Mode-II Interlaminar Fracture Toughness and Factors Affecting it

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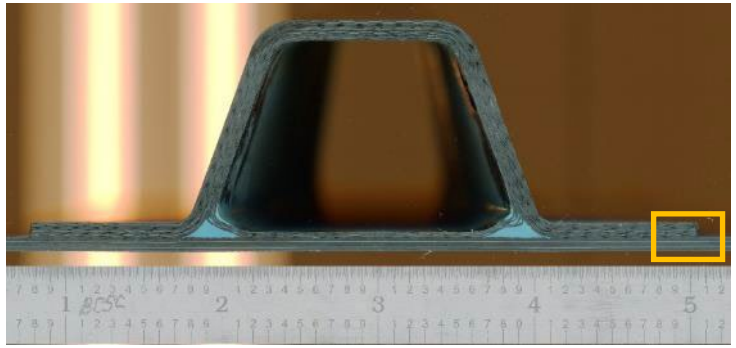
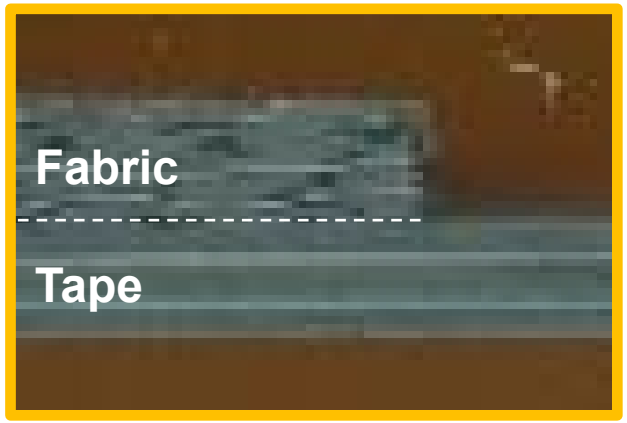
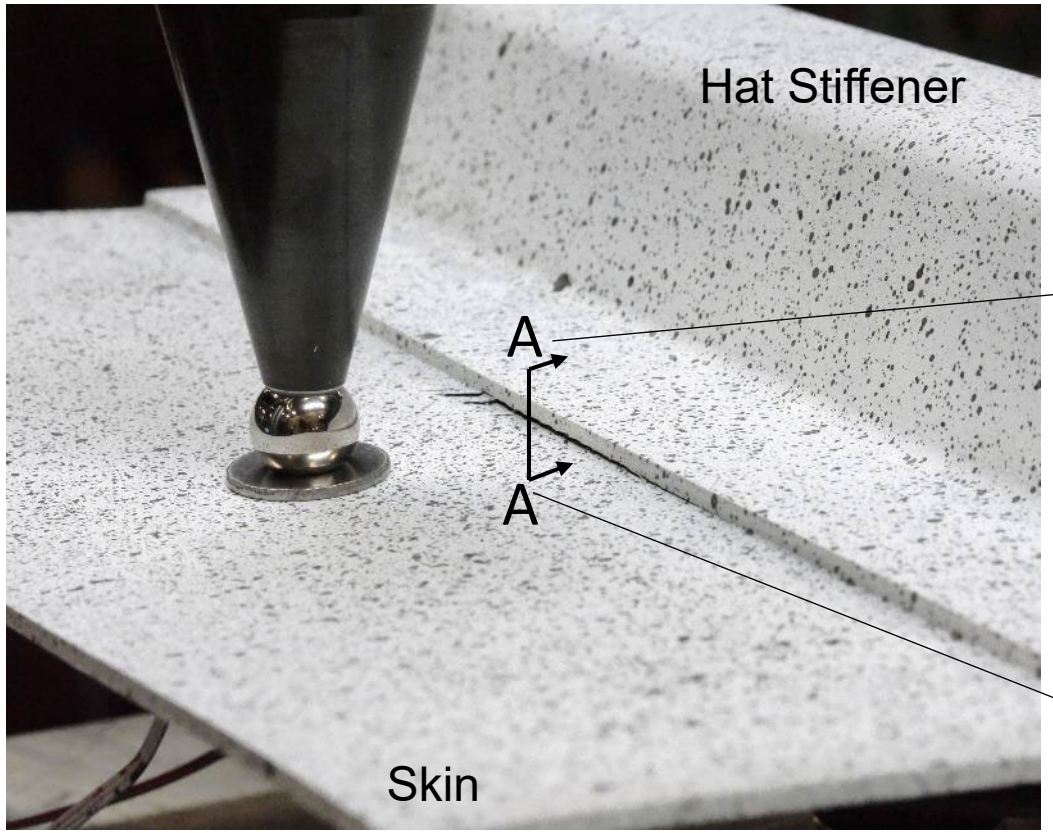
Polymer Matrix Composite (PMC) Laminates

