博 士 論 文 （要 約）

Internal geometries and mechanical properties of discontinuous carbon fiber reinforced thermoplastics

（不連続炭素繊維強化熱可塑性樹脂の内部形態と力学特性）

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Discontinuous carbon fiber reinforced thermoplastics (DCFRTP) are the combination
of randomly oriented discontinuous fibers having considerable complex-shaped
molding capabilities with the thermoplastics resins exhibit superior cycle molding
time and good in-plant recyclability. Consequently, DCFRTP are regarded as
potential substitutes for metallic materials applied in mass-production (e.g.
automotive manufacturing industry) fields.

The main barriers obstruct the DCFRTP from industrial applications at present are
the comprehensive understanding of fabricating, material compositions and
mechanical properties. Through this thesis, two kinds of DCFRTP with different
components and fabrication processes, carbon fiber mats reinforced thermoplastics
(CMT) and chopped carbon fiber tapes reinforced thermoplastics (CTT), are analyzed
in detail on the aspects of internal geometries and mechanical properties to achieve
further insight on the material researches and industrial applications of these
composites.

Two different X-ray micro-CT methodologies, VoxTex and TRI/3D-BON, were
developed. Multi-scale internal geometry analyses were conducted on CMT and CTT
to investigate the structural features in fiber-, layer- and macro-level. Limitations
and restrictions of X-ray facilities on the X-ray analysis were discussed in detail and

solved statistically. The relationships between the internal geometry and fabricating properties like molding conditions and component sizes were revealed quantifiably. In CTT, higher molding pressure was found can decrease the structure regularity due to tape splitting, and the tape length exhibits positive effect on increase the layer independence through thickness direction. The out-of-plane waviness and out-of-plane orientation tensor calculated from tape thickness of CTT show considerable linearity with corresponding tensile properties. The internal geometry properties like orientation tensors and layered orientation distributions were collected from the two X-ray micro-CT methodologies to achieve precise descriptions of CMT and CTT.

Two different analytical simulation methods, Mori-Tanaka method and equivalent laminate method were applied with tensile tests to evaluate the tensile properties of CMT and CTT in different fabricating processes and components. Fiber orientation tensors calculated from 3D-BON method were applied to the Mori-Tanaka methods and internal geometry properties collected from the VoxTex method were input to the equivalent laminate methods. The aspect ratio of reinforcements and components properties of CMT and CTT were also studied in detail to increase the accuracy and reliability of simulations. The CTT exhibit higher Young's moduli with lower tensile fracture strain compare with CMT. Considerable results were achieved in both the Mori-Tanaka method and equivalent laminate method simulation of CTT indicated good CAE capability. The Mori-Tanaka method provided better accuracy in tensile moduli while the equivalent laminate method demonstrated considerable tape length dependency on the tensile strengths due to the simplification processes during the modeling. Determination of optimal strand aspect ratio of CTT is given by the simulation methods based on the comprehensive consideration of mechanical simulation results with manufacturing conditions.

The combination of X-ray micro-CT methods and analytical simulation models open the new ways for comprehensive solution methodologies of DCFRTP analyses with the criterions and suggestions of DCFRTP applications.