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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:

- ✓ $E_{subst}=68$ Gpa
- ✓ $\nu=0,33$

Polymer: DGEBA/DETA:

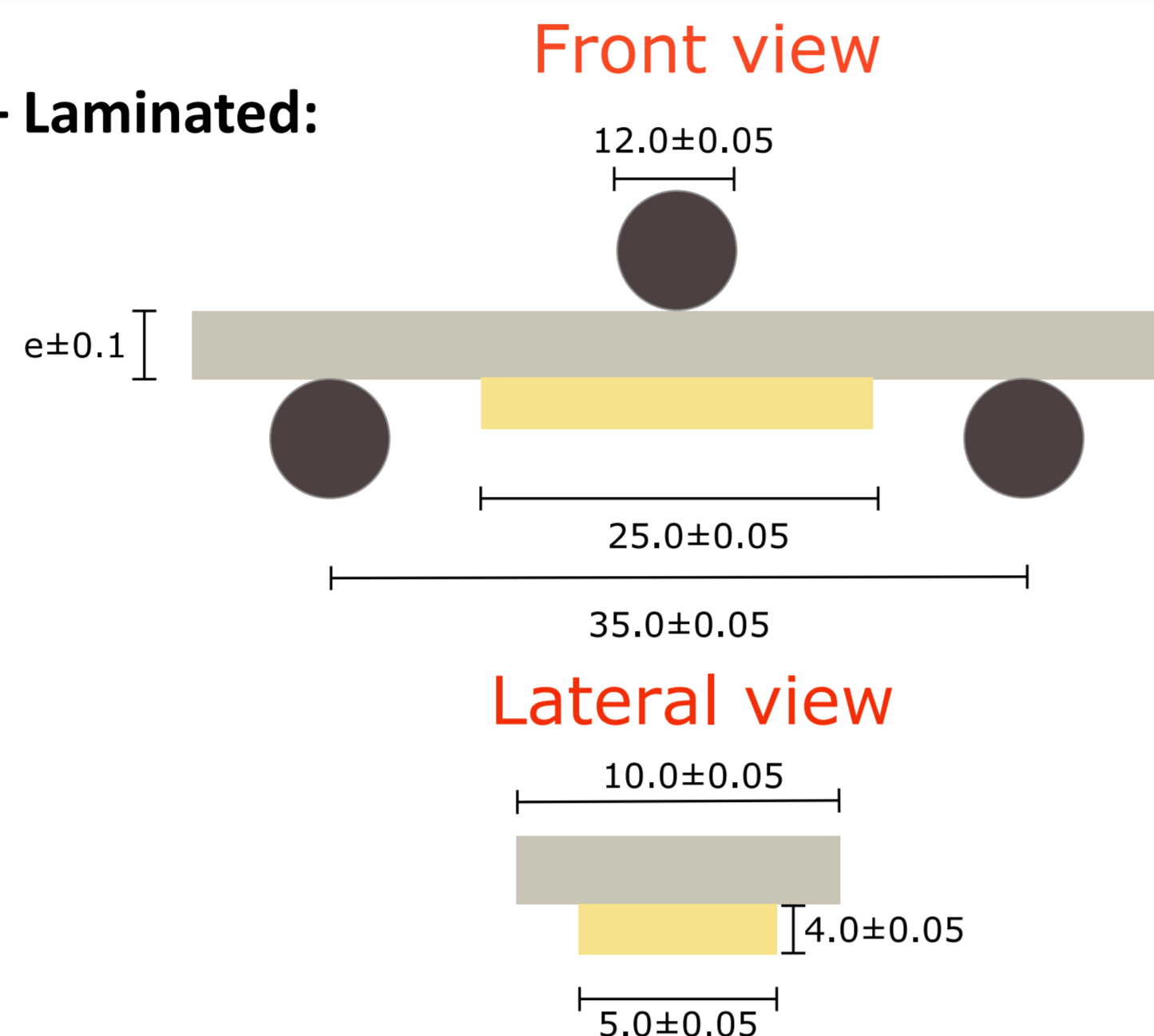
- ✓ $E_{poly}=3$ Gpa
- ✓ $\nu=0,33$

Surface treatment:

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

Polymerization cycle:

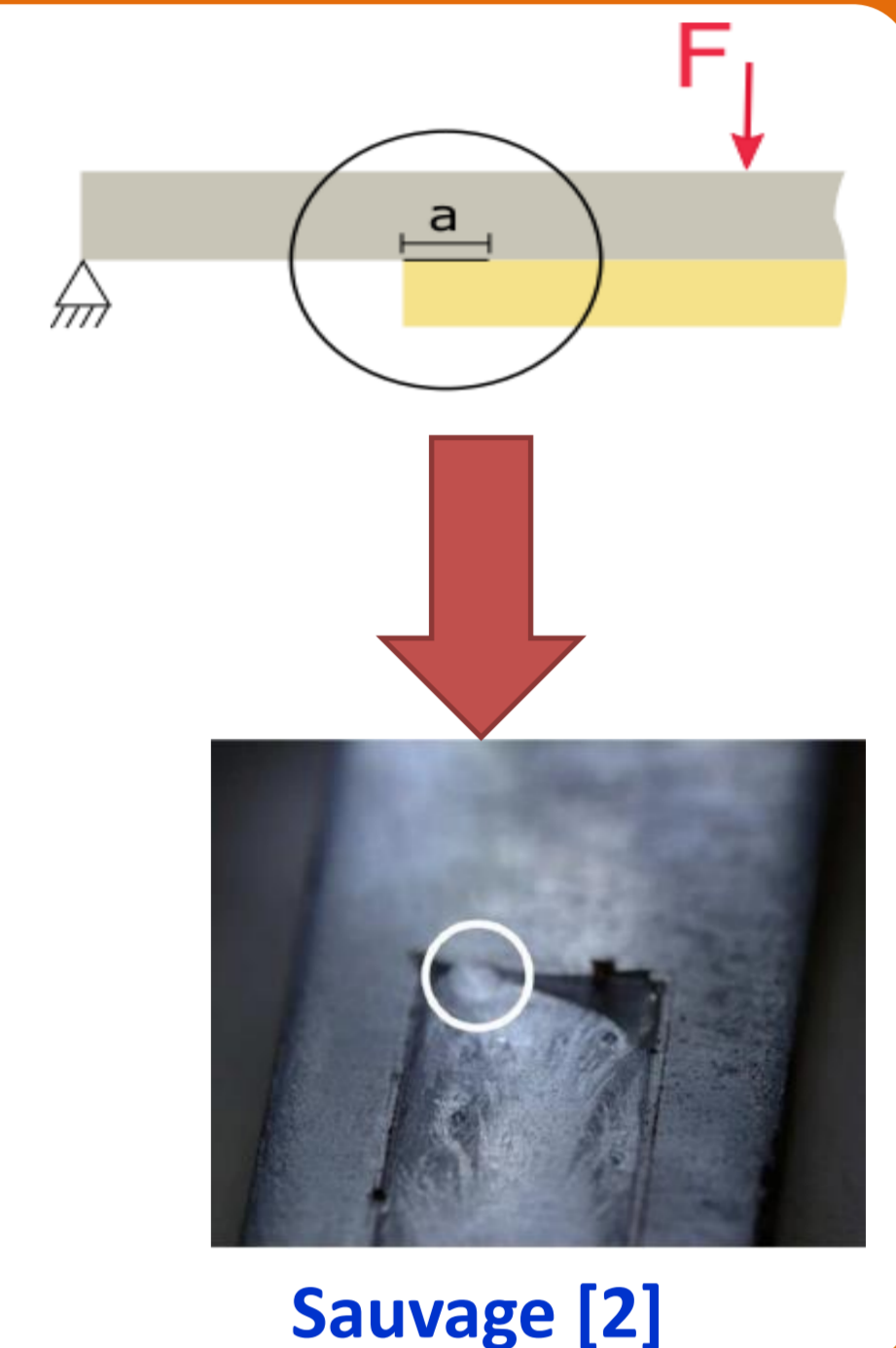