- Fabric plies often added to tape PMC laminates for protection and ease of manufacturing

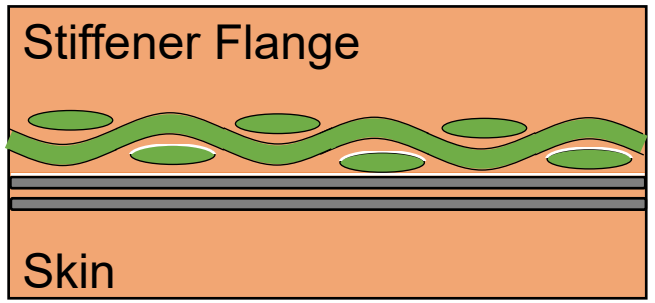






AA - detail

Fabric tape hybrid interface

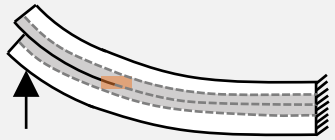


*courtesy NASA Advanced Composites Project

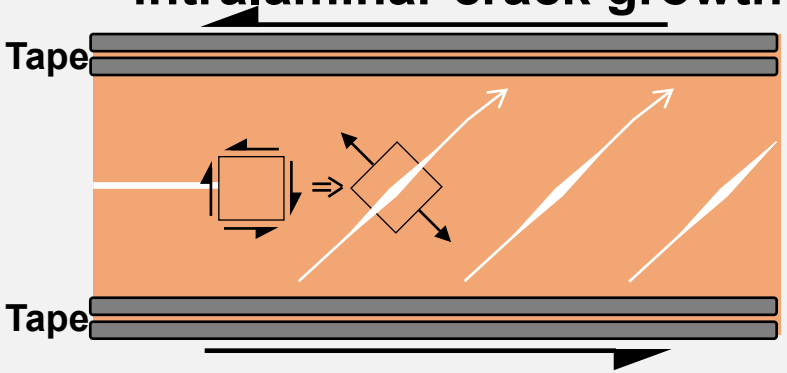
Interlaminar Fracture (Delamination) in PMC Laminates

Tape laminates

Mode-II



Tape fibers prevent intralaminar crack growth

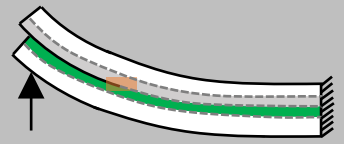


Unique interlaminar fracture toughness:

