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Ghazi A.F. Abu-Farsakh, Haitham M. Al-Jarrah

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# Micro-mechanical damage model accounting for composite material nonlinearity due to matrix-cracking of unidirectional composite laminates

**Ghazi A. F. Abu-Farsakh[1] and Haitham M. Al-Jarrah[2]**

Department of Civil Engineering, Faculty of Engineering, Jordan University of Science and Technology, PO Box 3030, Irbid 2210, Jordan

[1]Corresponding author: Ghazi Abu-Farsakh, ghazi@just.edu.jo
[2]Second Author: Haitham M. Al-Jarrah, haithamaljarrah66@yahoo.com

**Abstract**

A new micromechanical damage model for predicting the effect of matrix-cracking on the mechanical behavior of the composite material is proposed. The model is based on the volumetric change that occurred due to the presence of cracks in a composite lamina due to uniaxial off-axis loading. It determines the volumetric crack-density (VCD) by combining the macro-mechanical and micro-mechanical principles. A representative volume-element is proposed that determines the material mechanical properties ($E_1$, $E_2$, $G_{12}$ and $\nu_{12}$) in terms of crack-density, fiber and matrix properties and initial volume-fraction of fibers. The rule-of-mixture in combination with Halpin-Tsai model is used to determine the mechanical properties of a cracked composite lamina. It has been shown that, matrix-cracking is the main cause for composite-material nonlinearity. Moreover, the model has been shown to give a reliable and reasonable predictions of the VCD and the tangential damage-factor (TDF) for various fiber/matrix systems using the corresponding available data from literature. An alternative secant damage-factor is being proposed, which has a linear relationship with the VCD. In order to validate the model, two composite materials; Boron/Epoxy (Narmco-5505) and Graphite/Epoxy (4617/Modmor-II), have been considered using laminates at different fiber-orientation angles. The maximum volume-crack-density (MVCD) and maximum secant damage-factor (MSDF) are obtained using equations that depend on the fiber-orientation angle and the initial material mechanical properties.

**Keywords**: Micro-damage-model, composite-material-nonlinearity, composite-laminate, volumetric-crack-density, secant-damage-factor.