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A. Muc, P. Romanowicz

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Effect of notch on static and fatigue performance of multilayered composite structures under tensile loads

A. Muc, P. Romanowicz

Institute of Machine Design, Cracow University of Technology, Kraków, Poland

Abstract: Fatigue failure of laminated composites containing circular or elliptical (vertical and horizontal) holes and subjected to tension was studied. This research investigates the stress components, the initiation and propagation of static and fatigue damage and failure in notched composite laminates by analytic method and FE model, both of which are validated by experimental tests. The major focus was to understand the failure mechanisms of composites induced by stress concentrations, and to determine the effects of ply orientations, material properties and geometry on the fatigue damage. It was demonstrated that the crack initiation and growth was connected with the interaction of the stress intensity factors (SIFs) K_I and K_{II}.

Keywords: *Fatigue; Laminated plates and shells; Elliptical and circular holes; Stress concentrations; Inclined cracks; Experimental analysis.*

1. Introduction

Fracture resistance under fatigue loading of metallic materials is usually described either using stress versus number of cycles to failure curves (S-N curves) or analyzing fatigue crack propagation using crack speed versus applied stress intensity factor range curves (da/dN-ΔK curves). Still, methodologies for life prediction developed for metals have been carried over to fatigue of composite materials, resulting in heavy reliance on empirical data and lack of reliability although fatigue of continuous fiber reinforced polymer matrix composites has little in common with metal fatigue. In general, failure in a lamina lying within a laminate initiates in fibers or in the regions between fibers (matrix cracking or fiber debonding). The damage mechanisms involving fiber breakage are distinctly different from those that initiate cracking in the matrix or/in at the matrix-fiber interfaces. The laminated nature of composite structures can result also in tendency for delamination during service. This may be caused by direct out-of-plane loading or at features such as cut-outs or ply-drops which induce high through-thickness stresses. In addition, the fatigue damage mechanisms are depending on a great number of various factors that including: type of composite constituents (i.e. fiber type and matrix type), fiber architecture (unidirectional, mat, fabric, braiding, etc.), laminate stacking sequence, manufacturing defects, environmental and loading conditions.

A number of reviews have presented state-of-the-art understanding of the damage mechanisms in composite fatigue. It is worth to note that the majority of experimental fatigue tests on unidirectional composite materials with different stacking sequences are usually conducted in uni-axial tension/tension or tension/compression fatigue loading modes [1-5]. They are performed according to the regulations of international standards (ASTM D3479) and provide the appropriate S–N data for the tested materials.