論 文 の 内 容 の 要 旨

論文題目　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）

氏　　名　万　熠

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 obstructing the DCFRTP from industrial applications at present are the lack of 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 applied. 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, it was found that higher molding pressure can decrease the structure regularity due to tape splitting, and the tape length exhibits positive effect on increasing the layer independence through thickness direction. The out-of-plane waviness and out-of-plane orientation tensor calculated from tape thickness of CTT showed 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.

Tensile tests and two different analytical simulation methods, Mori-Tanaka method and equivalent laminate method were applied 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 compared with CMT. Considerable results were achieved in both the Mori-Tanaka method and equivalent laminate method simulations of CTT, while the simulation results of CMT generally overestimated the tensile properties. This difference indicated the difference in CAE capability between CTT and CMT. 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 different 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.