Prediction of Adhesion Failure of Bonded Joints using 3-Point Bending Test and Stress-Energy Coupled Criterion

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Context

In the recent years, a coupled energy and stress approach has been used successfully to treat problems involving stress concentration since the stress-based criteria only are no more valid near a singularity. For the adhesive failure characterization, Roche et al. [1] have developed a 3-point bending test which has a similar stress concentration condition, and thus the coupled criterion can be applied to predict the failure of the adhesively bonded joint.

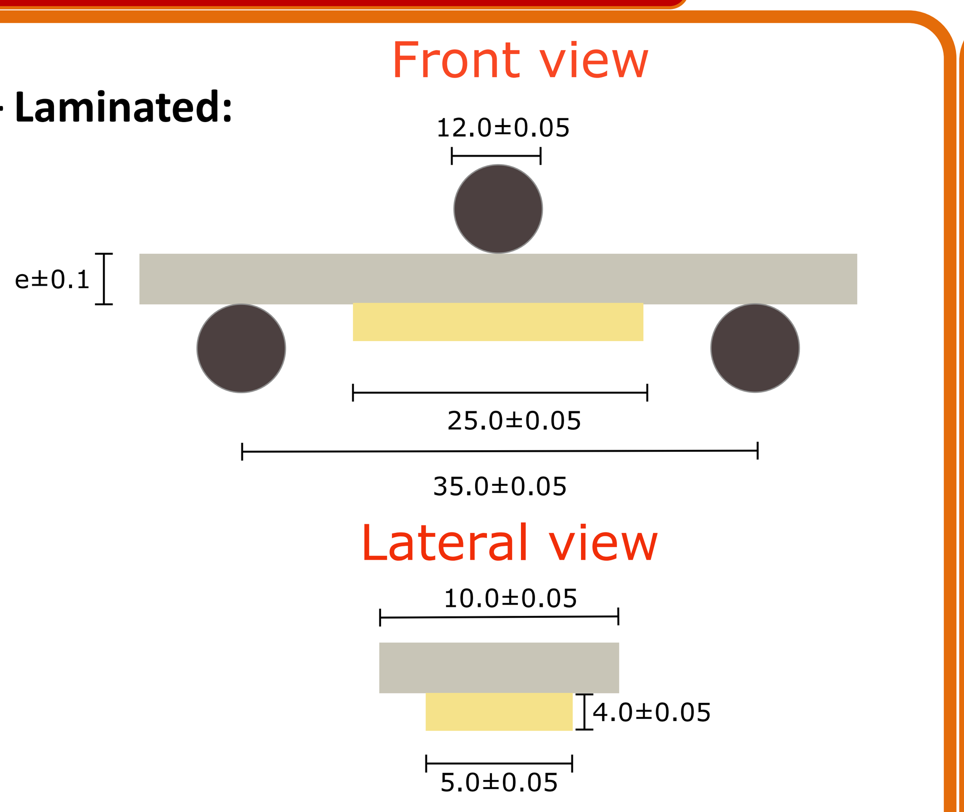
Material

Aluminum substrate 2024 T3 – Laminated:
- ✓ E_{subs}=68 Gpa
- ✓ ν=0,33

Polymer: DGEBA/DETA:
- ✓ E_{poly}=3 Gpa
- ✓ ν=0,33

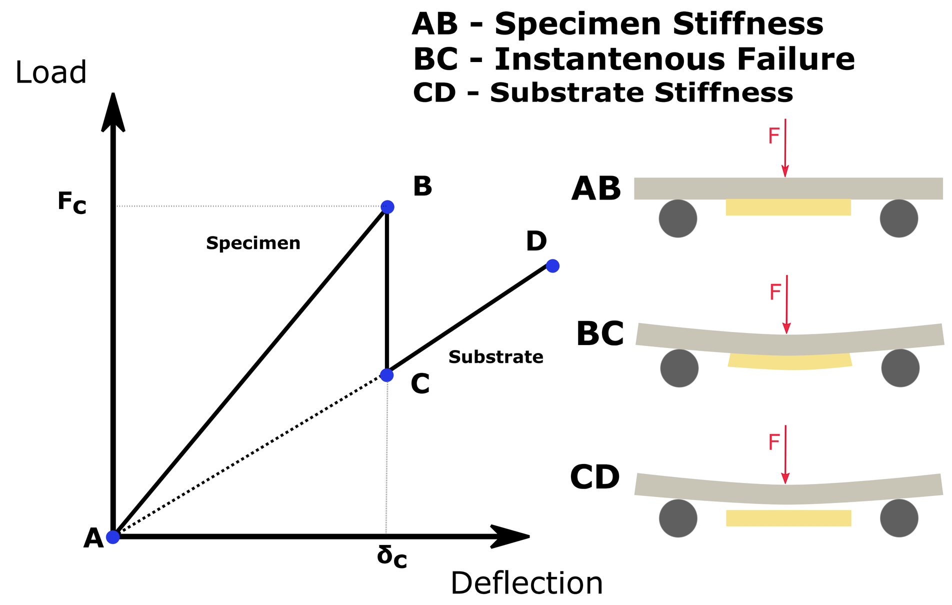
Surface treatment:
- ✓ Nitric acid: 400g/L
- ✓ Different temperatures
- ✓ Different time exposition

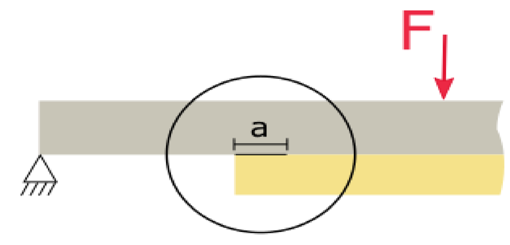
Polymerization cycle:
- ✓ 1 Hour at 150°C

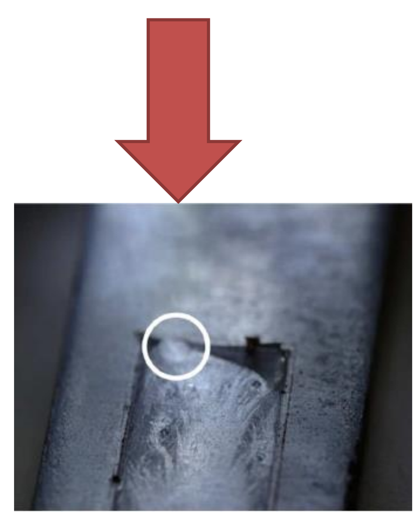


Method

3-Point bending test - **ISO 14679-1997**
- ✓ Main goal: **Adhesive failure initiation**



