Finite Elements Solution of the Fiber-Matrix Interface Crack: Effects of Mesh Refinement and Domain Size

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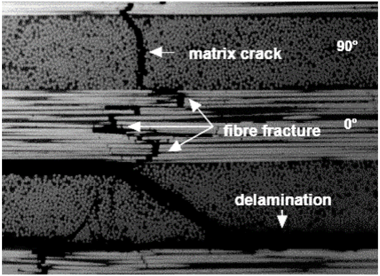
Outline

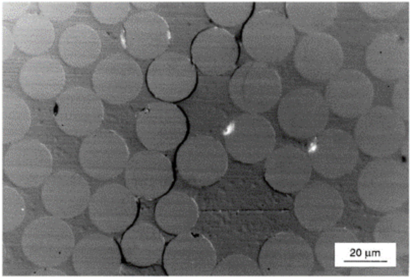
- Characterization of Fracture in FRPC Laminates
- The Fiber-Matrix Interface Problem in Fiber Reinforced Polymer Laminates
- Conclusions & Outlook
- Appendices & References

Characterization of Fracture in FRPC

Damage Onset and Propagation in FRPC Laminates



(a) By Dr. R. Olsson, Swerea, SE.



(b) By Prof. Dr. E. K. Gamstedt, KTH, SE.

A visual definition of intralaminar transverse cracking.

Characterization of the Fracture Process

➔ Energy Release Rate

$$G_m = G_m(p_1, \ldots, p_i, \ldots, p_n) \quad \text{where} \quad G = \frac{\partial W}{\partial A} - \left(\frac{\partial U}{\partial A} + \frac{\partial E_k}{\partial A}\right)$$

➔ Stress Intensity Factor

$$K_m = K_m(p_1, \ldots, p_i, \ldots, p_n) \quad \text{where} \quad \sigma_m \sim K_m \frac{\alpha}{(x-a)^{\beta}}, \alpha, \beta > 0$$

➔ J-Integral

$$J = J(p_1, \ldots, p_i, \ldots, p_n) \quad \text{where} \quad J = \lim_{\varepsilon \to 0} \int_{\Gamma_\varepsilon} \left(W(\Gamma) n_i - n_j \sigma_{jk} \frac{\partial u_k(\Gamma, x_i)}{\partial x_i}\right) d\Gamma$$

➔ Crack Opening & Shear Displacement

$$COD = COD(p_1, \ldots, p_i, \ldots, p_n) \quad \text{and} \quad CSD = CSD(p_1, \ldots, p_i, \ldots, p_n)$$

$$p_i \in \{\text{geometry}, \text{materials}, \text{boundary conditions}, \text{loading mode}, \text{scale}\}$$

$$m \in \{I, II, III, I/II, I/III, II/III\}$$

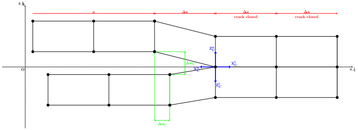
Evaluation of Fracture Parameters

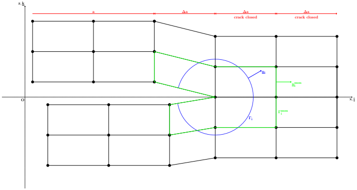
- Analytical
  - ✓ Closed form
  - ✓ Every material scale can be studied
  - ✗ Available only for particular configurations
- Experimental
  - ✓ Complex geometries can be studied
  - ✗ Not every material scale is accessible
- Numerical
  - ✓ Complex geometries can be studied
  - ✓ Every material can be studied
  - ✗ Discretization
  - ✗ Finite domains

Numerical Estimation of Energy Release Rates

➔ J-Integral

➔ Virtual Crack Closure Technique (VCCT)





$$G_I = \frac{Z_C \Delta w_C}{2B\Delta a} \quad G_{II} = \frac{X_C \Delta u_C}{2B\Delta a}$$

$$J_i = \lim_{\varepsilon \to 0} \int_{\Gamma_\varepsilon} \left(W(\Gamma)\, n_i - n_j \sigma_{jk} \frac{\partial u_k(\Gamma, x_i)}{\partial x_i} \right) d\Gamma$$

THE FIBER-MATRIX INTERFACE PROBLEM IN FRPC

The Fiber-Matrix Interface Crack

Conclusions

Conclusions & Outlook

Conclusions

- 2D micromechanical models have been developed to investigate crack initiation in thin ply laminates
- A numerical procedure has been devised and implemented to automatize the creation of FEM models
- Analyses for $VF_f \rightarrow 0$ (matrix dominated RVE) conducted to validate the model with respect to previous literature

Outlook

- Investigate the dependence on VF_f, t_{ply}, $\frac{t_{ply}}{t_{bounding\ plies}}$ and different material systems
- Study numerical performances with respect to model's parameters
- Repeat for different RVEs and compare

Appendices & References

Evaluation of G_0

$$G_0 = \pi R_f \sigma_0^2 \frac{1 + k_m}{8 G_m} \tag{1}$$

$$k_m = 3 - 4\nu_m \tag{2}$$

$$\sigma_0^{undamaged} = \frac{E_m}{1 - \nu_m^2} \varepsilon_{xx} \tag{3}$$

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