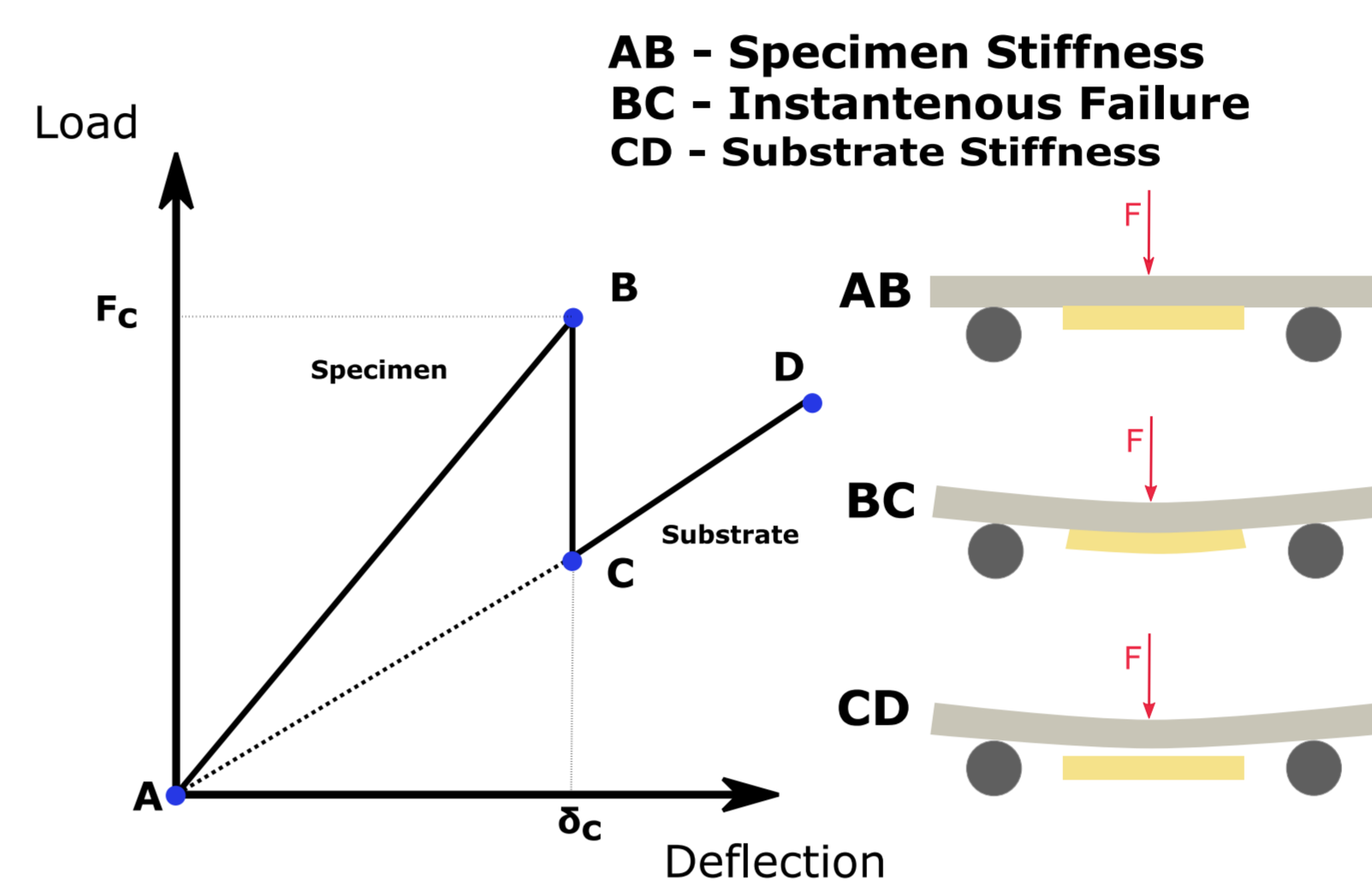
- ✓ 1 Hour at 150°C



