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Mode II interlaminar fracture toughness and the factors affecting it

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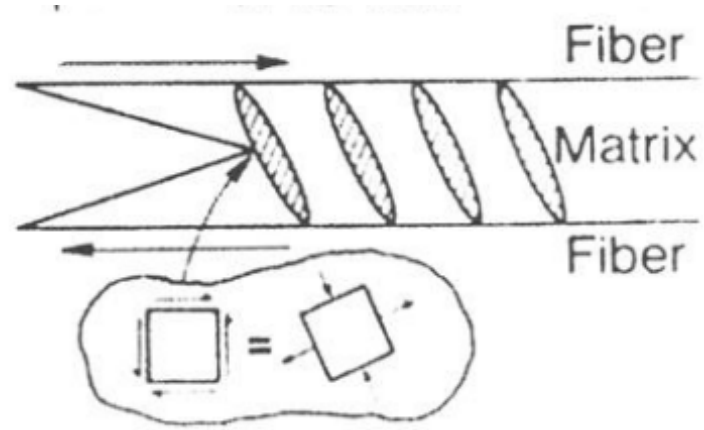
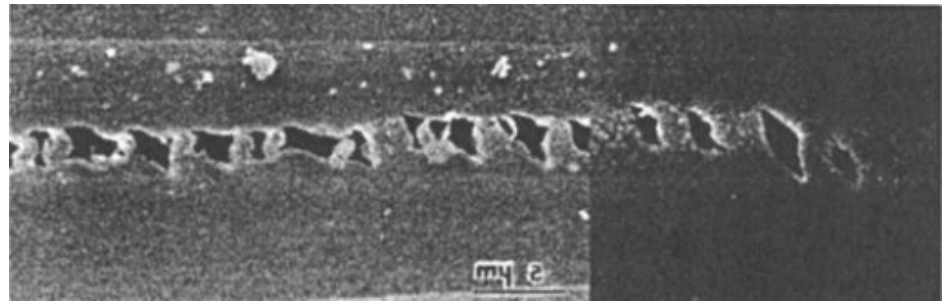
Overview of Workshops

- Previous series of workshops on Strength of Composites
- New series on Toughness of Composites
- First workshop discussed whether toughness is applicable as a material property in composites
- Second workshop on mode I fracture toughness
- See links in References
- Mode II interlaminar fracture toughness and the factors affecting it

Mode II fracture

- Occurs in resin regions between fibres or plies
- Shear due to matrix plasticity, then tensile cracks at 45° - direction of max. principal stress
- Extend and distort into sigmoidal microcracks, eventually coalescing into a macroscopic crack
- Failure results from tension - is it really shear failure at all?
- Right at the crack tip shear stress must go to zero – initiation really must be mode I?



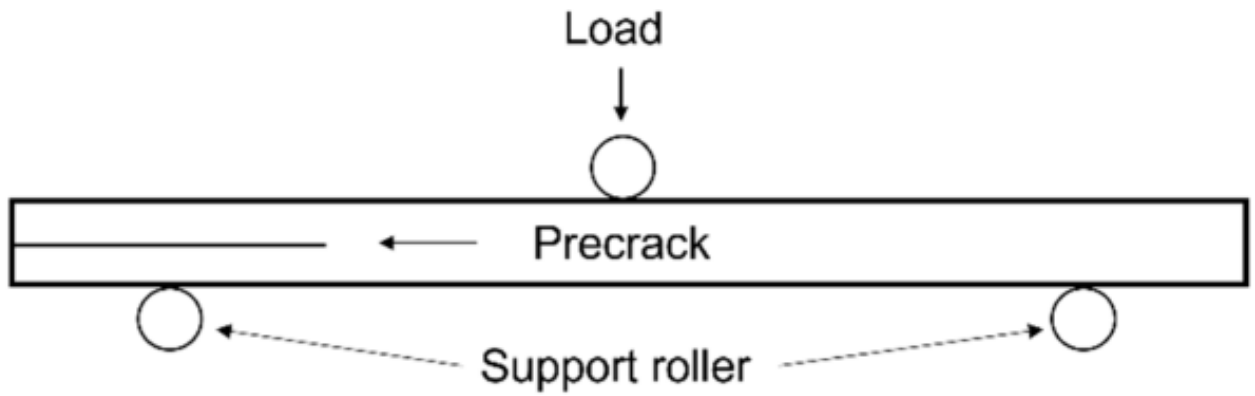


T. Kevin O'Brien[1]

Composite Interlaminar Shear Fracture Toughness, G_{IIc}: Shear Measurement or Sheer Myth?

