









# GROWTH OF INTERFACE CRACKS ON CONSECUTIVE FIBERS: ON THE SAME OR ON THE OPPOSITE SIDES?

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#### **Outline**

- Micromechanical Modeling of Initiation of Transverse Cracks
- Modeling the Fiber-Matrix Interface Crack
- Energy Release Rate of the Fiber-Matrix Interface Cracks
- Conclusions











## Initiation of Transverse Cracks



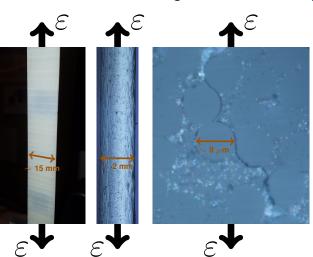








#### Initiation of Transverse Cracking in FRPCs: Microscopic Observations



## **Left:** front view of $[0, 90_2]_S$ , visual inspection.

### **Center:** edge view of $[0, 90]_S$ , optical microscope.

#### Right:

edge view of  $[0, 90]_S$ , optical microscope.





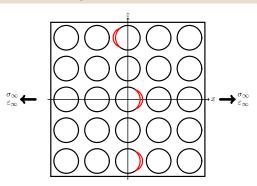






#### Initiation of Transverse Cracking in FRPCs: Micromechanics

#### Stage 1: isolated debonds







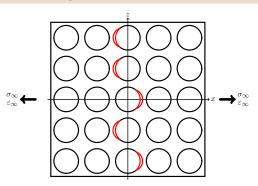






#### **Initiation of Transverse Cracking in FRPCs: Micromechanics**

#### Stage 2: consecutive debonds







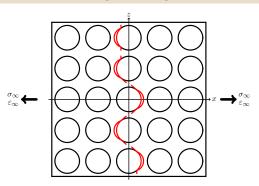






#### **Initiation of Transverse Cracking in FRPCs: Micromechanics**

#### Stage 3: kinking







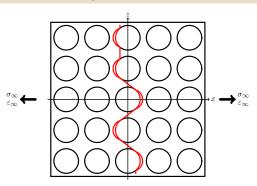






#### **Initiation of Transverse Cracking in FRPCs: Micromechanics**

#### Stage 4: coalescence













Initiation of Transverse Cracks Debond Modeling

Debond ERR Conclusions













Strain Magnification Crack Shielding Consecutive Debonds: Mode I Consecutive Debonds: Mode II Non-Consecutive Debonds







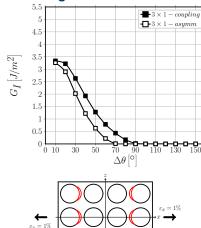


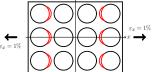




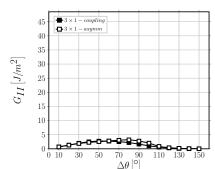
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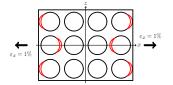
#### **Strain Magnification**





 $3 \times 1 - asymm$ 





 $3 \times 1 - asymm$ 





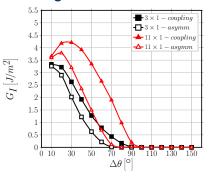


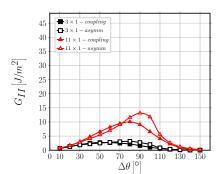


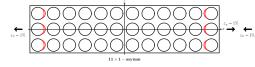


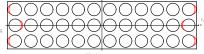
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#### **Strain Magnification**













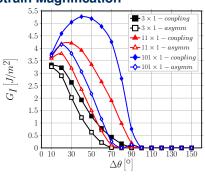


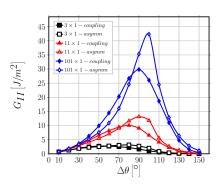




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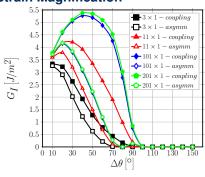


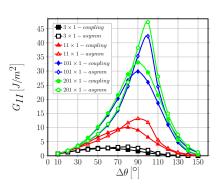




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#### **Strain Magnification**