$$G_{IIc\ -\ Tape}$$

Hybrid tape/fabric laminates

Mode-II: Tape ply skimmed



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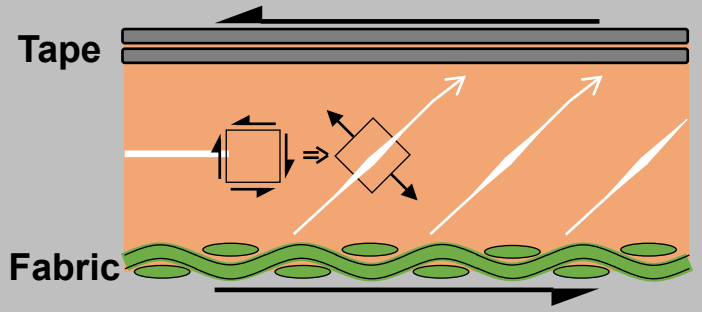
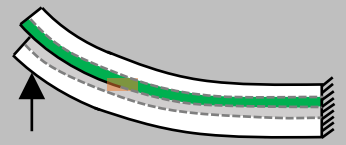
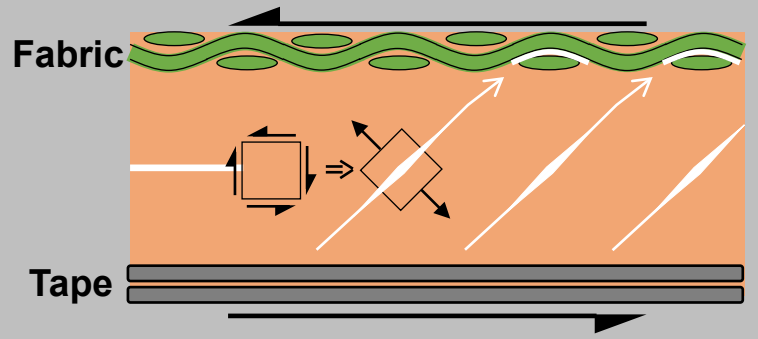


Mode-II: Fabric ply skimmed



Crack paths both sides of fabric weft tows?



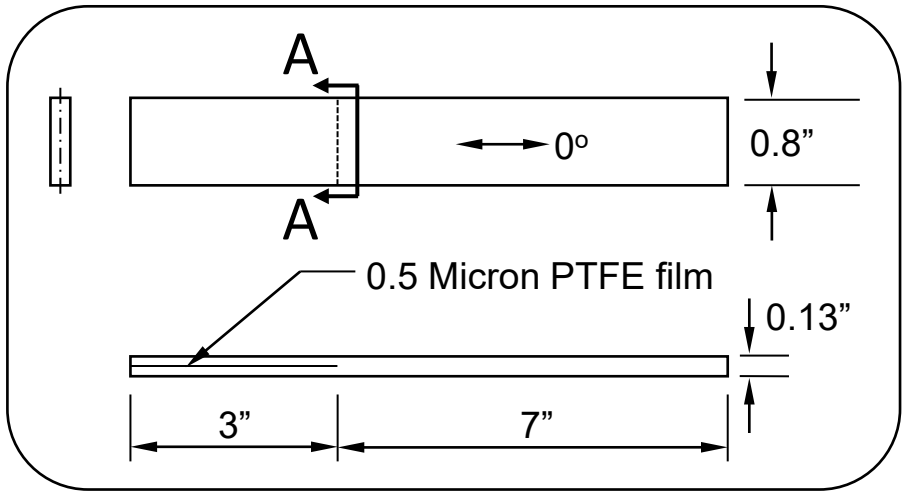
Fracture toughness *not unique?*

$$G_{IIc\ –\ Tape/Fabric} \quad > \; < \; = \; ? \quad G_{IIc\ –\ Fabric/Tape}$$

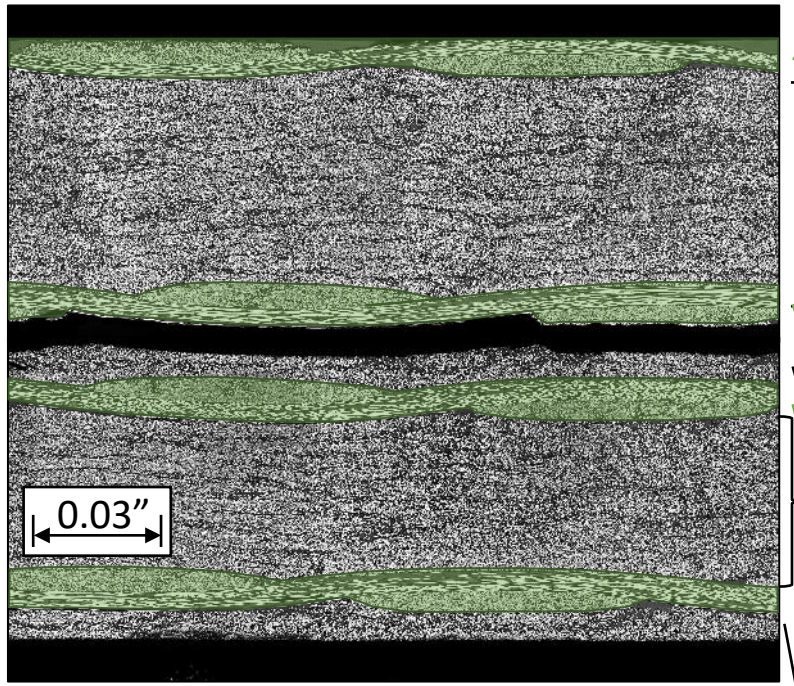
Materials and Interlaminar Fracture Specimens

