Three-dimensional analysis of transverse crack fiber bridging in laminated composite plates

D.H. Li

PII: S0263-8223(16)32479-5
DOI: http://dx.doi.org/10.1016/j.compstruct.2016.12.066
Reference: COST 8121

To appear in: *Composite Structures*

Received Date: 10 November 2016
Accepted Date: 23 December 2016

Three-dimensional analysis of transverse crack fiber bridging in laminated composite plates

D. H. Li*

College of Aeronautical Engineering, Civil Aviation University of China, Tianjin 300300, China

Abstract

A three-dimensional analysis method for the fiber bridging of transverse crack in the laminated composite plates was established by the extended layerwise method (XLWM), taking into account the influence of interlaminar delamination. In this method, the composite plate with delamination and transverse crack is simulated by XLWM, and the bridging fibers are simulated by three-dimensional bar elements. The governing equation of composite with damages and fiber bridging can be obtained from combining the equations of plate and fibers by the displacement compatibility conditions at the plate-fiber coupling interfaces. In order to obviate remeshing and reduce the modeling difficulties resulted from the meshing consistency requirement of plate and fibers, the displacements of fibers are expressed in terms of the interpolation polynomials employed in the element of each sublayer in composite plates. In the numerical examples, the plates with central and edge crack were investigated firstly to validate the proposed method, and then the effects of the fiber bridging on the opening displacement, the stress distribution in fibers and the stress intensity factor (SIF) of crack tips were investigated for the transverse crack in composite plates. The fiber bridging of the composite plates with delamination and transverse crack was considered as well.

Keywords: Composite plates; Fiber bridging; Extended layerwise method; Transverse crack; Delamination.

1. Introduction

The matrix in the composite materials serves to hold the fibers together and distributes the loads of fibers, while the function of fibrous reinforcement is to carry the external loads. The properties of matrix and bonding between fiber and matrix dominate the mechanical properties of composite materials. The matrix and matrix/fiber interaction are also the critical factors of the crack propagation. For the composites with high strength and modulus matrix and fiber/matrix bond strength, the crack may through the fiber and matrix directly. For the composites with low fiber/matrix bond strength, the matrix would act as a fiber bundle and the composite be very weak. For the composites with intermediate bond strength, the propagation of the cracks in resin or fiber would turn at and grow in the fiber/matrix interface. The composites failed in this mode would show considerable fiber pull-out and fracture surface would be very rough, it results in absorption of considerable energy and lengths of bare fiber being visible. The crack bridging mechanism will take effect unless the intact bridging fibers appear behind the crack front. Therefore, the stress intensity factor (SIF) of crack tip would reduced significantly due to the unloading effect of bridging fibers[1–3]. The debonding and pullout would increase the fracture toughness of transverse crack with bridging fibers, and the strength and fracture toughness of fiber reinforced composites is governed by the interplay of different damage processes. Therefore, the fiber bridging effect of transverse crack and delamination is a very important and challenging problem to understand the damage mechanism of composites, and many analysis methods had been established in the last thirty years. The main approaches of the cracking fiber bridging in composites include the fracture mechanics, the energy balance based models, the shear lag based model, and the discrete micromechanical/unit cell models[4].

☆Supported by the Natural Science Foundations of China (11502286) and the "Blue Sky Young Scholar" plan of Civil Aviation University of China

*Corresponding author

Email address: lidinghe@163.com (D. H. Li)