End Notch Flexure test

- G_{IIc} most commonly measured with ENF test, ASTM D7905
- Unstable - only generates an initiation toughness
- Potential complications - discussed in the standard
- Initial test from the film, generating a true pre-crack for main tests
- Normally gives a lower, more conservative value



Issues with measurements

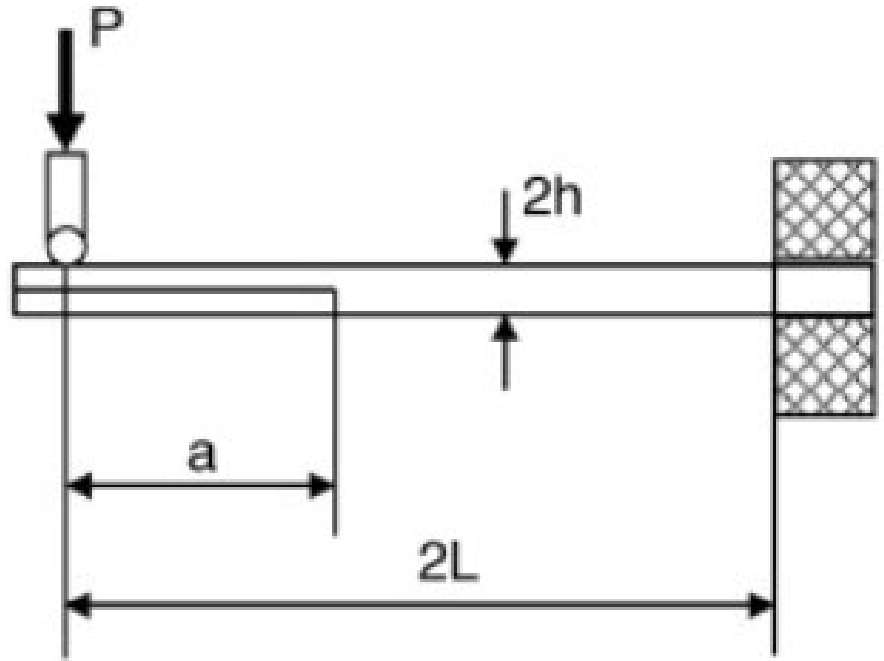
- Process zones in mode II can be very long
- Difficult to define and measure the crack length
- Hard to determine visually
  - little crack opening,
  - crack front not necessarily straight
- Crack length is normally calculated from compliance
- Several different data reduction methods

Designation: D7905/D7905M – 19$^{\varepsilon 1}$

Standard Test Method for Determination of the Mode II Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites[1]

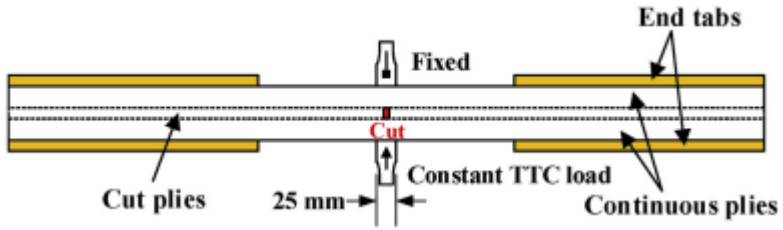
Measuring R-curves

- Stable delamination can be achieved by 4PB rather than 3PB ENF
- Allows determination of R-curves
- Potential concerns include increased friction (e.g. Davidson et al, 2007)
- Alternative stable configuration is the end-loaded split, ISO 15114
- R-curve effect has been found to be small (e.g. Blackman et al, 2006)

