§8. The Applicability of Small-sized Specimens for Tensile Property Determination of SiC/SiC Composites

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Silicon carbide (SiC) fiber reinforced SiC matrix (SiC/SiC) composites are attractive materials for fusion power reactors. In order to evaluate the effects of extreme environment particular to fusion reactors, development of small specimen test techniques (SSTT) is essential. For a simple tensile test of metals, optimized tensile testing with small specimen has been conducted to satisfy these demands. However this technique does not apply directly to ceramic matrix composites because of several complex issues characteristic in composites such as fabric architectures, anisotropy, initially induced defects and others. Therefore research on specimen size effect, which plays an important role for the establishment of SSTT, has been studied but they were not still enough. This particular work is intended to identify specimen size effect for various composites for the establishment of SSTT.

A plane-weave (P/W) and a three-directional weave (3-D) SiC/SiC composite were used for the size effect study. The composites were synthesized by the polymer impregnation and pyrolysis (PIP) process. These composite had relatively high porosity above 10 % after the PIP process and especially inter-bundle porosities were characteristic in them. Gauge sizes of each specimen were designed by the number of fiber bundles included in the cross-section. Tensile tests were carried out following general guidelines ASTM C1275.

Stress strain behaviors for all materials were mostly non-linear except for a very short linear region in the initial stage of the curves. For [±45°] directionally loaded SiC/SiC composite ([±45°] SiC/SiC), transition point, known as proportional limit, was quite a very lower than that of [0°/90°] directionally loaded SiC/SiC composite ([0°/90°] SiC/SiC). Especially stress drop for 3-D SiC/SiC was more prominent. Similarly elastic modulus had great decreases by changing loading direction. All of them were explained by anisotropy of composites mainly attributed to fiber.

Beyond proportional limit, accumulation of strain was quite different between [0°/90°] SiC/SiC and [±45°] one. For [±45°] SiC/SiC, composite strain significantly increased, with all stress increases were much little. This is because higher fiber strength, which also made composite strength higher, was attained by loaded in near longitudinal fiber direction.

Dependencies of tensile strength on specimen width indicated two characteristic tendencies (Fig. 1). One was stress decrease in larger width for 3-D SiC/SiC in the [0°/90°] direction. Another was stress decrease in shorter width for both [±45°] SiC/SiC.

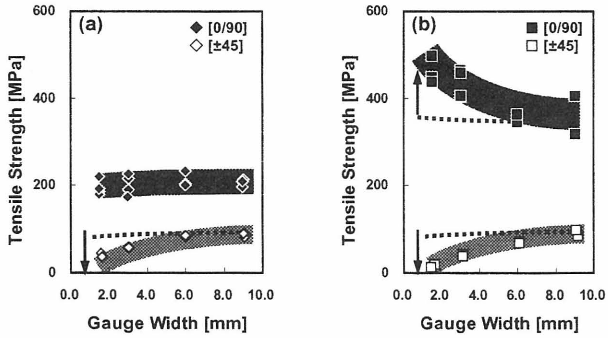

Fig. 1 Specimen width effect on tensile strength for (a) P/W and (b) 3-D SiC/SiC composites.

Strength reductions in larger width for 3-D SiC/SiC in [0°/90°] direction tests were not attributed only to the weakest link concept, often mentioned in discussing composites strength. In fact, the observed trend is more strongly related to the distribution of fibers embedded in gauge width. In order to address the effects of fabric architectures on composite strength, the discussion is focused on the volume fraction of fibers aligned in the loading direction. According to the normalized value, the dependency on specimen width nearly disappeared and normalized tensile strength for 3-D SiC/SiC became constant with no relation to specimen width. This is because for 3-D SiC/SiC variance of axial fiber volume fraction increased in shorter gauge width because of structural spacing between fiber bundles and hence composite strength had large distribution. Contrary, for P/W SiC/SiC in [0°/90°], this kind of size effect did not always occur since axial fiber volume fraction was nearly changeable.

As conclusions, specimen size effects were significantly dependent on fracture behavior of composite. Therefore it seems to be difficult to obtain the direct correlation between [0°/90°] SiC/SiC, which failed by mainly tension, and [±45°] SiC/SiC, which failed by interfacial shear. Moreover for [±45°] SiC/SiC derived by PIP process, interfacial shear strength had a great dependency on specimen width and this produced additional size effects on tensile properties. In shorter width, detachment of interface made it easy to lead to composite failure and hence composite strength became much lower. However, in larger width, interfacial shear and tension of fibers subsequently occurred after detachment of the fiber and matrix interface made composite strength quite higher. This also means that in order to reduce anisotropy of composite strength improvement of interfacial strength is critical issue in addition to controlling of the fabric architecture.

References

1) T. Nozawa, T. Hinoki, Y. Katoh, A. Kohyama, E. Lara-Curzio and M. Sato, "Influence of Specimen Geometry on Tensile Properties of 3D SiC/SiC Composites," *Ceramic Engineering and Science Proceedings*, in press.