Method

3-Point bending test - ISO 14679-1997

- ✓ Main goal: **Adhesive failure initiation**



Numerical Approach

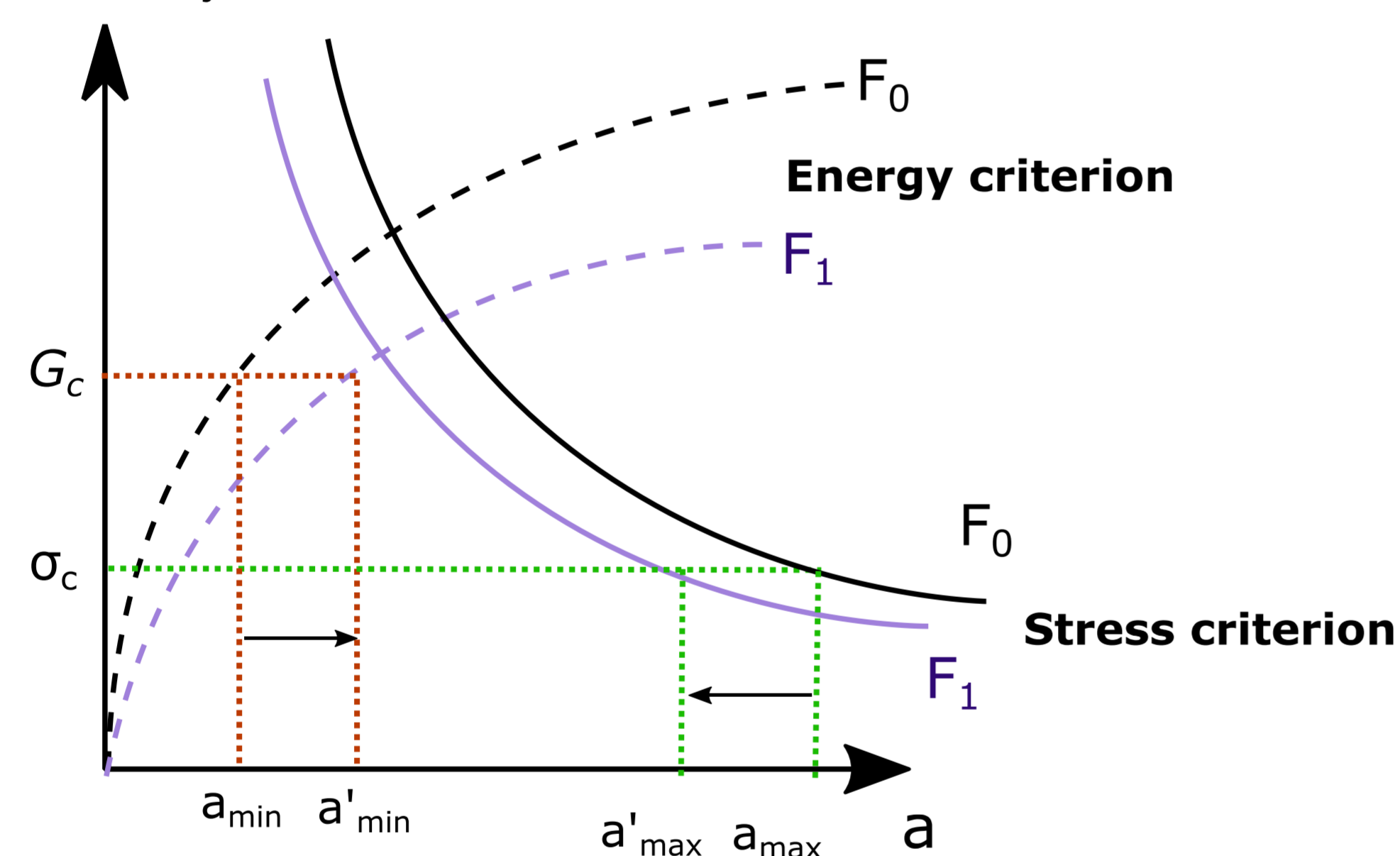
High stress concentration:

- ✓ Stress criterion is not enough to predict adhesive debonding

Coupled criterion Wei Bgraeber [3], Martin [5]:

