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Failure Prediction of Composite Laminates under Out-of-Plane Loading

Jin-Sung Kim, Dong-Guk Choi, Soo-Yong Lee, Jung-Sun Park
School of Aerospace and Mechanical Engineering/Korea Aerospace University
76, Hanggongdaehang-ro, Deogyang-gu, Goyang-city, Gyeonggi-do, South Korea
jinsungkim83@naver.com; codnkk@naver.com; sylee@kau.ac.kr; jungsun@kau.ac.kr

Extended Abstract

Composite materials are widely used in various fields including aerospace and automobiles because they have higher stiffness-to-weight and strength-to-weight ratio than metal materials. Composites can be fabricated to meet design requirements by changing their laminate configurations. For the structural stability of the composite structures, one of reliable failure theories should be applied in order to accurately predict the failure under given loading conditions for any chosen laminate configuration. Over the past several decades, there are numerous failure criteria proposed to more accurately predict the failure of composite laminates. Validity and reliability of composite failure criteria are well studied for in-plane loads. [1, 2] However, similar studies are quite limited in number for out-of-plane loads. In many industrial applications, composite structures are subjected to out-of-plane loads as well as in-plane ones. Mechanical behaviour of composite plates can be quite different depending on loading conditions. Even if a failure criterion is suitable for the in-plane loading condition, it cannot be suitable for out-of-plane loads. For this reason, it is necessary to evaluate the validity of the failure criteria for out-of-plane loads.

In this study, the failure behaviour of composite laminates under flexural loading is investigated. The non-linear finite element analysis is performed by using a piecewise linear incremental approach to describe nonlinear material behaviour. 2D strain-based interactive failure theory [3] is applied to more accurately predict the final failure of multidirectional laminates under multi-axial loading. A three-point bending test based on the ASTM D790 are performed for un-symmetric cross-ply $[0/90]_8$ and quasi-isotropic $[0/\pm45/90]_{2s}$ composite laminates. The analysis results are compared with the test results. Also, they are compared with the other failure criteria such as maximum strain, maximum stress and Tsai-Wu theories. Finally, 2D strain-based interactive failure theory shows more reasonable accuracy for the final failure prediction than other failure theories.

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