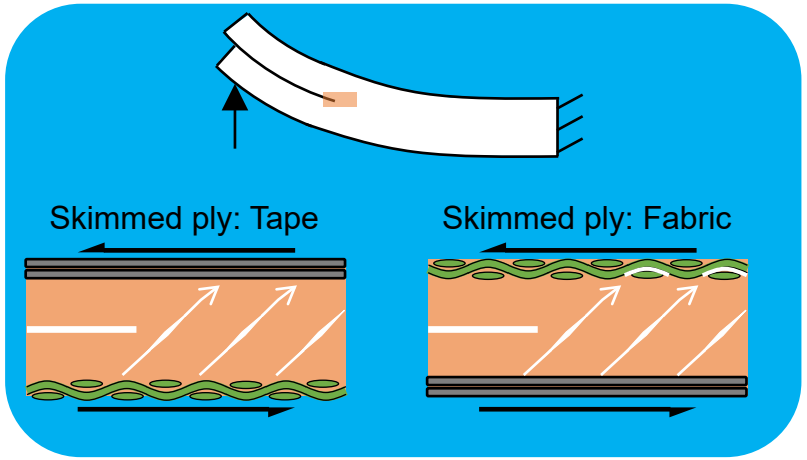
- **18-ply laminates: IM7/8552 carbon/epoxy unidirectional tape and plain weave fabric plies**
- **Layup with minimal mechanical coupling and thermal residual stresses**
- **Starter delamination at *tape/fabric ply interface***

