Observation of Fracture Behavior of CFRP Laminates with Fiber Discontinuities

K. Onozuka[1,*],K. Iizuka[2], S. Yuan[3] and S. Yoneyama[3]

[1] Graduate School of Science and Engineering, Aoyama Gakuin University, Sagamihara, Japan
e-mail: c5625184@aoyama.ac.jp

[2]Japan Aerospace Exploration Agency, Fuchu, Japan
e-mails: iizuka.keisuke@jaxa.jp

[3]Department of Mechanical and Engineering, Aoyama Gakuin University, Sagamihara, Japan
e-mails: yoneyama@me.aoyama.ac.jp

KEYWORDS: *CFRP, Fiber Discontinuities, Cohesive Zone Model, Damage Absorption.*

Carbon fiber reinforced plastics (CFRP) is widely used in aerospace, automotive, and medical devices due to its high specific strength and stiffness. However, its brittle fracture behavior caused by sudden fiber damage and interlaminar delamination poses challenges in ensuring in structural reliability. In order to improve energy absorption, techniques for intentionally incorporating fiber discontinuities within the material's internal architecture are increasingly being explored. Tang et al. [1] demonstrated that intentionally introducing fiber discontinuities is a promising approach to achieving pseudo-ductility.To achieve pseudo-ductility in CFRP laminates, this study presents the bending fracture mechanisms via experiments and analysis.

In this study, CFRP laminates with fiber discontinuities are fabricated by applying slit processing to specific layers prior to molding. For comparison, conventional continuous CFRP laminates without fiber discontinuities are also prepared. Bending tests are conducted on each specimen using compact tabletop tester to record the load-displacement relationships and observe damage propagetion beheviors. Furthermore, in order to evaluate the complex damege evolution mechanisms-such as delaminetion and fiber damage in detail, numerical simulations using the finete element method (FEM) are employed. The Cohesive Zone Model (CZM) is applied to the analysis to accurately model the delamination propagation and the progresive stress droping process originating from the fiber discontinuities.

The bending test result reveals that the continuous CFRP exhibited typical brittle failure, where fiber damage occurred immediately after reaching the maximum load, resulting in an instantaneous loss of load-carrying capacity. In contrast, the specimens with fiber discontinuities do not show a severe stress drop after the peak load. Instead, delamination and interlaminar damage originating from the fiber discontinuities are observed to propagate progressively. Due to this progressive failure, the CFRP with fiber discontinuities maintain a certain level of load-carrying capacity until complete fracture, exhibiting pronounced pseudo-ductile behavior. Additionally, the energy absorption capacity, calculated from the area under the load-displacement curves, is confirmed to be significantly improved compared to the conventional materials.

[1] J. Tang, Y. Swolfs, M. Yang, K. Michielsen, J. Ivens, S.V. Lomov, L. Gorbatikh, Discontinuities as a way to influence the failure mechanisms and tensile performance of hybrid carbon fiber/self-reinforced polypropylene composites, *Composites*, Part A 107, 354–365, 2018