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Validity of mode II fracture toughness measurements in composites and joints

Bamber Blackman (b.blackman@imperial.ac.uk)

Department of Mechanical Engineering

Imperial College London

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Outline

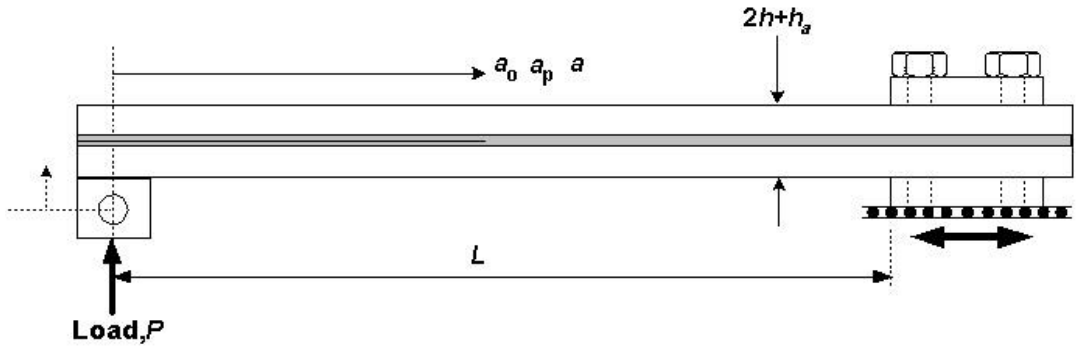
1. Historical perspective and development of ISO 15114: 2014
2. Where this works and where some problems lie
3. Possible solutions

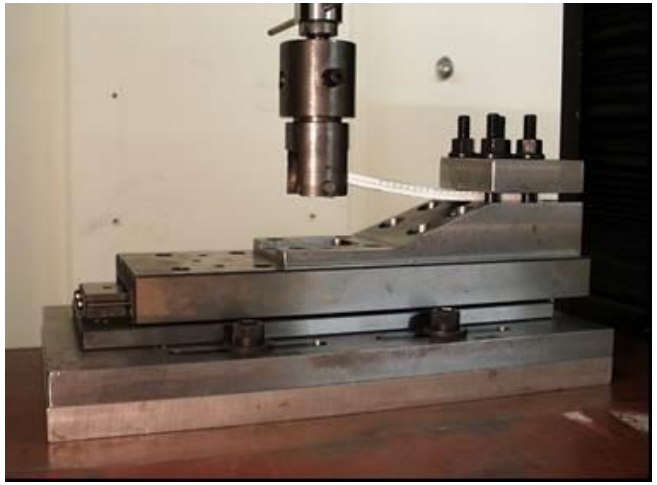
Historical perspective and development of ISO 15114: 2014

- The European Structural Integrity Society (ESIS); Technical Committee on Polymers, Composites and Adhesives (TC4) have been working on mode II delamination resistance since its formation in the mid 1980s.
- Due to the desire to measure the resistance to crack initiation and propagation, the end-loaded split (ELS) test was favoured over the less stable, end-notched flexure (ENF) test.
- However, early TC4 round-robins using the ELS test suffered poor reproducibility between labs, corrected beam theory did not accurately reproduce the axial modulus of the composite arms, and all participants struggled to accurately measure crack length.

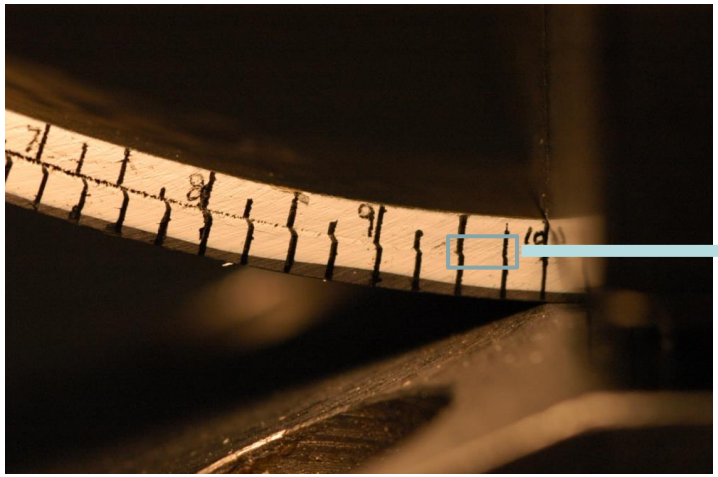
- These issues were also identified in the joint ASTM/ESIS/JIS round-robins co-ordinated by VAMAS in the late 1990s.
- The first round-robin compared the different mode II methods available: ELS, ENF, and a stabilised version of the st-ENF.
- The second round-robin also considered a newly developed 4-point loaded version of the ENF.
- All methods had limitations and there was no general consensus.