- ✓ Strength + Energy criterion

$$G_{inc} f(\sigma_{ij})$$



Numerical solution

Finite element method

- ✓ Use shape function
- ✓ Include singularities
- ✓ **Time consuming**

Stress and fracture toughness

Analytical solution

Limited geometries

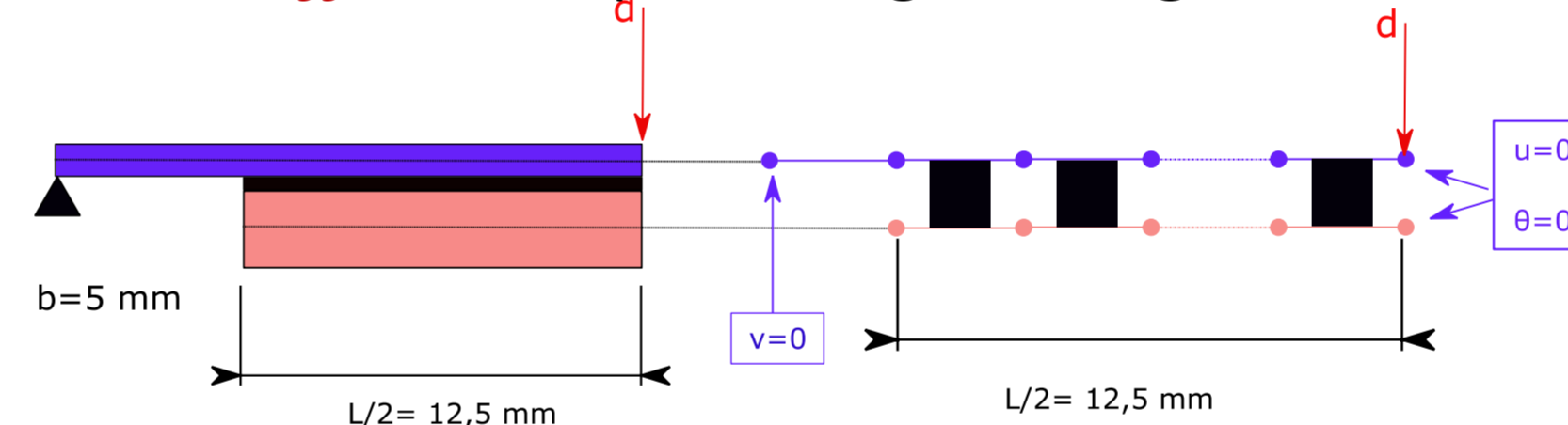
Semi-analytical solution

Macro-element method

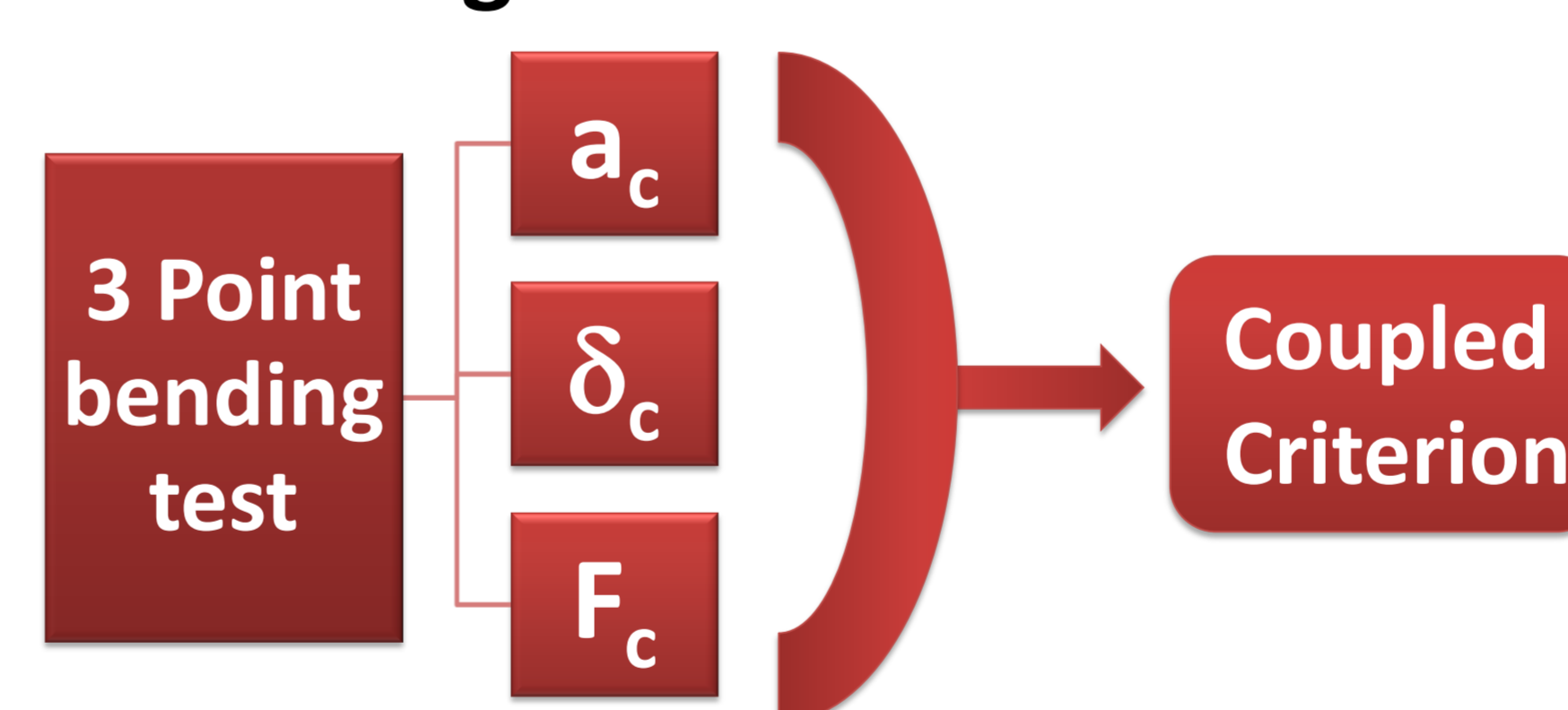
- ✓ No shape function: Local equilibrium of adherents
- Shape of EDO solutions
- ✓ **Fast solution**

