Compressive Properties of Laminates with UACS Plies and Their Applications to the Crashworthy Structure

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https://doi.org/10.15017/1785391

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論 文 名　：Compressive Properties of Laminates with UACS Plies and Their Applications to the Crashworthy Structure
（UACS 積層板の圧縮特性および耐衝撃性構造への応用に関する研究）

区　　分　：甲

論 文 内 容 の 要 旨

In this dissertation, highly aligned discontinuous fibre reinforced composites, namely, unidirectionally arrayed chopped strands (UACS) are proposed to improve crashworthiness properties of conventional continuous fibre reinforced composite. The basic strategy is by developing a new trigger function directly in the interior of composite laminate, thus making the failure process in a controllable way and increasing energy absorption performance of structure. These concepts offer scope through shearing slit at small inclined angle of 11.3° in intra-laminar region and reduce catastrophic failure through suppression of delamination at inter-laminar region to ensure that the laminated structure is progressively collapsed in a controlled manner. Static compression test and progressive crushing test for UACS quasi-isotropic laminates, cross-ply laminates with UACS 0° plies, and cross-ply circular tube with UACS 0° plies were carried out to investigate the compressive properties of UACS quasi-isotropic laminates and the feasibility of applying UACS plies to automotive crashworthy structure. This dissertation consists of following five chapters.

Chapter 1 introduces the general background of composite crashworthiness, its challenges on automotive structural application, overview of previous research on the UACS laminates, and the motivation of the present study.

Chapter 2 describes experimental investigation on compressive and progressive crushing properties of quasi-isotropic bi-angle UACS laminates with different slit angles. Fabrication of bi-angle UACS laminates and experimental procedure are described in detail. The effects of three different slit angles in UACS laminates with bi-angle configuration on their compressive stiffness, strength, and energy absorption ability are clarified. For a benchmark, conventional quasi-isotropic laminate without slit was also fabricated and tested. Experimental results showed that UACS laminate with 11.3° bi-angle slits has the highest compressive strength, which is 88% of the compressive strength of conventional laminates without slit, compared to UACS laminates with 27.5° and 45° bi-angle slits. Furthermore, UACS laminate with 11.3° bi-angle slits has comparable energy absorption ability with conventional laminates without slit. These results implied that highly aligned short fibre reinforced composites has acceptable compressive properties and comparable energy absorption ability in progressive crushing process compared to continuous fibre reinforced composites.

Chapter 3 presents a research on the compression and crush responses of cross-ply laminates with UACS 0° plies. Cross-ply laminates of $[0/90]_{4s}$ and $[90/0]_{4s}$ with different kinds of UACS 0° plies were chosen to investigate the effect of UACS 0° plies on the compression and progressive crushing properties of laminates. UACS plies with bi-angle slit pattern and staggered pattern were used as 0° ply, respectively, instead of conventional continuous fibre ply. Static compression tests and progressive crushing tests were carried out to explore the feasibility of applying UACS ply to crashworthy structure to make the failure process in a controllable manner and increase energy absorption performance of structure. Test results showed that the $[0/90]_{4s}$ and $[90/0]_{4s}$ laminates with UACS 0° plies of bi-angle slit pattern improved the energy absorption compared to conventional cross-ply laminate without slit. These results implied the potential of UACS ply in the crashworthy structure application.

Chapter 4 investigates the progressive crushing behavior of cross-ply composite circular tube with UACS 0° plies. Two kinds of UACS 0° plies with bi-angle slit pattern and staggered slit pattern were used as 0°plies in the fabrication of composite circular tubes instead of conventional continuous fibre 0° plies, respectively. Prepreg based fabrication technique was used for the fabrication of cross-ply composite circular tube and progressive crushing tests for various tubes were carried out. For a benchmark, conventional cross-ply composite circular tube with continuous fibre 0° plies was also fabricated and tested. Furthermore, progressive crushing tests for steel circular tube and E-glass/polyester square tube were also conducted for a comparative study. Test results showed that composite circular tubes with UACS 0° plies have higher energy absorption ability than conventional tubes with continuous fibre 0° plies. These facts further validated the feasibility of applying laminate with UACS plies to automotive crashworthy structure.

Chapter 5 summarises the major results of the dissertation and suggests some future research topics which may concern to this study.