ESIS-TC4- Development of ISO 15114: 2014





As clamping fixtures were not standard, the ELS method was revised to calibrate the clamp



Using higher magnification to measure 'a' did not help, so the ELS method was revised to employ effective crack lengths

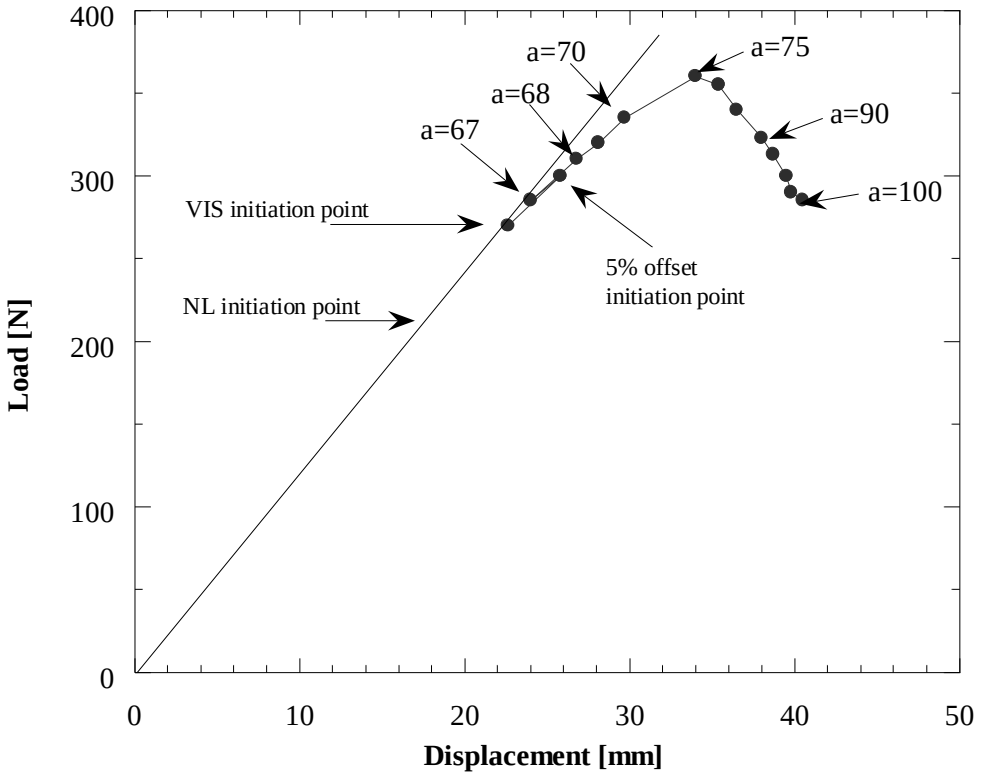
Round-robin results for IM7/977-2 laminate: Reproducibility over 4 test labs

