論 文 の 内 容 の 要 旨

論文題目　　Fracture behaviors and design optimization of chopped carbon fiber tape reinforced thermoplastics structures
（炭素繊維テープ強化熱可塑性複合材料部材の破壊挙動と設計最適化）

氏　　名　　郭　啓濤

Carbon fiber reinforced plastics (CFRP) are increasingly used in the primary structural components of vehicles and aircraft due to exhibiting high specific moduli and strength. However, the applications of conventional continuous fiber composites are limited by the high manufacturing costs and complex shape formability issues of these materials. In contrast, discontinuous carbon fiber reinforced thermoplastics (DCFRTP) are well suited for high-cycle and complex shape molding, being viewed as favorable materials for mass-produced vehicles. Consequently, chopped carbon fiber tape reinforced thermoplastics, one kind of randomly oriented strands (ROS) composites, have recently attracted increased attention.

Complex-shaped structures (e.g., L-shaped or hat-shaped ones) are frequently encountered in aeronautical and automotive applications. The curved sections of these structures are considered to be their weakest points due to the out-of-plane stresses induced by external loadings. Therefore, with the emergence of ROS as structural materials of mass-produced automobiles, studies on delamination behavior in ROS should be conducted. Besides, hat-shaped hollow beam, one of the main frame structural members of automobiles, requires high stiffness for vehicle maneuverability and high energy absorption for collision safety. This work aims to characterize fracture behaviors and design optimization of complex structures made from ultra-thin chopped carbon fiber tape reinforced thermoplastics (UT-CTT).

The interlaminar fracture toughness and interlaminar tensile strength of UT-CTT were theoretically, experimentally and numerically determined. Double cantilever beam (DCB, mode I) and end notched flexure (ENF, mode II) were studied to experimentally determine the interlaminar fracture toughness, while interlaminar tensile strength was determined using L-shaped specimen under four-point bending test. Furthermore, numerical analysis utilizing the surface-based cohesive zone model based on the triangular traction–separation law was used to predict the delamination behavior in UT-CTT. The numerically predicted load-displacement curves showed good correlation with the theoretical and experimental results.

Comprehensive experiments and fracture simulation method were proposed to study fracture mechanisms characteristics of UT-CTT hat-shaped hollow beam under transverse static and impact loadings. The numerical model was to incorporate some hypothetical inter-layers in UT-CTT and assign them with the failure model as cohesive zone model, which can perform non-linear characteristics with failure criterion for representing delamination failure. The dynamic material parameters for the impact model were theoretically predicted with consideration of strain-rate dependency. It shows that the proposed modelling approach for interacting damage modes can serve as a benchmark for modelling damage coupling in composite materials.

Strength-based optimization and lightweight optimization of complex structures under single flexural loading and multi-loadings were studied to show potential applications of UT-CTT for mass-produced vehicles by taking full advantage of the merit “thickness variation”.