Mechanical Properties of SiC Fiber Reinforced TiAl Composite

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Introduction

Although metal matrix composites for the high temperature structural material have been investigated extensively[1,2]), applications of MMC have been limited. Among many combinations between the ceramic fibers and matrix materials, combination of SiC fiber and TiAl based intermetallic compounds has been expected to be one of the best combination since both SiC fiber and TiAl show the heat resistant and low density. Lack of the affordability of TiAl sheet has been inhibited the development of the TiAl base composites. Among several approaches[3,4]), SiC fiber reinforced TiAl has been successfully fabricated in 1997[5]) by present authors group. However, investigation has not been hardly found to follow the results of our SiC/TiAl composites. In this study, the fabrication conditions of SiC fiber and TiAl sheet using the hot press in a vacuum have been investigated[6]). The purpose of this research is to understand the relationships between process conditions and mechanical properties of SiC/TiAl composites. Furthermore the reaction layers between fiber and TiAl matrix have been analized in detail. Results would lead to establish the most appropriate fabrication condition of composite.

Materials and Methods

TiAl ingots were remelted by the plasma arc melting (PAM) facility. Then they received HIP process at 1323K for homogenizing treatment in order to eliminate casting defects. Ingots were compressed up to 80% deformation at 1473K, in a vacuum atmosphere to get fine microstructure which shows a superplastic deformation capability above 1473K. The sheets of γ-TiAl specimens whose thickness were 0.2mm were cut by the diamond multi wire saw machine. Using a specially designed jig, five TiAl sheets (20x20x0.2mm^3) and properly chopped SiC fibers were laminated in layer by layer as shown in Fig.1. Unidirectional compression on the preform were carried out by means of the hot press facility at various temperatures in a vacuum. After the preform was set in the chamber, temperature was raised with heating rate 15K/min, and kept for 40min. Preform was hot pressed under the condition of 7.0-8.0MPa for 10min. SiC/TiAl specimens were cut from composites perpendicular to the fiber direction by the diamond wheel saw, and then polished by diamond powder. Cross section of the specimens were observed by SEM-EDS operated at 15keV. Micro- indentation appartus has been utilized to evaluate the pull out strength of matrixTiAl and a SiC fiber. Mechanical properties of unidirectional composite specimens (7.5x20.4x0.9mm^3) have been examined by three point bending tests at room temperature.

Results and Discussion

Determination of an adequate hot press condition for SiC/TiAl composite is the most important purpose of this study. The volume fraction of fiber in matrix is examined from the cross-section of SEM photographs. Based on the SEM observations, composites of 1473, 1498 and 1523K are well deformed and show relatively good interfaces. Matrix TiAl has deformed significantly around the fibers and the initial TiAl sheets have bonded together perfectly as like a bulk TiAl specimen. The thickness of reaction layers between SiC fiber and TiAl matrix has been strongly affected on the hot press temperatures. Optimum conditions of consolidation have been determined as following; pressure is 8.0 MPa, temperature is 1498K.

Mechanical properties of SiC/TiAl have been evaluated by means of the three points bending test using strain gauge attached on the bottom side of the specimen. Specimen (8.0 MPa, 1498K) whose fiber volume fraction was 8.0% shows bending strength was 290MPa and strain was 0.15%, respectively. Based on the three points bending data, elastic modulus for fiber direction would be calculated. Elastic constant of fiber direction is 193GPa. Youngs modulus of fiber is 400-415GPa and its matrix TiAl is 164GPa respectively, therefore, ideal elastic constants would be 182-184GPa according to apply the law of mixture. It is demonstrated that this SiC/TiAl composite material shows excellent elastic properties.

In order to examine the pull out strength of SiC fiber quantitatively, micro-indentation on a single fiber were carried out. Figure 2 shows an observation of SiC fiber pull out after micro-indentation, arrow in Fig.2 is indicating the scar of the diamond. Load cell placed under the specimen has monitored the received force during indentation. At the top, the force reached to 8.8N. The area of interface was 1.4 x 10^{-12} m^2 (specimen thickness 0.10mm, SiC fiber diameter 0.133mm). Estimated pull out strength was 202MPa, that is reasonable values since tensile strength of TiAl matrix was 505MPa and the maximum shear stress would be the half of tensile strength. Reaction layers and the interface between SiC fiber and TiAl have been analyzed by SEM-EDS and XRD. At least two or more reaction layers have been formed. These reaction layers can be explained based on the Si-Ti-C ternary equilibrium phase diagram at 1373K[7].

Summaries

SiC fiber reinforced TiAl composites have been successfully fabricated using hot press method. Optimum temperature and pressure have been determined. SiC/TiAl composite having relatively low fiber volume fraction shows nearly an ideal elastic property applying the law of mixture. Effects of interface layers on the mechanical properties of composites have been discussed.

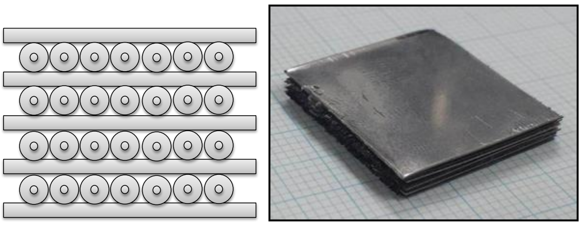

Fig. 1 Schematic drawing of SiC/TiAl arrangement and preform

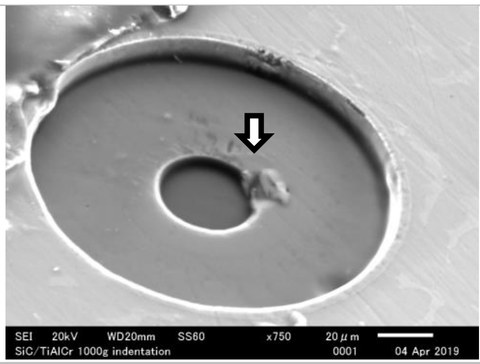

Fig. 2 Observation of SiC fiber pull out after indentation by diamond pyramid

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