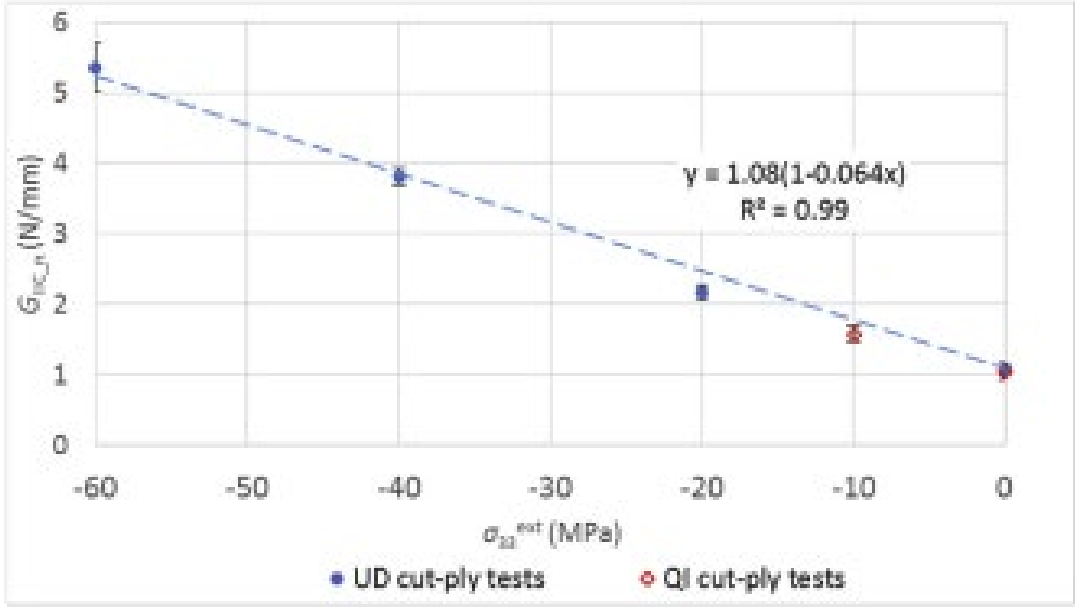


Is G_{IIc} a fixed value?