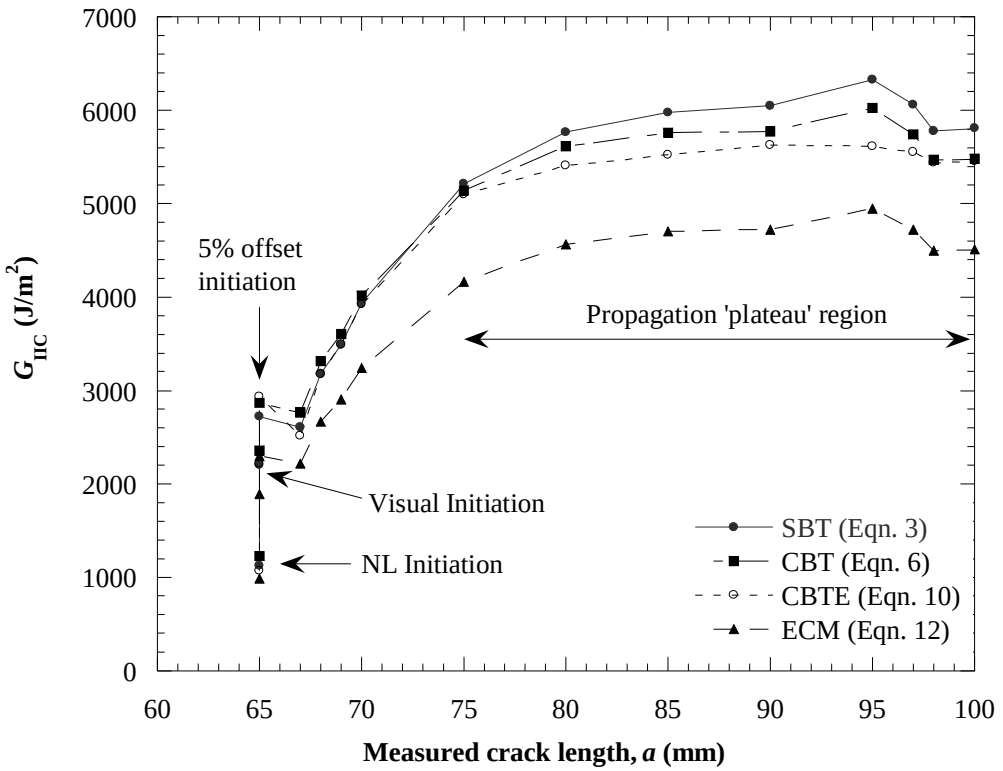
	SBT (CoV)%	ECM (CoV)%	CBTE (CoV)%
G_{IIc} (init) 5% offset	11.5%	22.2%	8.5%
G_{IIc} mean propagation	11.0%	19.5%	4.7%

Relatively flat R-curves observed in this composite

But in ELS joints bonded with structural adhesives…..

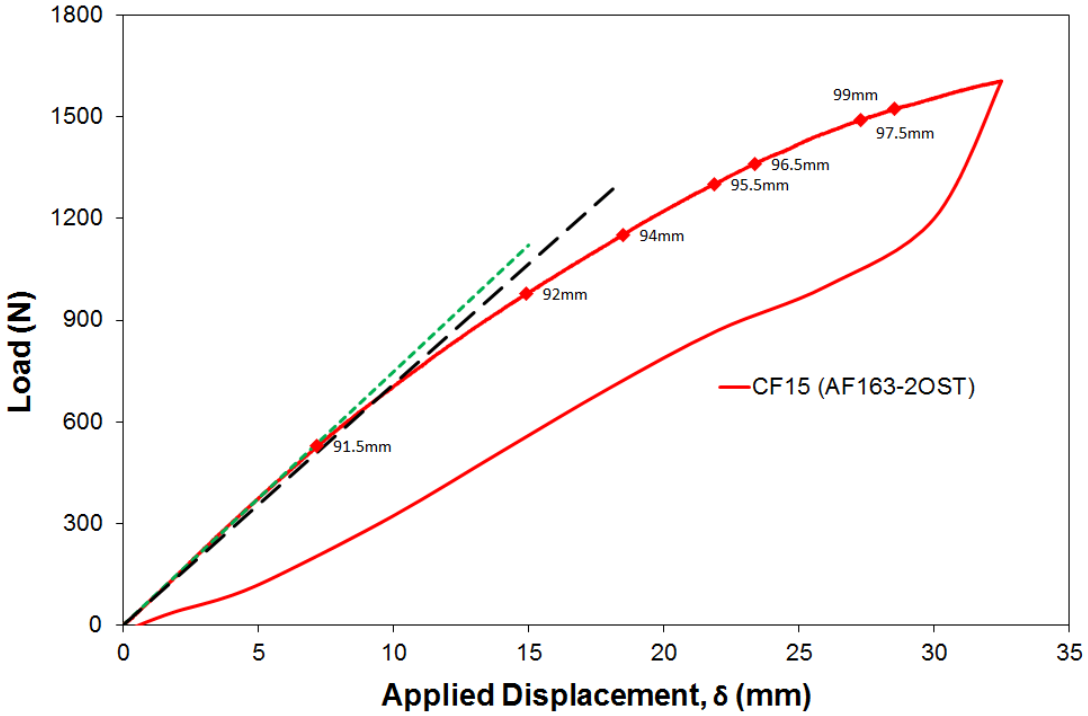
Application of ISO 15114 to an adhesive joint with relatively low toughness

