SIMULATION ON DAMAGE IN QUASI-ISOTROPIC UNIDIRECTIONALLY ARRAYED CHOPPED STRANDS LAMINATES UNDER OPEN-HOLE TENSION

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Keywords: UACS laminates, Open-hole, Strength, Damage simulation, Finite element analysis

ABSTRACT

Fiber reinforced composite materials are now replacing the traditional metallic materials and widely used in aircraft, marine, automotive structures, and so on, due to the advantages such as low density, high stiffness and high strength etc. It is relatively easy to apply CFRP with continuous fibers to large and flat or straight structural components, but it is not so simple to apply such CFRP to other structural components with various complicated geometries due to the poor flowability of CFRP in the fiber direction. Therefore, injection molding and sheet molding compound (SMC) are widely used in fabricating structural components with complex shapes because of its excellent formability and relatively low cost. However, the random spacial distribution of fibers and relatively low fiber volume fraction lead to low stiffness and strength compared to conventional CFRP with continuous fibers. To improve the strength and stiffness of short fiber reinforced polymers (SFRP), Unidirectionally arrayed chopped strands (UACSs) are proposed by introducing parallel and angled continuous or discontinuous slits into a unidirectional carbon fiber prepreg. Previous studies [1-4] indicate that UACS laminates have higher strength and modulus than conventional SFRP due to the high aligned fibers and high fiber volume fraction, and show superior formability. In practical engineering application, most of composite laminates usually require the presence of holes or cut-outs. Damage will initiate and grow from these notches due to the stress concentration and finally result in strength or life reduction of composite structures [5,6]. Over the past decades, many approaches have been proposed to investigate the open-hole strength and failure modes of composite laminates [7-9]. Therefore, it has the vital significance to understand the mechanical behavior, crack propagation and damage mechanism of UACS laminates with a central hole under various loads. In order to simulate the progressive damage and mechanical properties of open-hole UACS laminates with stacking sequences of [45/0/-45/90]s and [45/0/-45/90]2s, finite element analysis is used to simulate the open-hole tensile damage of UACS laminates and conventional CFRP, respectively. To accurately simulate the progression of delamination and other damage modes occurring in the UACS laminates near the hole, intra-laminar cohesive elements and inter-laminar cohesive elements are inserted into the slits and the interfaces, respectively. Good agreements are obtained between the elastic constants from experimental results and finite element analysis, and certain limitations of the finite element models are observed and discussed. Numerical results such as the onset and propagation of the damage, the delamination propagation process and the final failure modes are captured, and show good agreement with experimental results. The combined experimental and numerical studies provide a detailed understanding of the tensile behaviour of open-hole UACS laminates, and also indicates that the model is applicable to analysis of progressive damage of open-hole UACS laminates under tensile load.

[1] Li H, Wang W X, Takao Y, et al. New designs of unidirectionally arrayed chopped strands by introducing discontinuous angled slits into prepreg[J]. Composites Part A: Applied Science and Manufacturing, 2013, 45: 127-133.
[2] Li H, Wang W X, Matsubara T. Multiscale analysis of damage progression in newly designed UACS laminates[J]. Composites Part A: Applied Science and Manufacturing, 2014, 57: 108-117.
[3] Xue J, Wang W X, Zhang J Z, et al. Experimental and numerical study on the tensile behaviour of UACS/Al fibre metal laminate[J]. Applied Composite Materials, 2015, 22(5): 489-505.
[4] Xue J, Wang W X, Hu J F, et al. Influence of fiber length on the tensile behavior of fiber metal laminates with discontinuous reinforcement[J]. Journal of Reinforced Plastics and Composites, 2015: 0731684415594890.
[5] Zhuo Y, Guan Z D, Zhou R, Tan R M. Test on progressive damage of open-hole composite laminates under compression load[J]. Acta Materiae Compositae Sinica, 2015, 32(6): 1762-1768.
[6] Bao H C, Liu G Y. Simulation on damage in quasi-isotropic fiber-reinforced composite laminates under open-hole tension[J]. Acta Materiae Compositae Sinica, 2016, 33(5): 1026-1032.
[7] Bao H, Liu G. Progressive failure analysis on scaled open-hole tensile composite laminates[J]. Composite Structures, 2016, 150: 173-180.
[8] Zheng Y, Cheng X, Yasir B. Effect of stitching on plain and open-hole strength of CFRP laminates[J]. Chinese Journal of Aeronautics, 2012, 25(3): 473-484.
[9] Su Z C, Tay T E, Ridha M, et al. Progressive damage modeling of open-hole composite laminates under compression[J]. Composite Structures, 2015, 122: 507-517.