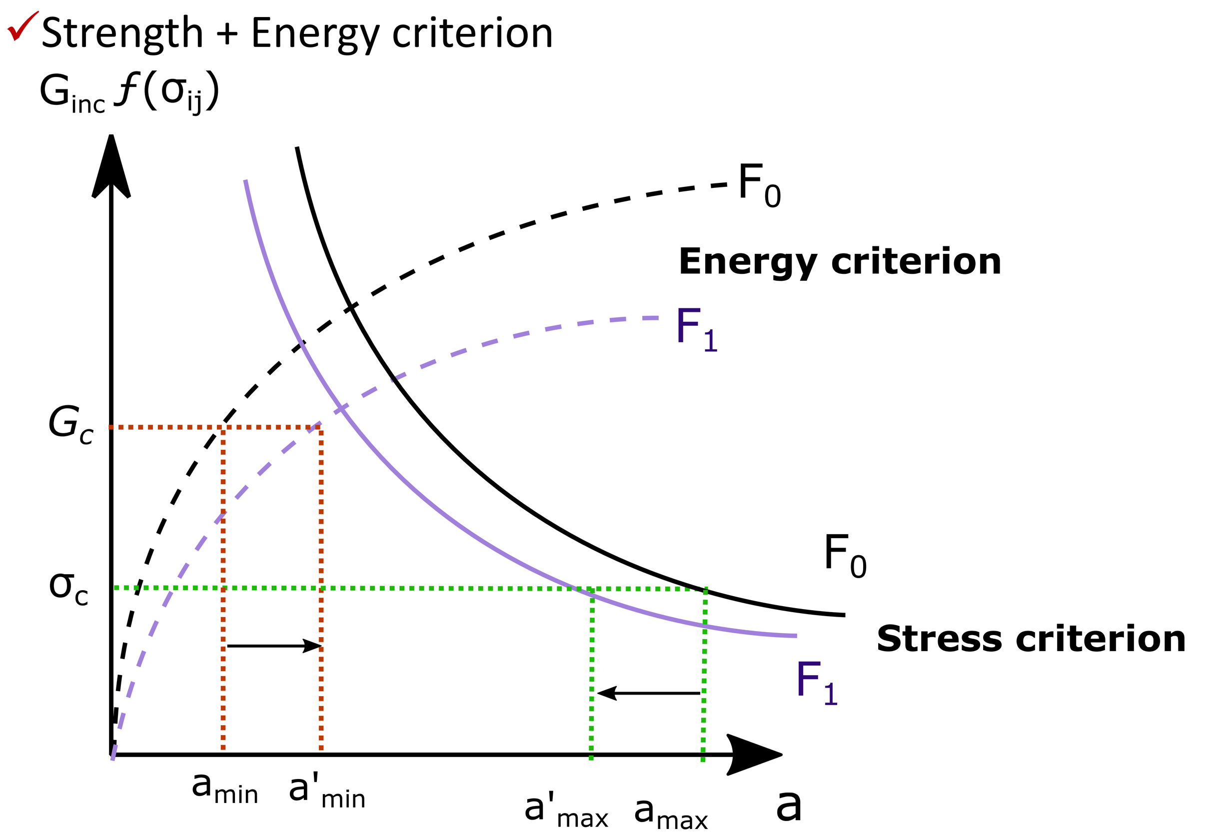


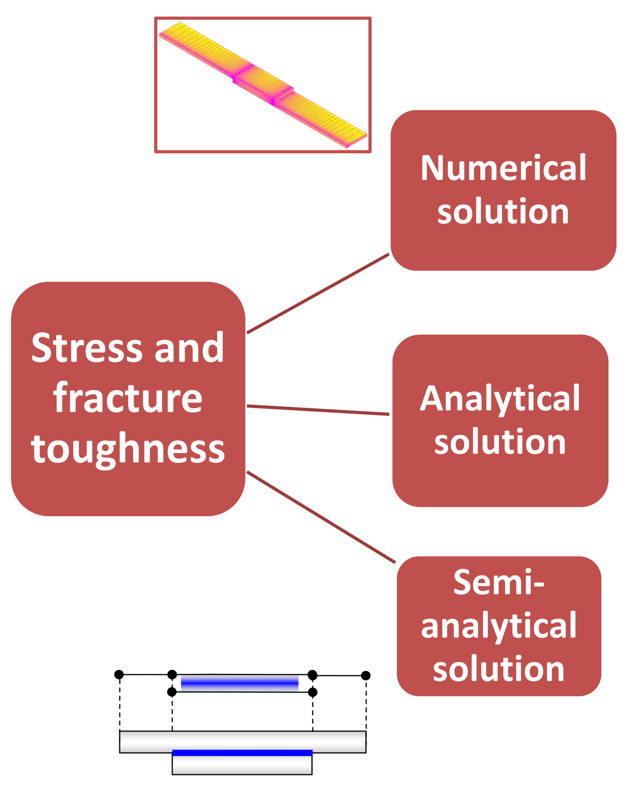


Sauvage [2]

Numerical Approach

- **High stress concentration:**
  - ✓ Stress criterion is not enough to predict adhesive debonding
- **Coupled criterion** Wei ßgraeber [3] , Martin [5] :
  - ✓ Strength + Energy criterion