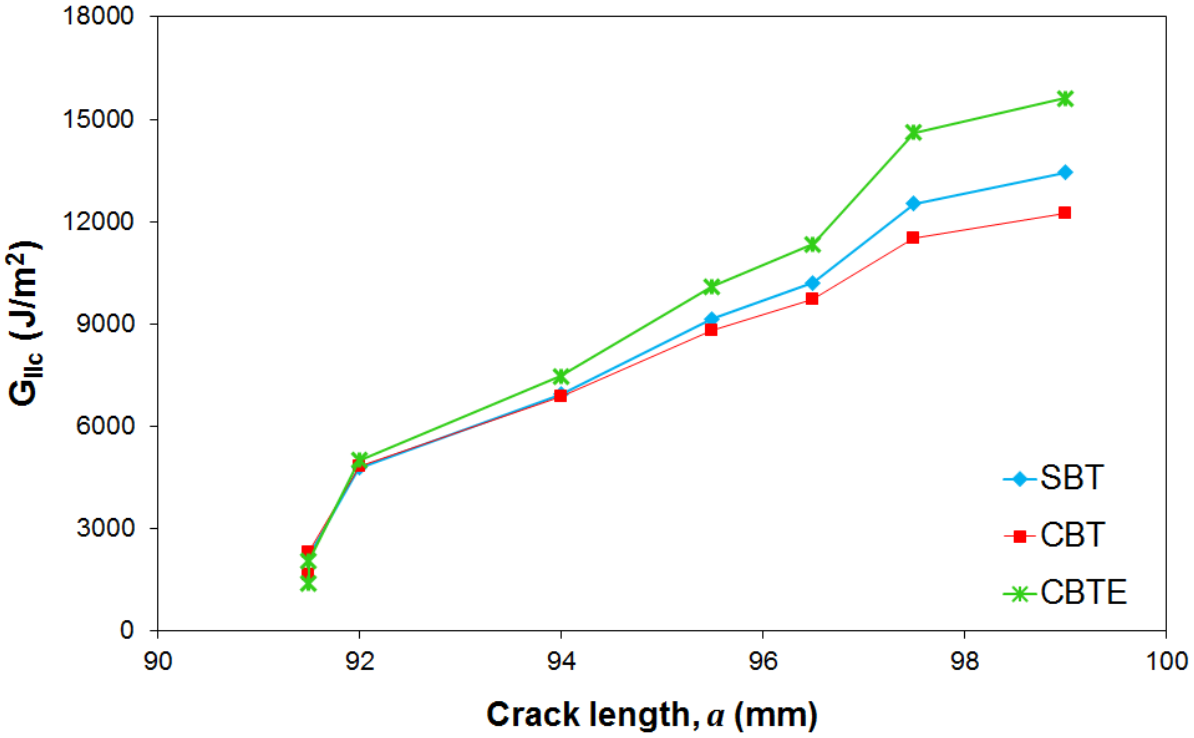




Strong rising mode II R-curves measured but reaching a steady-state.