Interlaminar Fracture Specimen



AA - detail





Stacking Sequence

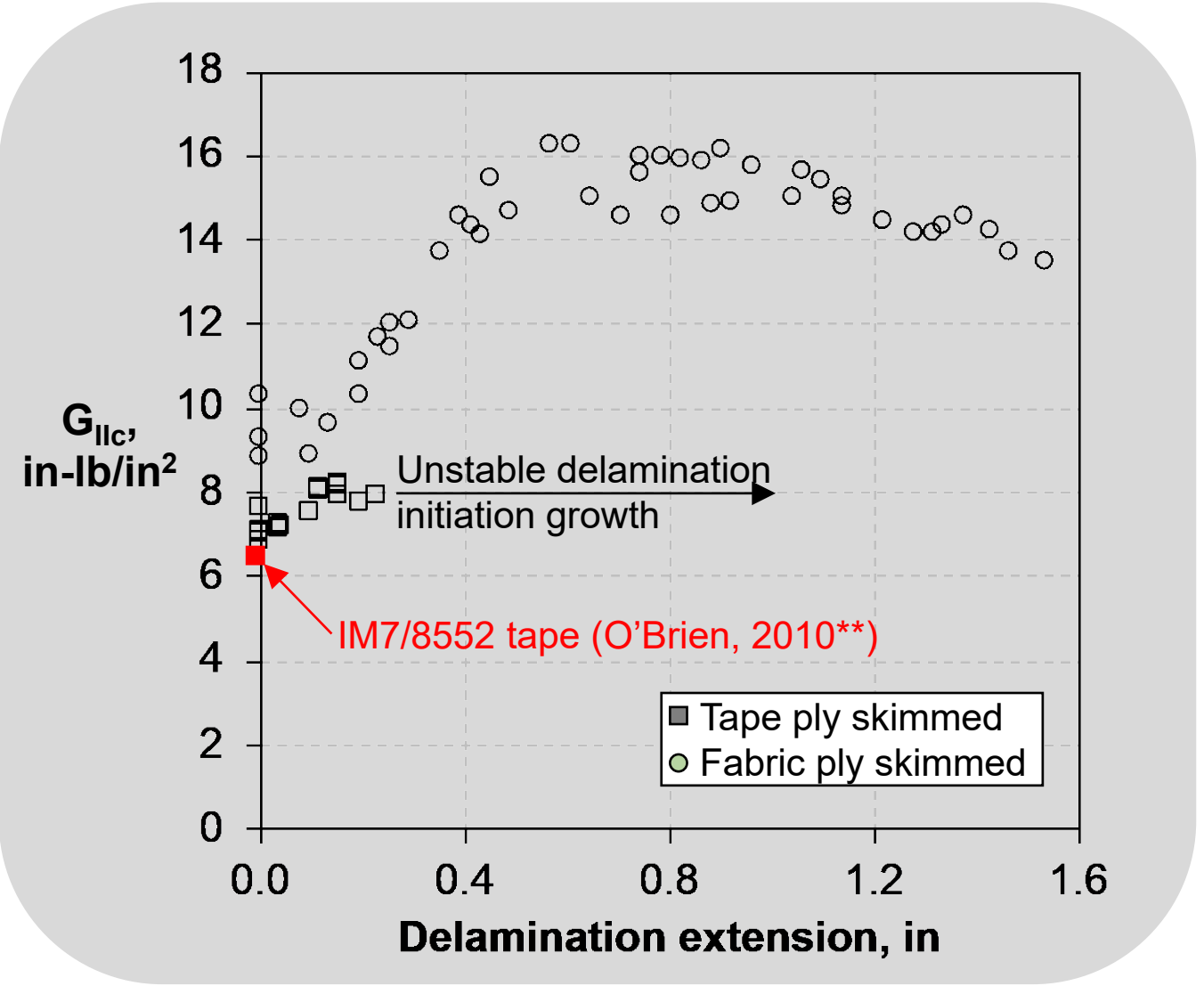
Ply Type	Orientation
Fabric	**0**
Tape	0
Tape	0
Tape	0
Tape	0
Tape	0
Tape	0
Tape	0
Fabric	**0**
PTFE film	-
Tape	0
Fabric	**0**
Tape	0
Tape	0
Tape	0
Tape	0
Tape	0
Fabric	**0**
Tape	0

Mode-II Fracture Toughness, G_{IIc}

- **Tape skimmed specimens: Constant G_{IIc} prior to unstable growth**
- **Fabric skimmed specimens: Significant increase in G_{IIc} with delamination extension**

Initiation G_{IIc}, in-lbf/in^2	
Tape	Fabric
7.8 (10.1)*	9.5 (15.1)

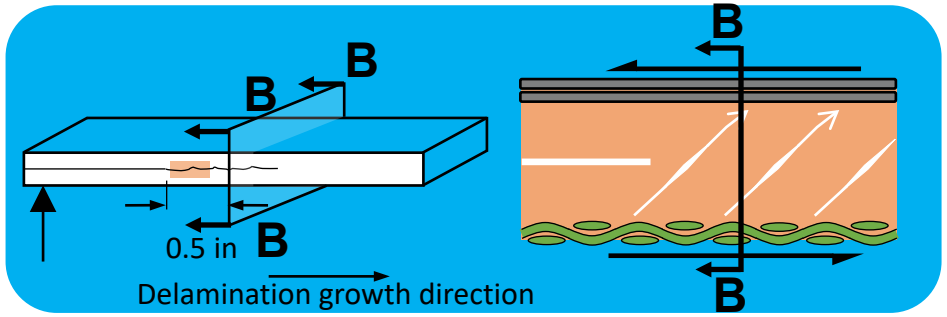
Propagation G_{IIc}, in-lbf/in^2	
Tape#	Fabric&
7.9 (8.8)	15.1 (3.4)



