Materials and Design 32 (2011) 4394–4401

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Designing the fiber volume ratio in SiC fiber-reinforced SiC ceramic composites under Hertzian stress

Kee Sung Lee [a,*], Kyung Soon Jang [a], Jae Hong Park [a], Tae Woo Kim [a], In Sub Han [b], Sang Kuk Woo [b]

[a] School of Mechanical Engineering, Kookmin University, Seoul 136-702, Republic of Korea
[b] Energy Materials Research Center, Korea Institute of Energy Research, Daejeon 305-343, Republic of Korea

ARTICLE INFO

Article history:
Received 1 February 2011
Accepted 31 March 2011
Available online 9 April 2011

Keywords:
A. Ceramic matrix composites
B. fibers and filaments
E. Mechanical

ABSTRACT

Finite element method (FEM) analysis and experimental studies are undertaken on the design of the fiber volume ratio in silicon carbide (SiC) fiber-reinforced SiC composites under indentation contact stresses. Boron nitride (BN)/Pyrocarbon (PyC) are selected as the coating materials for the SiC fiber. Various SiC matrix/coating/fiber/coating/matrix structures are modeled by introducing a woven fiber layer in the SiC matrix. Especially, this study attempts to find the optimum fiber volume ratio in SiC fiber-reinforced SiC ceramics under Hertzian stress. The analysis is performed by changing the fiber type, fiber volume ratio, coating material, number of coating layers, and stacking sequence of the coating layers. The variation in the stress for composites in relation to the fiber volume ratio in the contact axial or radial direction is also analyzed. The same structures are fabricated experimentally by a hot process, and the mechanical behaviors regarding the load–displacement are evaluated using the Hertzian indentation method. Various SiC matrix/coating/fiber/coating/matrix structures are fabricated, and mechanical characterization is performed by changing the coating layer, according to the introduction (or omission) of the coating layer, and the number of woven fiber mats. The results show that the damage mode changes from Hertzian stress to flexural stress as the fiber volume ratio increases in composites because of the decreased matrix volume fraction, which intensifies the radial crack damage. The result significantly indicates that the optimum fiber volume ratio in SiC fiber-reinforced SiC ceramics should be designed for inhibiting the flexural stress.

1. Introduction

SiC ceramics have been known for high hardness and wear resistance as well as good resistance to oxidation, thermal shock, and corrosion. These excellent thermo-mechanical properties of SiC material, as compared to those of conventional metals, suggest the promise of SiC in high-temperature environments [1–8]. By making monolithic SiC into ceramic composites, the brittle nature of this material can be alleviated; this can enhance the strength and fracture toughness at room and higher temperatures [9,10]. Whiskers, particles, and/or well-dispersed continuous fibers have been incorporated into ceramic monolithic matrices leading to ceramic matrix composites (CMC). SiC composites, in particular, have evolved much with SiC matrices being reinforced with SiC continuous fibers [10–14]. The SiC fibers that are available in the market are produced by Japanese firms. One of the trademarks of fibers include Tyranno fibers with various grades. The fibers can also be woven in the form of SiC mats to be inserted between matrix layers. One of the well-known processing methods for composites includes SiC ceramic woven fibers that have been coated to produce fiber preforms, which are then infiltrated with an SiC matrix and densified [11,12].

The excellent thermo-mechanical properties of SiC fiber reinforced SiC composites enable various applications for advanced high-performance structures. High strength and thermal-resistant characteristics provide reliable radiation burners for cook-top applications [15]. Repetitive thermal loading requires high thermal shock resistance of the burner. Additionally, mechanical loading requires high mechanical strength and contact resistance of the burner. The load-bearing ceramic composites used for radiation burners at high temperature have been extended to industrial parts, as found in heating elements and supporters for high-temperature furnaces, heat exchangers, automobile brake disks, and components for gas turbine and nuclear power structures [9,16,17]. SiC CMCs are also promising materials for defense, spatial, and aeronautical applications. The thermal protection system (TPS) of aeronautical applications, such as launched vehicles, features the application of CMCs [17,18]. In these applications, the design of the composite structure has an important role in tailoring the thermal and mechanical properties of final products. The fiber volume ratio, fiber arrangement (orientation), matrix

* Corresponding author. Tel.: +82 2 910 4834; fax: +82 2 910 4839.
E-mail address: keeslee@kookmin.ac.kr (K.S. Lee).

0261-3069/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2011.03.080