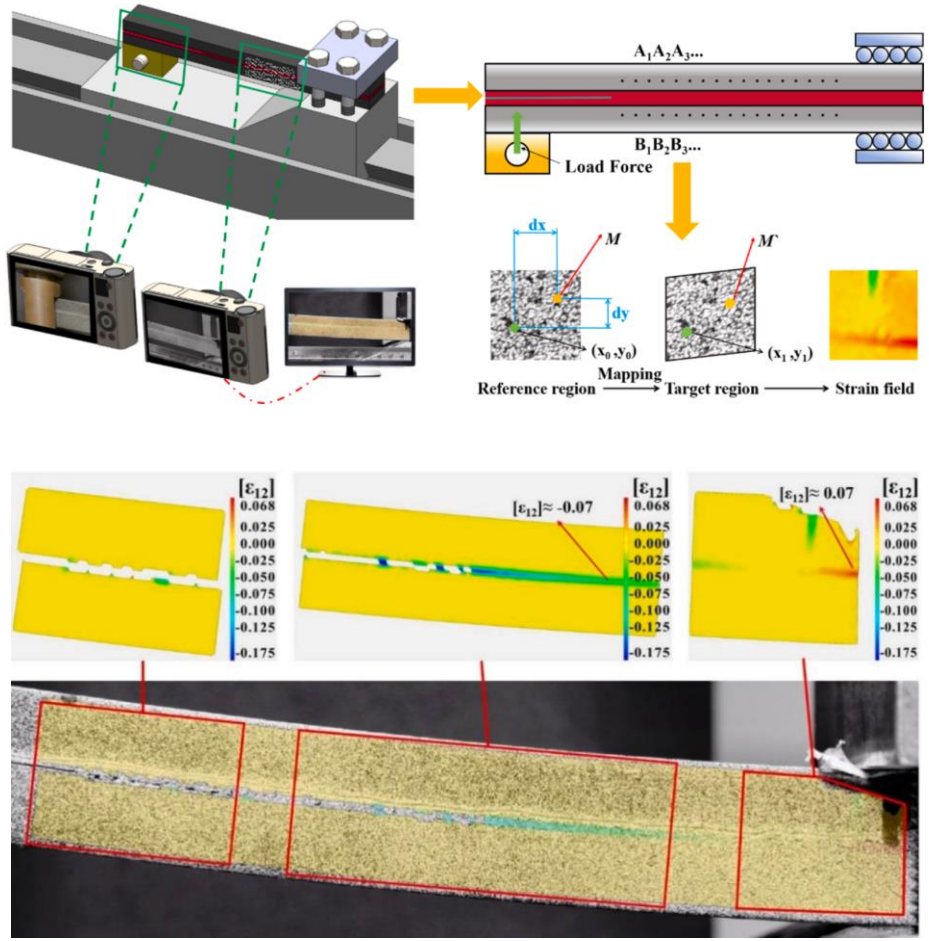
Application of ISO 15114 to an adhesive joint with higher toughness

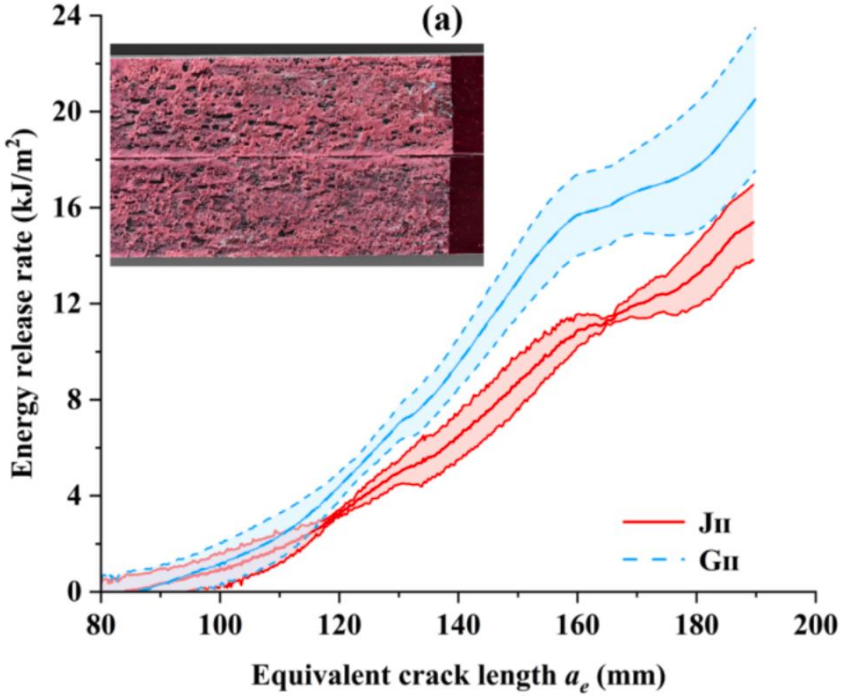




Even stronger rising mode II R-curve measured but not reaching a steady-state.
Some indication of specimen damage around clamping support.

Measuring G and J simultaneously (via DIC method)





Long process zone, plus local damage in clamp region.

Exclude local damage via careful selection of contour integral

Sun, Wang & Blackman. Composites: Part A, 192 (2025) 108777

Possible solutions

- Make specimens larger to accommodate full development of process zone.
  - For adhesive joints, specimen lengths could be from 200mm up to 1m.

- Measure G and J simultaneously (via DIC method) setting J-contour to avoid clamped region.

Acknowledgement

To the members of the ESIS TC4 committee on the fracture of polymers, composites and adhesives.