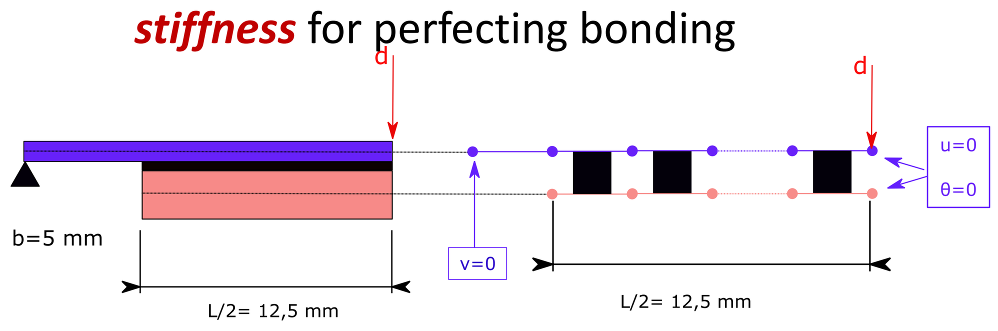


Finite element method
- ✓ Use shape function
- ✓ Include singularities
- ✓ *Time consuming*

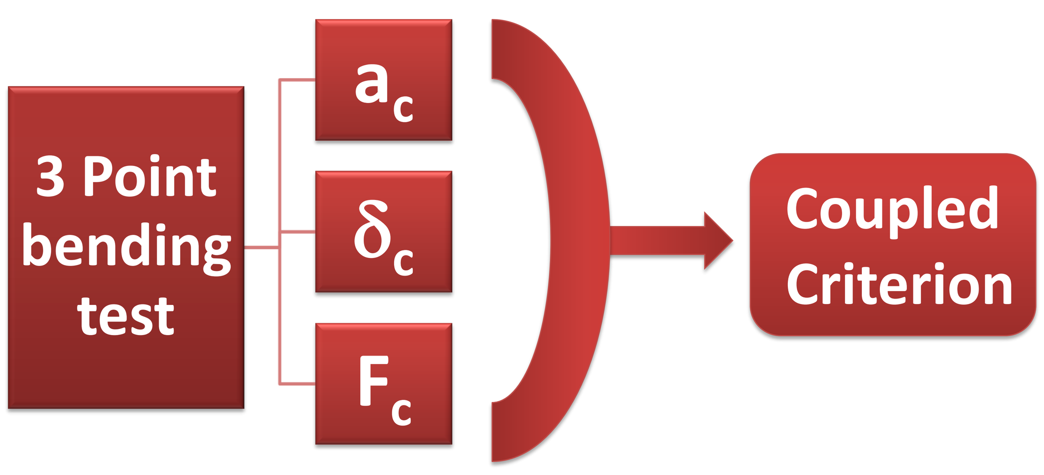
Limited geometries

Macro-element method
- ✓ No shape function: Local equilibrium of adherents
  - ○ Shape of EDO solutions
- ✓ *Fast solution*

- **Macro-Element representation** Paroissien [4]
  - Simplified approach for the stress analysis of bonded or hybrid (bolted/bonded) joints
  - Bed of shear and peel springs
  - Two materials simulated as Euler-Bernoulli beams
    - ○ Interface region: bed of springs – *high stiffness* for perfecting bonding