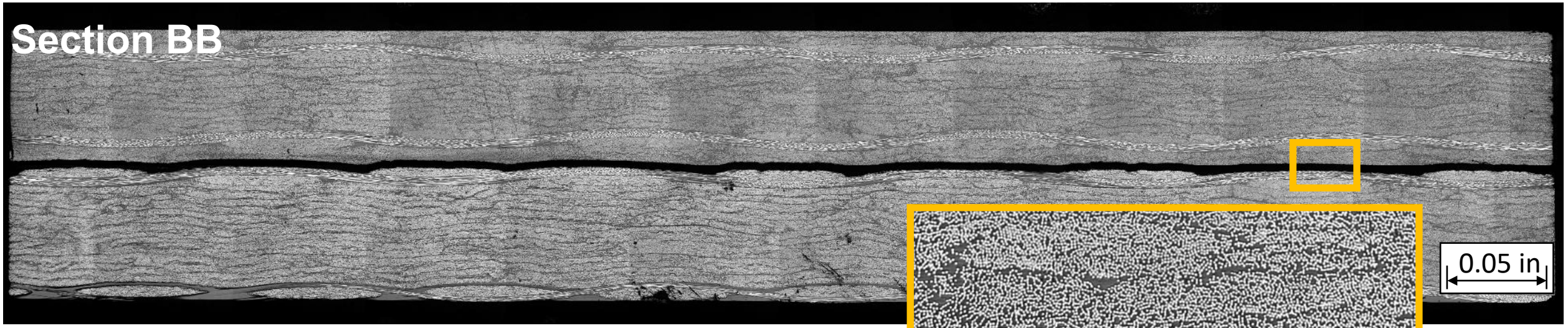
* Coefficient of variation (%) in parenthesis
# Average of all propagation G_{IIc} values from tape containment specimens
& Average of propagation G_{IIc} values for delamination extension greater than 0.5" from fabric containment specimens

**O'Brien, T.K, et al, "Mode II Interlaminar Fracture Toughness and Fatigue Characterization of a Graphite Epoxy Composite Material." NASA/TM-2010-216838, Aug. 2010 (Table 2, pp. 16)

