CUMULATIVE FRACTURE BEHAVIOR OF SHORT FIBER TYPE C/SiC

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Short carbon fiber reinforced SiC matrix composites (short fiber type C/SiC) have been successfully applied to automobile brake disks, because they possess benefits of hot wear property, thermal shock resistance, light weight and lower product cost than continuous fiber reinforced C/SiC. Expanding the usage of short fiber type C/SiC requires clarification of its cumulative damage behavior. Fracture behavior of short fiber type C/SiC had been investigated by several researchers. Inoue et al. observed mixed mode crack propagation process around the notches by a Brazilian disk test [1]. The result shows that cracks around the notch tip propagate in Si and SiC phase and they stop when they reached fiber bundles. However, cracks propagate in fiber bundles when the inclination of fiber bundle to crack is greater than 30 degree. This fiber bundle inclination effect on the crack propagation angle was also confirmed by Shi et al. [2]. Consequently, crack propagation area and fracture behavior around stress concentrated area (around a notch tip) were found experimentally. In terms of mechanical properties, strength and modulus of tensile, compressive, bending were investigated well and also stress intensity factors of mixed mode I and II [1]. These earlier works only specifically examine damage processes before and after total fracture. Details of cumulative damage behavior have not yet unrevealed. This study was conducted to reveal the cumulative damage mechanism of short fiber type C/SiC under tension and compression by conducting loading-unloading tests and by measuring the stress-strain relations. The cumulative damage process and characteristics of cracks after each loading-unloading cycle were investigated. Finally, damage mechanics model was proposed to connect damage behavior and mechanical properties, mainly nonlinear stress-strain relation [3, 4].
Material tested was carbon short fiber reinforced silicon carbide fabricated by silicon infiltration process. This material was shaped into a 10 mm thick disk (diameter: 240 mm) by hot press processing. Many longitudinal fiber bundles are dispersed randomly in a plane because of the hot press process, whereas many transverse fiber bundles exit in the orthogonal plane. The fiber volume fraction was about 30%. The fiber length less than 6 mm. The material was composed mainly of carbon fiber bundles with carbon phase between them, which resembles a unidirectional carbon/carbon composite. SiC phase, Si phase and carbon phase fills between the fiber bundles. Non-negligible quantities of process-cracks exist, caused by infiltration and cooling process. Single compressive, single tensile test and loading-unloading tests were conducted to examine cumulative fracture behaviors. Unloading modulus for tensile and compressive test was measured by calculating the tangent of stress-strain relations near maximum stress under unloading. Nonlinear stress-strain relations for tensile and compression were found. For both tests, nonrecovery strain and maximum strain increased concomitantly with increased stress. The unloading modulus was identical between tensile and compressive test, and they did not change irrespective of the stress increase until total fracture, because of lack of fiber fracture and because of the small effect from transverse modulus of fiber bundle on the decrease of unloading modulus. In compression test, Cracks propagated in the fiber bundle oriented from 10 to 0 degree to the compression axis without fiber fracture, with connection to other process cracks and pores before fracture. While in tensile test, cracks propagated in the direction of 80 to 90 degree oriented to the tensile axis. Most cracks propagated in the transversely oriented fiber bundles without fiber fracture.
To elucidate the reasons for the nonlinear stress-strain relation, we propose a damage mechanics model valid under both tension and compression. The nonlinear stress-strain relation was estimated from the measured damage characteristics of through-thickness plane, where most cracks propagated. Assuming two-dimensional deflected ellipsoid cracks in the isotropic body for simplification, we infer the applicability of equations of the inelastic strain of cracks caused by each mode crack opening, mode I and mode II. The newly proposed damaged model estimated the stress-strain relation quantitatively, which suggests that the nonlinear stress-strain relation resulted from the mixed mode I and mode II crack opening.

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