§12. Relationship Between Interfacial Microstructure and Fracture Behavior of SiC/SiC Composites

Hinoki, T., Zhang, W., Katoh, Y., Kohyama, A.
(Kyoto Univ.)
Shibayama, T., Takahashi, H. (Hokkaido Univ.)

INTRODUCTION

Ceramic matrix composites (CMCs) are expected to be applied to not only airplanes and spaceplanes but also advanced energy systems such as high thermodynamic efficiency gas cycles and fusion systems because of their high temperature strength and inherently low induced radioactivity.

The importance of interfacial fracture behavior on mechanical properties of CMCs has long been emphasized. Interfacial fracture behavior and shear stress of SiC/SiC composites depends on preparing process, fiber and fiber coating. The effect of interfacial microstructure on interfacial fracture behavior has not clearly been understood mainly because of difficulty in preparing thin film specimens for microstructural examination by TEM.

The objective of this work is to reveal relationship between interfacial fracture behavior and microstructure and to optimize preparing process and interfacial microstructure.

EXPERIMENTAL PROCEDURE

Materials used in this study were Hi-Nicalon™ SiC fibers reinforced SiC matrix composites. SiC/SiC materials were fabricated by chemical vapor infiltration (CVI) method, following fiber coating with carbon of various thickness.

To evaluate interfacial fracture behavior, push-out and push-back tests of single fibers were carried out with constant displacement rates by means of an ultra-micro indentation test machine. The surface of debonded fiber was examined by scanning electron microscopy and analyzed by EDS.

Specimens for TEM examination were prepared with a focused ion beam-processing device. Microstructures of both undebonded (prior to the push-out test) and debonded (after the push-out test) interfaces were examined.

RESULTS AND DISCUSSIONS

Interfacial Mechanical Properties

In order to understand fracture behavior, push-out. and push-back tests were carried out. Interfacial shear stress and frictional stress were obtained from load-displacement curve of those tests. The resultant effect of carbon coating thickness on interfacial shear stress is shown in Fig. 1. Each carbon coating thickness in the specimens was measured from SEM images. Interfacial shear stress drastically decreased with increasing of carbon coating thickness.

As interfacial shear stress included frictional stress, just frictional stress was evaluated from push-back tests. Effect of carbon coating thickness on interfacial frictional stress is also shown in Fig. 1. Compared with interfacial shear stress, frictional stress is stable to carbon coating thickness. This means surface roughness of debonded interface is independent of carbon coating thickness and bonding stress is factor depending on carbon coating thickness. Examination of interfacial microstructure corresponded with this result.
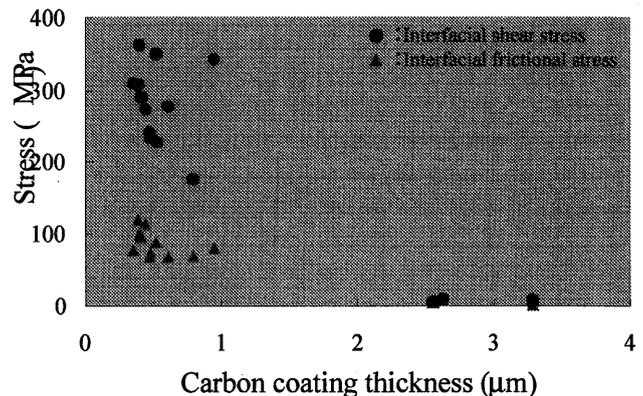

Fig. 1: Effect of carbon coating thickness on interfacial shear stress and frictional stress

Interfacial Microstructure

Debonded interface after fiber push-out test showed that the site at which the debonding occurred during the push-out test was identified as the carbon layer adjacent to the fiber. In order to clarify fracture behavior directly, microstructure of interface between fiber and carbon coating was examined by TEM. It was showed that aligned layer was surrounded by granular carbon layer and thickness of aligned carbon layer was independent of carbon coating thickness. Deformation of this aligned layer by indentation test was seen in high-resolution TEM image. This result suggested aligned carbon layer was weak part of interphase and crack initiated in this part.

The current interpretation of carbon coating thickness effect is that the granular carbon layer affects the soundness of aligned carbon layer and crack behavior in aligned carbon layer determines interfacial shear strength.

REFERENCE

[1] T. Hinoki, W. Zhang, A. Kohyama, S. Sato and T. Noda, J. Nucl. Mater. 258-263 (1998) 1567.

[2] W. Zhang, T. Hinoki, Y. Katoh, A. Kohyama, T. Noda, T. Muroga and J. Yu, J. Nucl. Mater. 258-263 (1998) 1577.

[3] T. Hinoki, W. Zhang, Y. Katoh, A. Kohyama and H. Tsunakawa, Proc. ECCM-8, Vol.4 (1998) 209.

[4] W. Zhang, T. Hinoki, Y. Katoh and A. Kohyama, Proc. ECCM-8, Vol.4 (1998) 359.