論 文 の 内 容 の 要 旨

論文題目　Characterization of flow behaviors during compression molding of chopped carbon fiber tape reinforced thermoplastics

（炭素繊維テープ強化熱可塑性樹脂圧縮成形時の流動挙動）

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Carbon fiber reinforced thermoplastics (CFRTP) have been the subject of various studies in the aerospace and automotive technologies for recent years because of their high mechanical performance and possibility for a mass production process. Although the actual mass production of the composite system are achievable when those are linked to the automated, continuous and rapid processing, there have been particular advances and challenges. Chopped carbon fiber tape reinforced thermoplastics (CTT) describes the thermoplastic composite system, prepared by preform sheets consisting of chopped pre-impregnated tapes, and molding technologies. The thermoplastic composite has the potential for achieving the features of cost effective process because the composite can be classified as randomly oriented strands (ROS) composites with multi-axial discontinuous strands. Therefore, the formed CTT parts (>50%) exhibit balanced properties in terms of both reliable mechanical performance and ease of forming.

Much of recent efforts has been investigated in experimental evaluations of mechanical properties and internal geometry analysis using final molded CTT samples in a range of minimizing the possible defects. On the other hand, even though the forming of the material generally does not require impractical forming conditions, flow behaviors of the material have not been clarified under current circumstances. Thus, it is valuable to characterize flow behaviors such as forming characteristics and relevant flow mechanisms in forming of CTT components. The efforts aim to investigate influential factors on forming behaviors and build the related governing equations using purposeful and systematic approaches.

This study aims to encompass various aspects of flow and rheology, which significantly are related to the processing efficiency and cost effective use of materials. In order to specifically discuss the objective, this study is divided into three main parts for characterizing flow behaviors of CTT composites. In Chapter 1, the recent achievements of comparable composite systems are introduced, mainly related to fiber filled thermoplastic composites. The forming techniques for highly filled composite systems at the temperature above the melting point are dissimilar to the typical polymer processing techniques with the low volume fraction of fillers (diluted suspension). In the case of former, forming techniques are not easy to align filler directions, whereas the flow of polymer melt and its velocity field highly affect filler orientation in the latter case. It leads the constraints of the former case when approaching to the methods from a fluid mechanics perspective. It is necessary to embrace an alternative methodology compared to the conventional ways of analyzing polymer melts.

Chapter 2 and 3 involve to experimentally demonstrate the relations between forming parameters and forming behaviors in the given cases in various forming conditions. Chapter 2 focuses on identifying formability of CTT parts in various forming conditions in the given geometry with complex features. Chapter 3 is devoted to an experimental observation of flow progression and validation of defect formation, which are closely related to forming complex parts. It is possible to observe the flow front during compression molding of CTT suspensions in particular forming conditions using a unique mold configuration. Several squeeze flow tests are designed to discuss forming conditions and mold filling behaviors to create a valid comparing group for numerical simulation.

Chapter 4 presents a characterization of rheological properties adapted from valid theoretical approaches for shear viscosity of fiber filled suspensions. With the approaches, shear viscosity of CTT suspensions is expressed in the form of the Herschel-Bulkley fluid model with yield stress. In particular, preform preparation and deformation mode are dominant issues because the assumptions applied in the methodology are closely connected with an internal geometry such as fiber orientation and sample consistency.

Chapter 5 contains the results of thermo-mechanical behaviors by employing a thermo-mechanical analyzer. This study aims to obtain coefficients of thermal expansion (CTE) and deduce corresponding volumetric thermal expansions, which are significant aspects of process modeling for thermoplastic composites. The measured results clearly deliver anisotropic properties of materials, and the results are analyzed by defining CTE in principal directions, and suggest a valid interpretation for fiber reinforced composites.

Eventually, most of the essential issues for applying numerical approaches are assessed and characterized; formability, squeeze flow behaviors, defect formation in manufacturing, rheological properties, and thermo-mechanical properties. Much of efforts has been primarily focused on establishing the baseline for process modeling in CTT manufacturing. Therefore, the efforts possibly guide one to achieve the design of mold frames, drawing a processing window for newly developing products with a geometric feature, the deduction of optimal processing conditions, and finally the cost-effective usage of materials. It is expected to promote commercial applications of the material in an industrial field by offering systematic and practical solutions in cases when utilizing the m the materials.