture toughness of composites depends on both fiber volume fraction and aspect ratio. Scanning electron microscopy (SEM) was employed to elucidate the fracture behavior and crack deflection of composites. The study also, showed that the toughening mechanism depends strongly on fiber volume fraction, aspect ratio and the degree of wetting between fiber and matrix.

Keywords: Carbon fiber; Aluminum; Aspect ratio; Plain strain fracture toughness; Metal matrix composite

1. Introduction

Over the past few years, carbon fibers have been considered as very important reinforcements for aluminum (Al) and its alloys in fabricating advanced composite materials. Carbon fiber (CF) reinforcement/aluminium matrix composites are of great interest because of their high specific strength and stiffness, low coefficient of thermal expansion, and high thermal/electrical conductivity [1]. Consequently, Al/CF composites have the most potential to be applied as structural and functional materials in the future. Aluminum matrix composites reinforced with a preformed carbon are presently envisaged as parts of aeronautic complex shaped components, either totally reinforced composite parts or components with a local composite reinforcement [2].

There are some different techniques for fabrication of composite materials consisting of aluminium, matrix and carbon fibers. The methods are: squeeze casting, metal spray and metal infiltration [3].

The main problems encountered in the development of Al/CF composites are the reactivity of carbon fibers with aluminum and the poor wetting characteristics of carbon by liquid aluminum [4]. Various methods are applied to improve the wetability of carbon fiber in melt of Al such as: addition of some alloying elements to melt, making a wrapper on the surface of fiber by CVD or PVD methods [5], making mechanical toss in melt, applying force on melt and controlling atmosphere.

The carbon–aluminum interface importantly affects the overall performance of composite materials. Improper wetting and chemical reactions at the interface during synthesis or under service conditions can degrade the mechanical properties of the composites. The reaction at the carbon–aluminum interface at temperatures above 800 °C, to form aluminum carbide (Al_4C_3), has long been considered to affect critically the strength of Al/CF composites [6].

From the viewpoint of composite making, fabrication of Al/CF composite divided in to several routes, regarding their production temperatures. The processes can be sorted in to (1) Production in liquid state, (2) production in semisolid state and (3) production in solid state [7].

The liquid processes have several advantages on other production routes. High production rate, low cost and potential of production of complex parts are some of them. This route

* Corresponding author.
E-mail address: Zebarjad@ferdowsi.um.ac.ir (S.M. Zebarjad).

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doi:10.1016/j.msea.2007.09.030

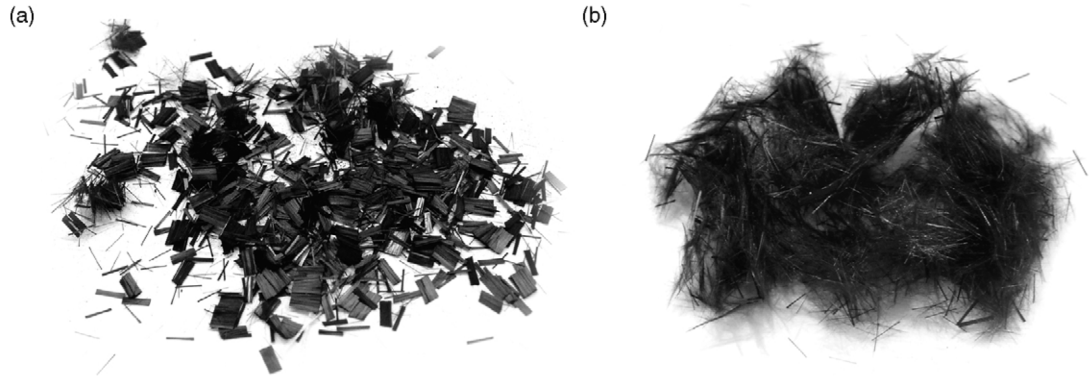

Fig. 1. Cut carbon fibers, (a) before and (b) after mixing.