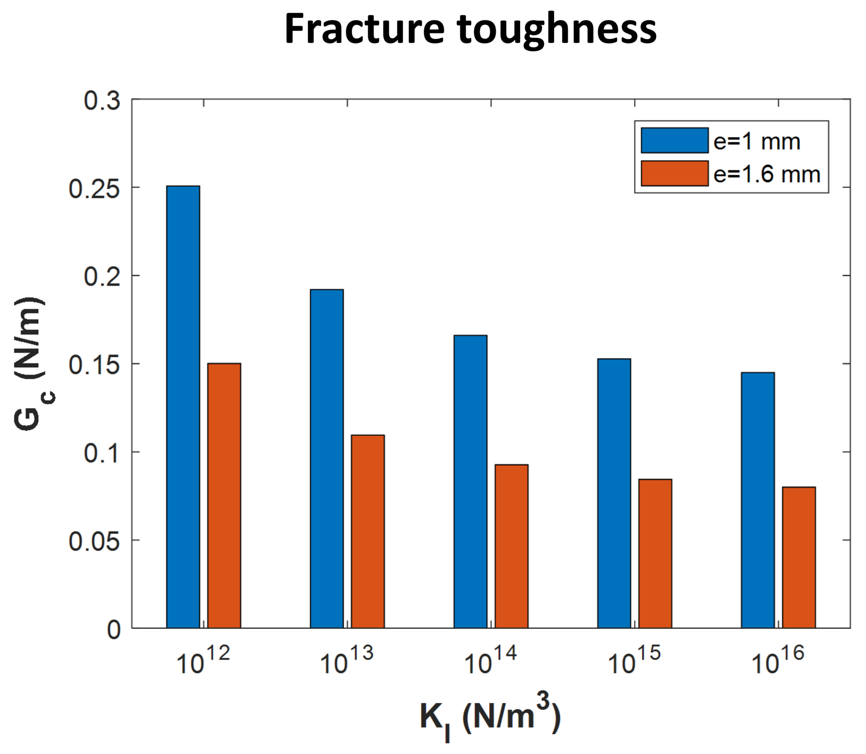
Dialogue test - simulation

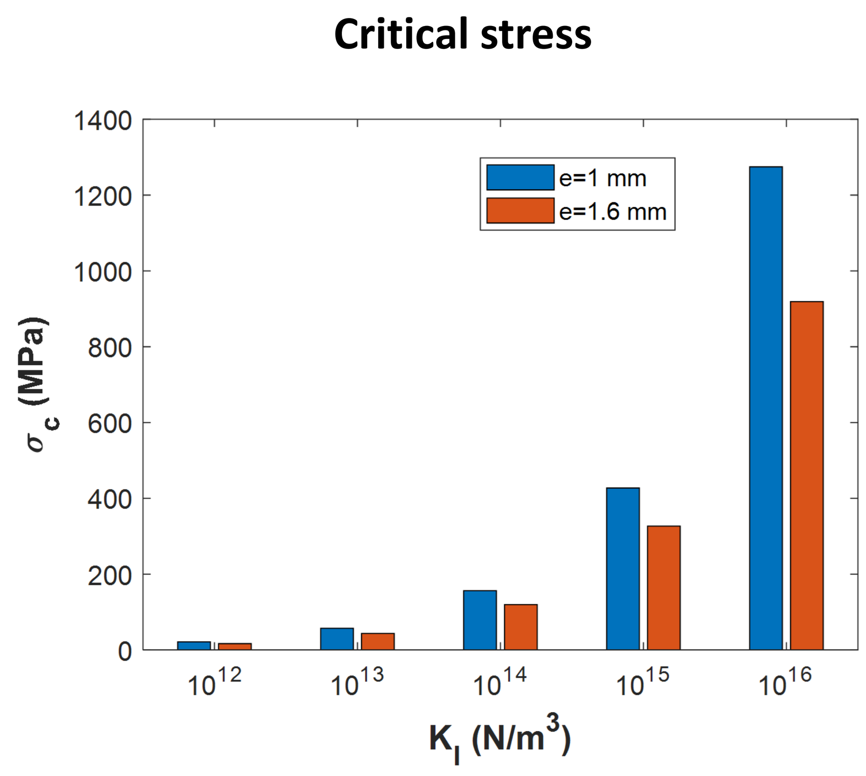


Inputs – Sauvage [2]

	F_c (N)	a_c /2 (mm)
e_{subst}=1,0 mm	86,0	0,055
e_{subst}=1,6 mm	126,6	0,0559

- Evaluation of peel stiffness on fracture toughness and critical stress (K_I=K_{II})
- First approach: **mixed mode not included**





Conclusions and perspectives

Conclusions
- ✓ Dispersions: they disallowed a complete equivalence of fracture toughness
- ✓ Fracture toughness of bulk polymer (0,1 $N/mm \leq G\_Ic \leq 0{,}333\ N/mm$)
- ✓ Find a simpler surface treatment to provide the initiation – **HOW?**
  - ○ Nitric acid etching – Different duration and temperatures

Perspectives
- ✓ Include the mixed mode
- ✓ Evaluation of residual stresses and the gradient of properties

References

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