THERMO-ELASTIC PROPERTIES OF NON-UNIFORMLY DAMAGED LAMINATES AT HIGH CRACK DENSITY

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Intralaminar cracking in laminates is the most typical mode of damage in laminates. Due to this kind of microdamage the laminate undergoes stiffness reduction when loaded in tension. Stiffness reduction simulation in damaged laminates is usually performed assuming that cracks are equidistant and crack density is the only parameter needed [1].
However, the crack distribution in the layer may be highly non-uniform as schematically shown in Fig.1, especially in the initial stage of multiple cracking.

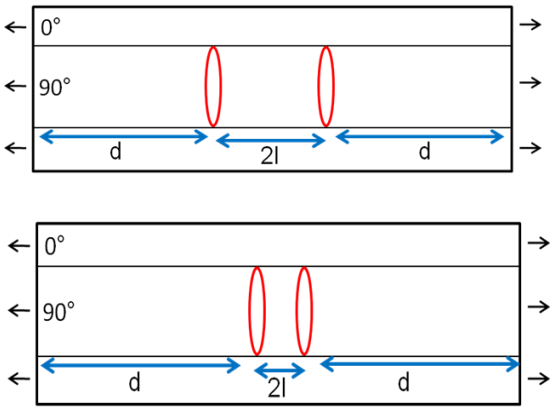

Fig.1. "super element" models for COD studies with non-uniformly cracked 90-layers.

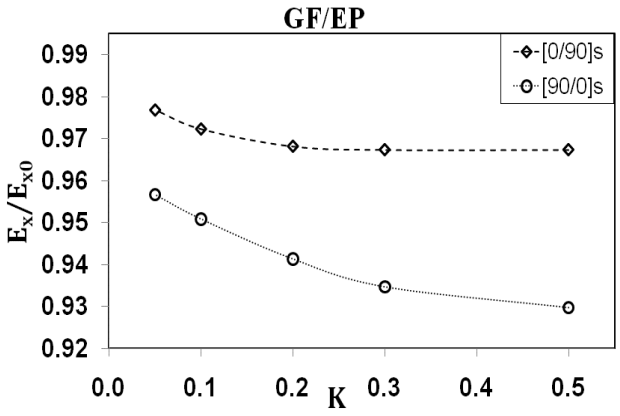

Fig.2. Effect of non-uniform crack distribution on axial modulus of GF/EP cross-ply laminates with normalized crack density $\rho_{90n} = 0.1$

The earlier developed model for general symmetric laminates is generalized to account for non-uniform crack distribution. Parameter K is introduced as the ratio $\mathrm{K} = \frac{2\mathrm{l}}{\mathrm{l}+\mathrm{d}}$ to characterize the non-uniformity of the spatial distribution (Fig.1).
In parametric analysis, the axial modulus of cross-ply laminates with cracks in internal and surface layers is calculated. Fig.2 shows that the axial modulus reduction is the highest if cracks have uniform distribution ($\mathrm{K} = 0$).
A "double-periodic" approach presented to calculate the COD of a crack in a non-uniform case as the average of two solutions for periodic crack systems is very accurate for cracks in internal layers, whereas for high crack density in surface layers it underestimates the modulus reduction.

REFERENCES

1. Lundmark, P. and Varna, J., "Constitutive Relationships for Laminates with Ply Cracks in In-plane Loading," *International Journal of Damage Mechanics*, Vol. 14, No.3, pp. 235-261, 2005