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

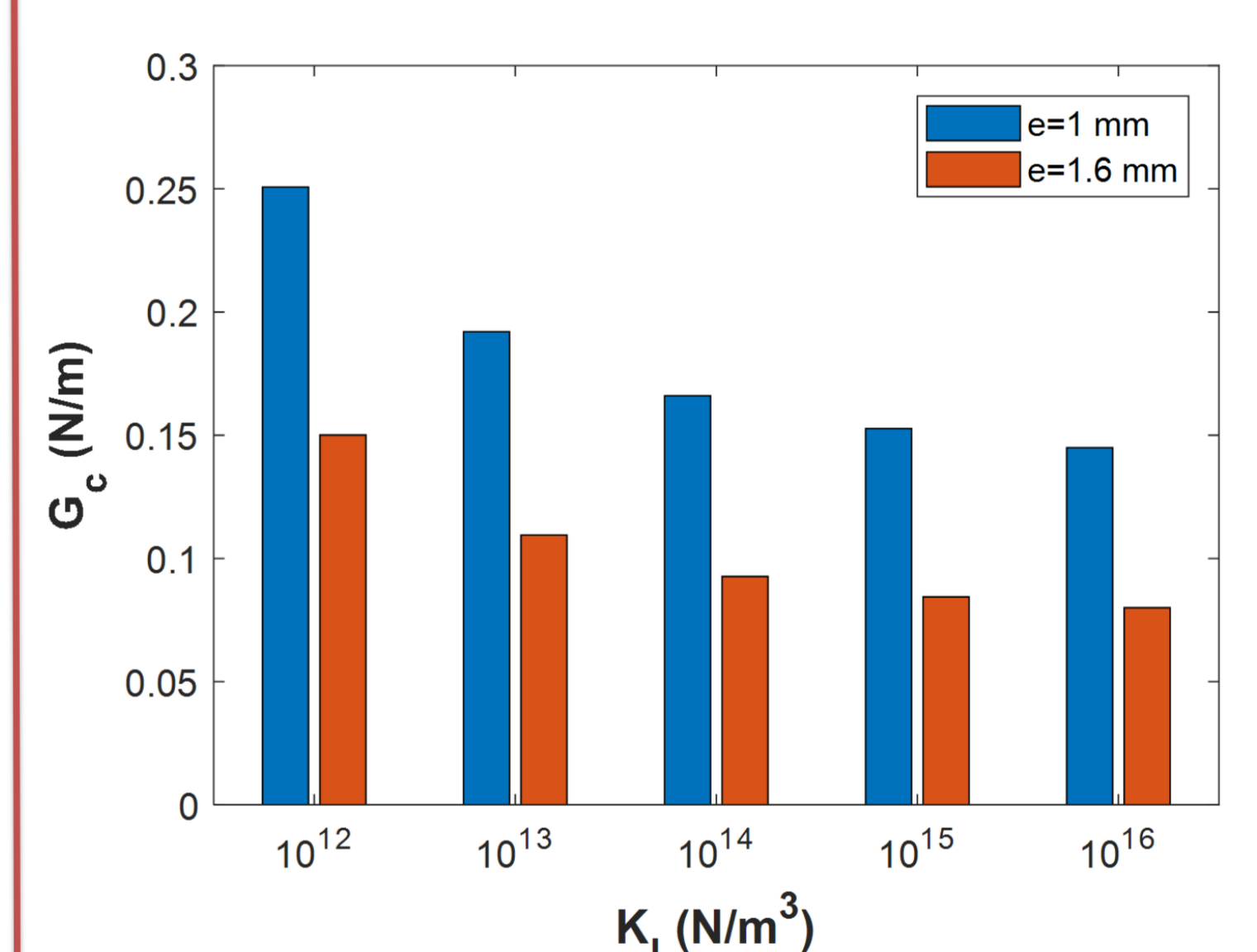


Inputs – Sauvage [2]