- Through-thickness compression increases G_{IIc} e.g. in IM7/8552

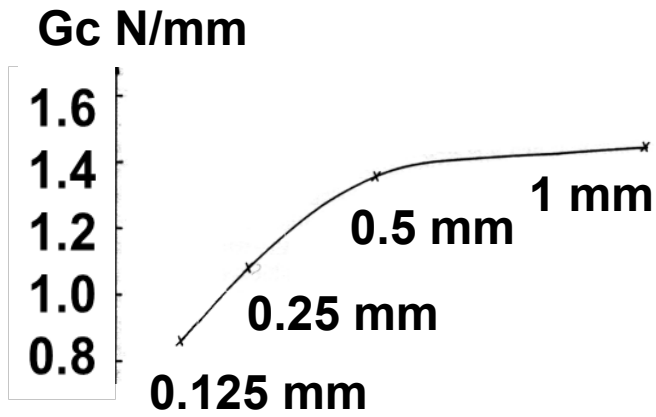


Xu et al, 2018



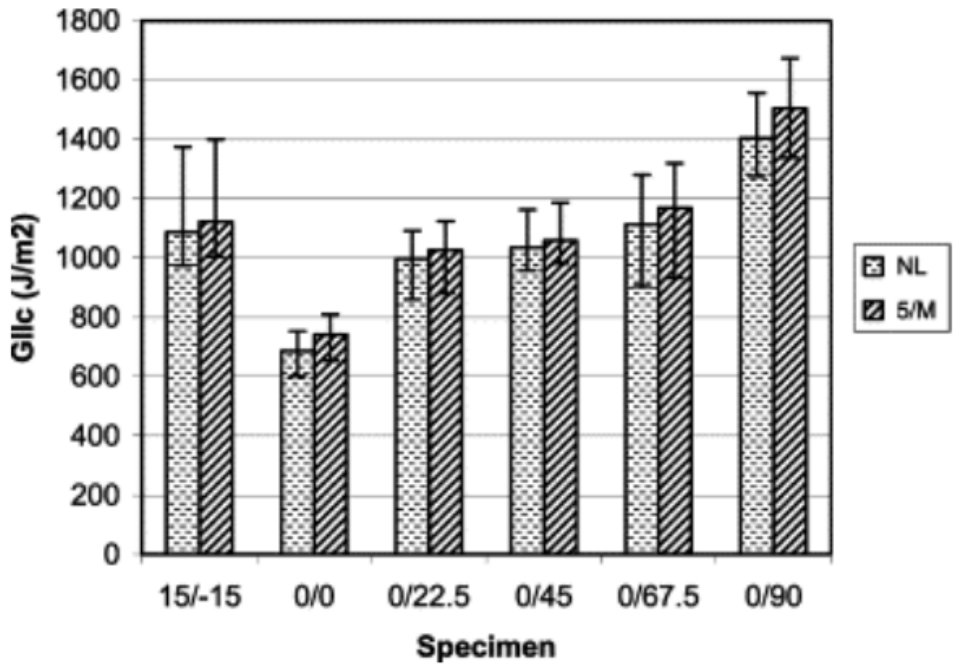
- Increases with specimen size?
  - scaled cut ply tension, e.g. in E-glass/913

Wisnom 1992



G_{IIc} in multidirectional laminates

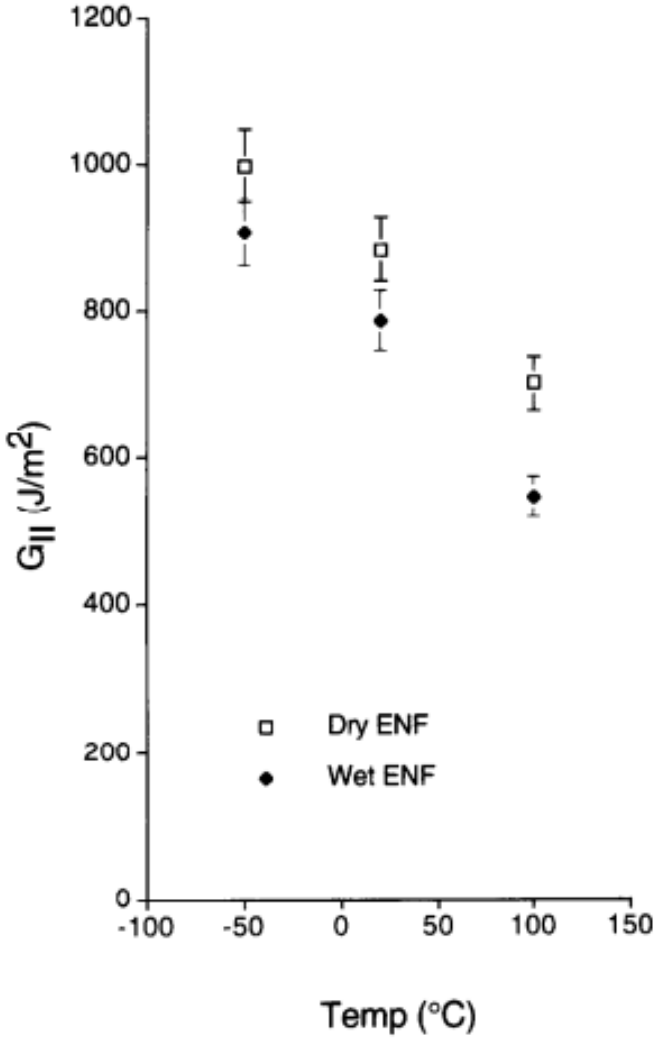
- More complex damage
- Typically give higher G_{IIc} for delamination between interfaces at larger angles
- Unidirectional composites give the lowest values
  - should be conservative
- Multidirectional composites face issues with delamination migration



Pereira et al, 2004

Environmental effects

- Reductions of G_{IIc} have been reported with both increasing temperature and moisture
- May be conflicting effects due to these conditions increasing plasticity but reducing interfacial strength
- Effect of strain rate is also difficult to determine, with conflicting trends reported (e.g. May et al, 2020)



HTA/6376C **Asp, 1998**

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