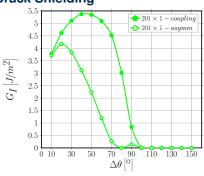


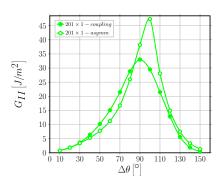












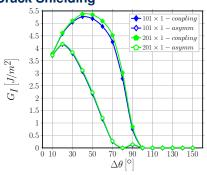


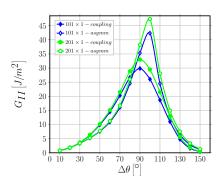












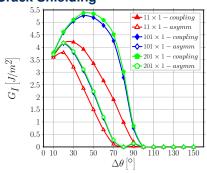


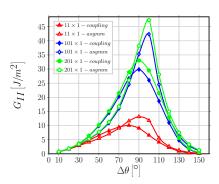












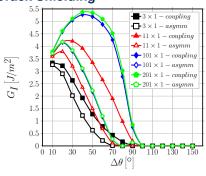


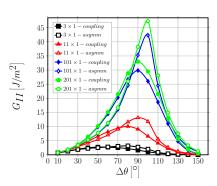
















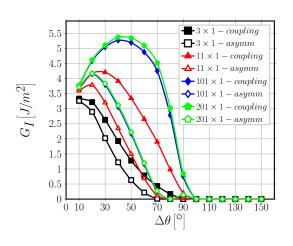


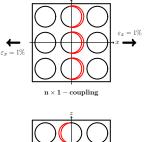


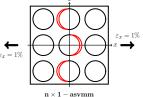




#### Consecutive Debonds: Mode I









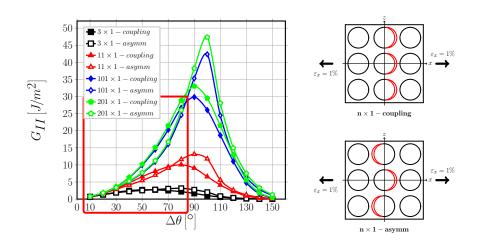








#### Consecutive Debonds: Mode II





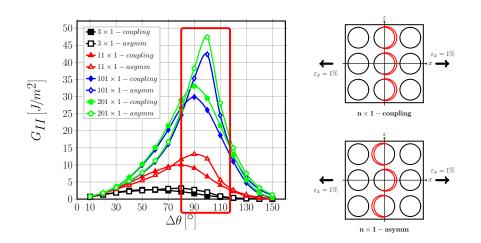








#### Consecutive Debonds: Mode II





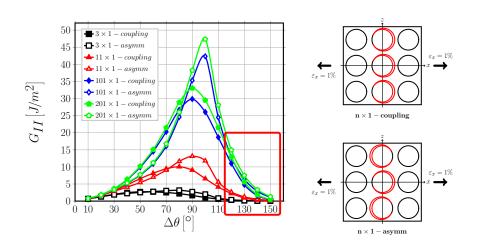








#### Consecutive Debonds: Mode II





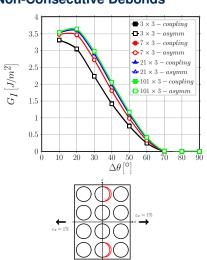




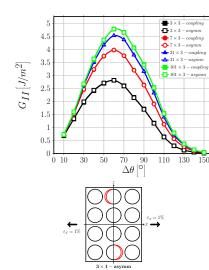




#### **Non-Consecutive Debonds**



 $3 \times 1$  – coupling













Initiation of Transverse Cracks Debond Modeling

Debond ERR Conclusions













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Debond Modeling

and ERR Conclusions

#### **Conclusions**

 $\rightarrow$   $f_{\text{straight crack}}(\Delta \theta): \sqrt{G_I}, \times G_{II}$ 

 $f_{\text{inclined crack}}(\Delta\theta): \sqrt{G_I}, \sqrt{G_{II}}, \times \nexists f_{\text{inclined crack}}(\Delta\theta = \frac{\pi}{2})$ 

 $f_{\text{curved crack}}(\Delta \theta): \sqrt{G_I}, \sqrt{G_{II}}$ 

⇒ scaling breaks for  $\Delta\theta \leq 20^{\circ}$  → microstructure is important for small debonds!

