CHARACTERISATION OF CRACK NETWORK IN LAMINATED COMPOSITES USING TOMOGRAPHY OBSERVATIONS ON LOADED SAMPLE

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Summary: This communication focuses on the experimental procedure used to characterize the crack network in laminated composites. Damage was produced sequentially with the help of increasing load step on a tensile machine. A dedicated device was designed to apply a sufficient tensile load on the sample in order to open the cracks during the computation of tomography pictures.

1. Introduction

Designing liner-less composite vessels for launch vehicles enables cost and weight savings at the same time, and is therefore a core issue for aerospace industry. One challenge of this application is to reach the permeability requirements with the composite wall itself. Pristine composite laminate meets the permeability requirement, but damage growth may occur for low thermo-mechanical loading cases, with very little effect on the stiffness. Transverse cracks and micro-delamination in adjacent plies may connect together, resulting in a leakage network through the composite wall (see Fig. 1(a)) [1,2]. The aim of this study is to provide a relevant description of damage growth and the resultant network for leakage prediction. This work is based on an experimental analysis which aims at developing a damage meso-model built on strength and energy criteria as proposed in FFM (Finite Fracture Mechanics) [3].

This communication focuses on the experimental procedure used to characterize the crack network in laminated composites produced by mechanical loading.

A first work based on cross section examinations with an optical microscope through the width of specimens submitted to tensile loading demonstrates that damage densities are significantly affected by edge effect [4]. For example, after removing by abrading and polishing a few microns of the edge, in $[0_2/90_n/0_2]$ lay-ups, delamination almost disappears and in $[+45/-45]_s$, transverse cracks almost disappears. However, the observation of crack connexions between adjacent plies is fastidious with cross section examinations. An experimental procedure based on computed tomography was therefore set up.

2. Experimental method

The crack density defined as the mean distance between transverse cracks is in the order of magnitude of 1mm. Thus, the observation of the crack network and specially the crack connexion requires an observation size close to 10mm which leads to a resolution (size of voxel) higher than 5µm. Without loading, crack opening is lower than this resolution making the observation of damage impossible. The experimental procedure is therefore based on observations made on loaded sample. However, because of the material properties of Carbone Fibre Reinforced Polymers (CFRP) used for spatial applications, a high load is required to develop damage. So, the role of the experimental device designed for this test was only to keep a sufficient tensile load on the sample during the computation of tomography pictures in order to sufficiently open the cracks. Damage was produced sequentially with the help of increasing load step on a tensile machine and tomography was performed after each loading step.

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3. Results

Figure 1(c) shows a tomography picture on a [0/+67.5/-67.5$_2$/+67.5/0] laminate which highlights a regular pattern of short cracks in the two +67.5 plies connected to a long transverse crack in the -67.5° ply. Successive observations demonstrate that the long transverse crack is created first and that density of short cracks increases progressively. This result points out the high interaction between the damage processes of adjacent plies and will be very useful for the modelling of damage.

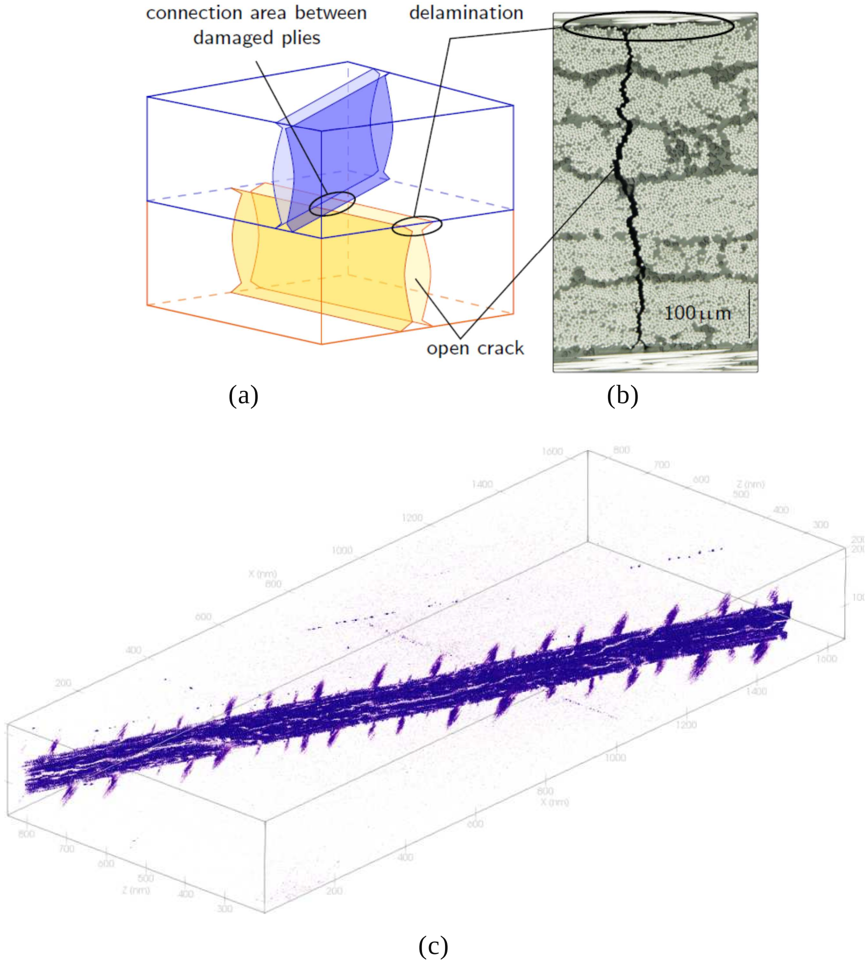

Figure 1: (a) Transverse crack and delamination: crack network in two damaged plies and (b) micrograph of one transverse crack with delamination at crack tip, (c) tomography picture of a [0/+67.5/-67.5$_2$/+67.5/0] composite laminate

References

[1] H. Kumazawa, T. Aoki, I. Susuki, Analysis and Experiment of Gas Leakage Through Composite Laminates for Propellant Tanks, AIAA J. 41 (2003) 2037–2044.

[2] C. Bois, J.-C. Malenfant, J.-C. Wahl, M. Danis, A multiscale damage and crack opening model for the prediction of flow path in laminated composite, Compos. Sci. Technol. 97 (2014) 81–89. doi:10.1016/j.compscitech.2014.04.002.

[3] D. Leguillon, Strength or toughness? A criterion for crack onset at a notch, Eur. J. Mech. ASolids. 21 (2002) 61–72.

[4] H. Laeuffer, B. Guiot, J.-C. Wahl, N. Perry, F. Lavelle, C. Bois, A model for the prediction of transverse crack and delamination density based on a strength and fracture mechanics probabilistic approach, in: ECCM17 - 17TH Eur. Conf. Compos. Mater., Munich, Germany, 2016.