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Moisture absorption effect on the stress distribution of the cross-ply laminates with transverse matrix cracks

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Abstract

The purpose of this paper is to investigate the moisture absorption effect on the stress distribution of the cross-ply laminates with transverse matrix cracks. Two analytical models were used to evaluate the stress distribution, Shear Lag and the variational approach. The results show that a complete parabolic variation of displacement gives a good approximation of the stress distribution compared to the finite element analysis. Furthermore, the cracked cross ply laminate is submitted different temperature and moisture concentration distribution. The predicted model shows that moisture absorption has a significant effect on the stress distribution especially at the higher crack density.

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Keywords: Transverse cracking, Longitudinal stress, Hygrothermal effect, Cross ply laminates; Moisture absorption

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1. Introduction

The evolution of the transverse cracking in the 90° layers was characterized in 1977 by Reifsnider (1977) and Garrett and Bailey (1977) for cross-ply laminates loaded in the 0° ply direction by static or fatigue traction test. Then developed in many analyses in the literature (Boniface and Ogin 1989, Groves et al. 1987) where they provide a means of evaluating the different hypotheses of the approaches and their consequences on the material properties of cracked laminates.

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The modeling of transverse cracking is generally schematized by the models which make the analysis of the shear transfer between fiber and matrix (Berthelot 1997, Berthelot and Le Corre 1999) with the assumption that the mechanical loading is transferred between the layers to 0° and 90° via a fine layer located at the interface between the layers. The authors (Hashin 1985, Varna and Berglund 1992) propose a law of evolution of the transverse cracking which considers that the normal ply stresses in load direction are constant over ply thickness. The approximate solution is obtained by minimizing complementary energy in the two layers of the laminate.

In this paper, two analytical models have been studied and compared with the finite element method, the shear-lag model modified by introducing the stress perturbation function and the variational approach, are used to predict the effect of transverse cracks on the stress distribution. Then, the longitudinal stress reduction due to transverse ply cracking in cross-ply laminate when this latter is initially exposed to the moisture absorption is taken into account. The obtained results illustrate well the dependence of the stress distribution on the cracks density, temperature and humidity variation and moisture absorption.

2. Stress distribution analyses

2.1. Shear lag model

The problem to solve is the problem of elasticity of the cracked laminate. Like any elasticity problem, the exact solution is to look in the elementary cell of the displacement and stress field, at each point satisfying the equilibrium equations, strain-movement relations, the compatibility conditions, the continuity conditions at the borders and the behavior laws in 0° and 90°-layers. We consider a symmetric cross-ply laminate which is subjected to uniaxial loads. It is assumed that the 90 ° ply has developed continuous intralaminar cracks in fiber direction which extend from edge to edge in the z direction. The cross ply laminate is characterized by $2.t_{90}$ the width of 90° ply, t_0 the width of 0° ply and the spacing between two cracks is $2.l_0$ (Fig. 1).

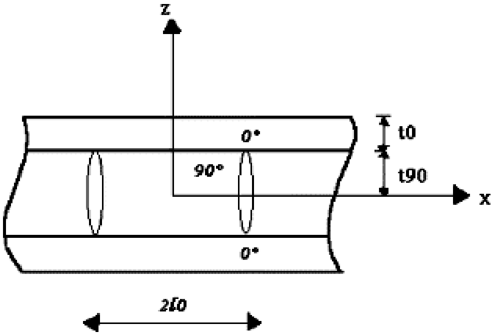

Fig. 1. Transverse cracked cross ply laminate and geometric model

The longitudinal displacement in both layers 0° plies and 90° ply is (Berthelot 1997):

$$u_0(x,z) = \overline{u_0}(x) + f(z)A_0(x) \tag{1}$$

$$u_{90}(x,z) = \overline{u_{90}}(x) + \left(z^2 - \frac{t_{90}^2}{3} \right) A_{90}(x) \tag{2}$$

Where $\overline{u_0}(x)$ and $\overline{u_{90}}(x)$ are the average longitudinal displacements in 0° plies and the 90° ply, respectively.

$A_0(x)$, $A_{90}(x)$ and $f(z)$ to be determined.