Fig. 2. Mixing the carbon fiber with the aluminum matrix by making a vortex flow.

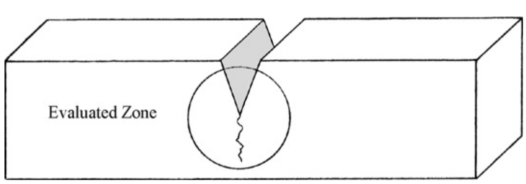

Fig. 3. Schematic picture of standard sample and evaluated zone.

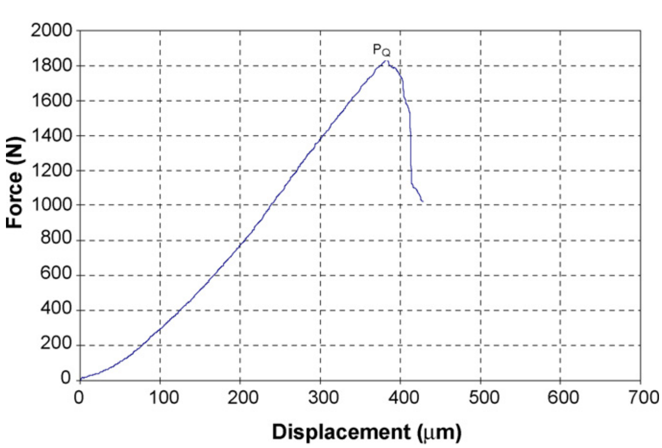

Fig. 4. A typical load-displacement graph. For a sample with 3 vol.% fraction and aspect ratio of 500.

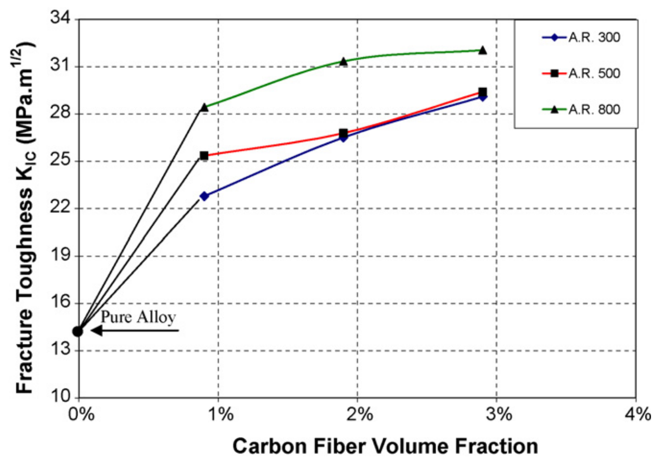

Fig. 5. Effect of volume fraction of CF on fracture toughness as a function of aspect ratio.

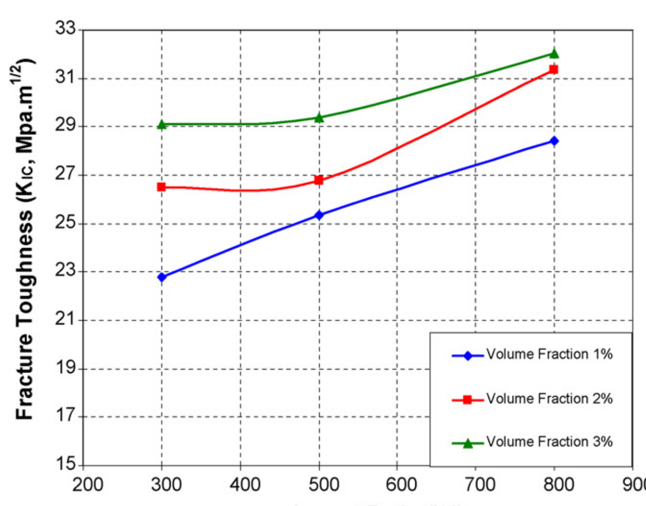

Fig. 6. Effect of aspect ratio on fracture toughness as a function of CF volume fraction.