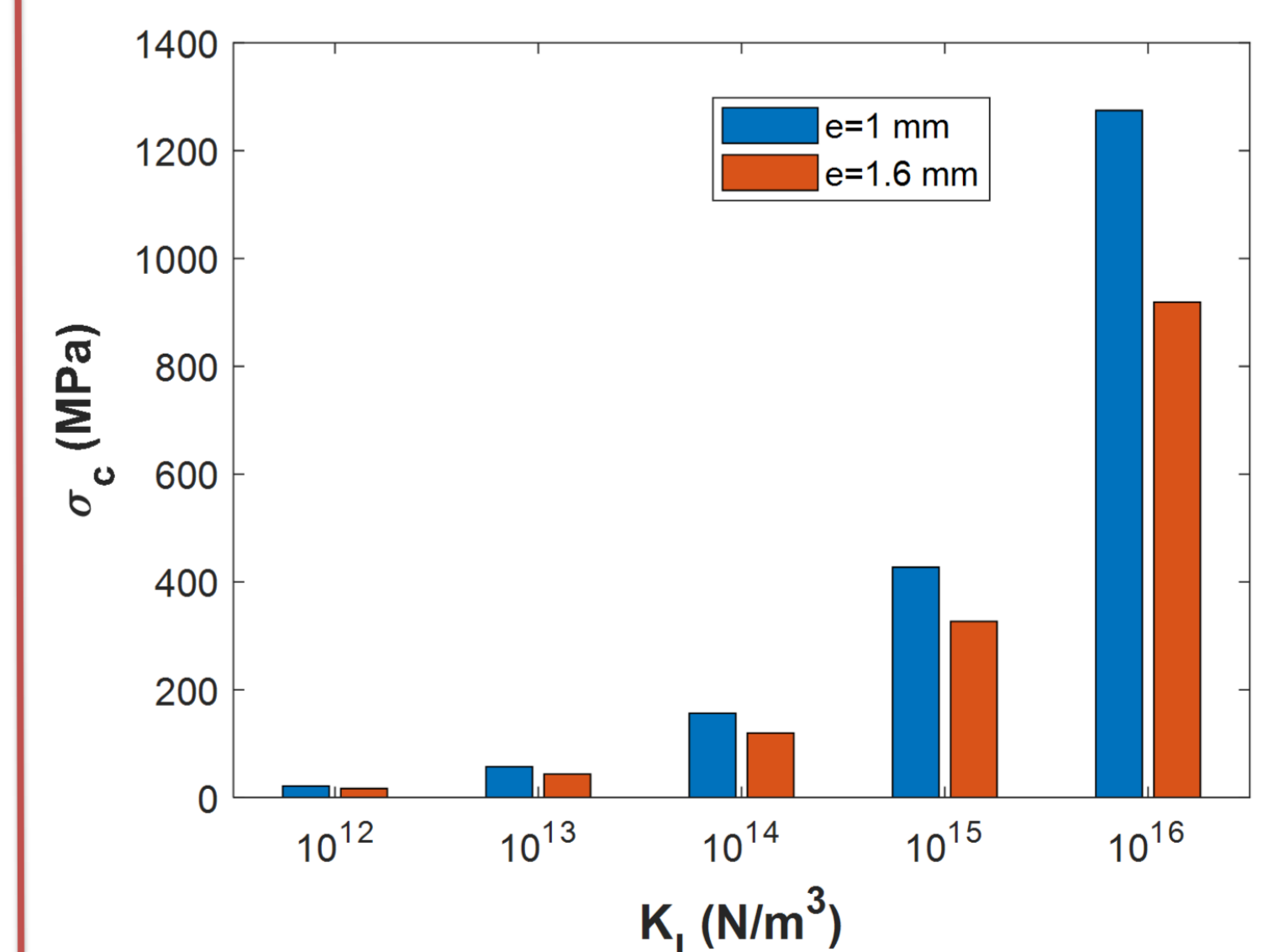
	F_c (N)	$a_c/2$ (mm)
$e_{subst}=1,0$ mm	86,0	0,055
$e_{subst}=1,6$ mm	126,6	0,0559

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

Fracture toughness



Critical stress



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

- [1] A.A. Roche, A.K. Behme, J.S. Solomon, Int. J. Adhes. Adhes., 2, 24 (1982).
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