Tape Skimmed Specimen Cross-Section

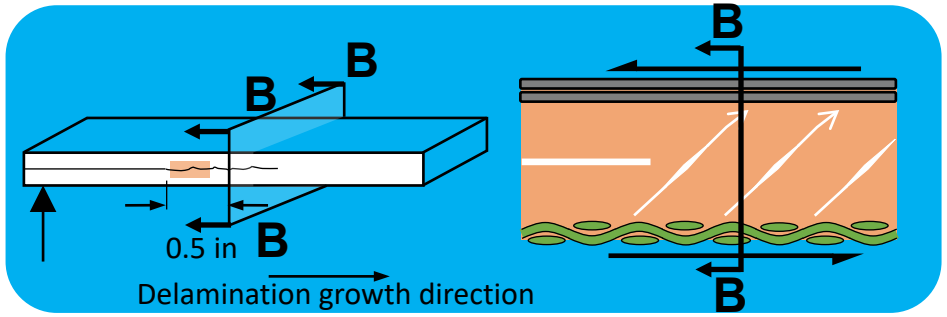


BB – 0.5 in ahead of starter delamination front

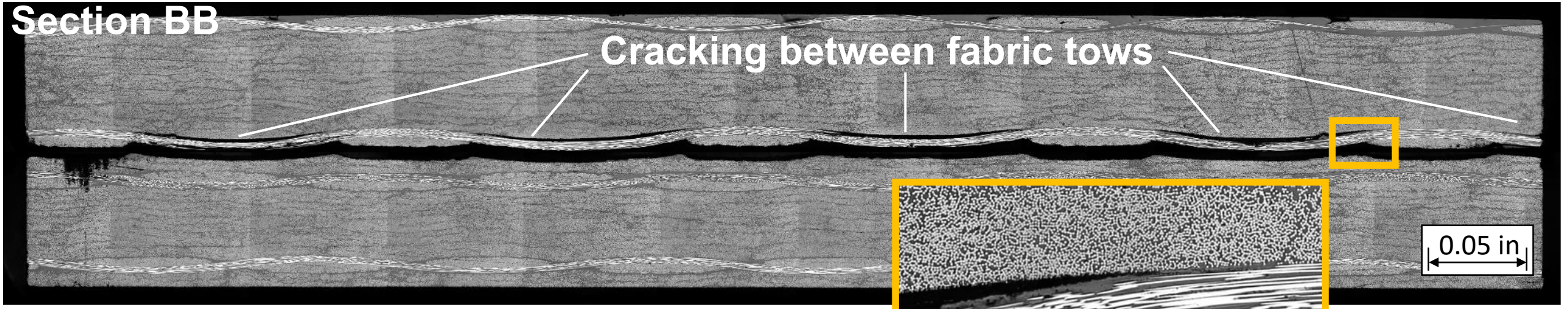


Delamination contained within tape/fabric ply interface

Fabric Skimmed Specimen Cross-Section



BB – 0.5 in ahead of starter delamination front



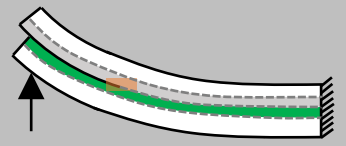
Cracking occurs between warp and weft tows causing delamination resistance

Closing Remarks:

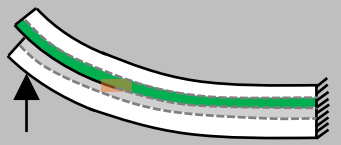
- **Hybrid tape/fabric fracture specimen developed**

Hybrid **tape/fabric laminates**

Mode-II: Tape skimmed

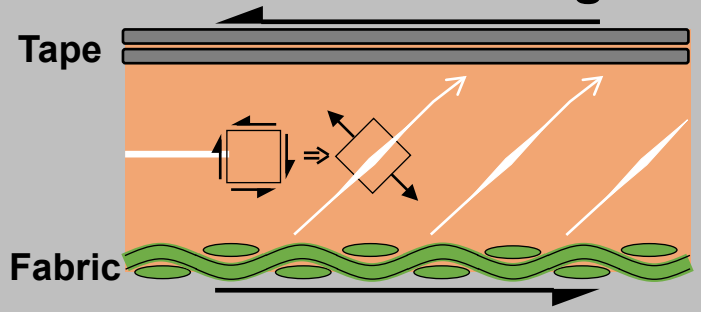


Mode-II: Fabric skimmed

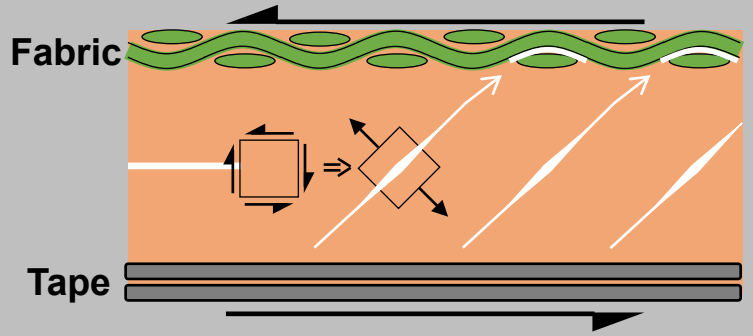


- **Delamination skimming fabric plies results in greater resistance**

Tape fibers prevent intralaminar crack growth



Crack paths both sides of fabric weft tows



- **Hybrid interfaces exhibit different fracture toughness as a function of skimmed ply**
- **Key for design and simulation**

Fracture toughness ***not unique***

$$G_{IIc\ -\ \underline{Tape}/Fabric} < G_{IIc\ -\ \underline{Fabric}/Tape}$$