Adhesive wear study Term presentation

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ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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Outline

Adhesive wear

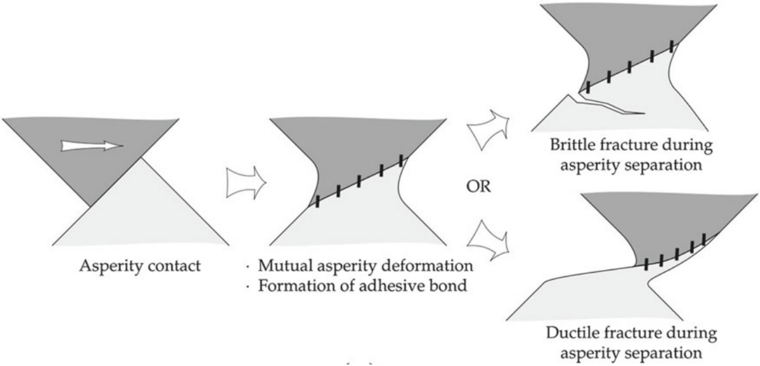
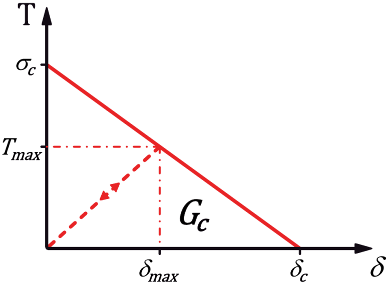


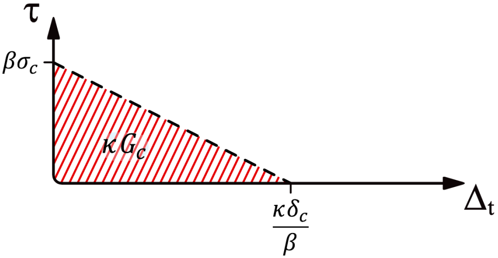
Figure: V. Carollo, M. Paggi, J. Reinoso [10]

Extrinsic cohesive elements [9]

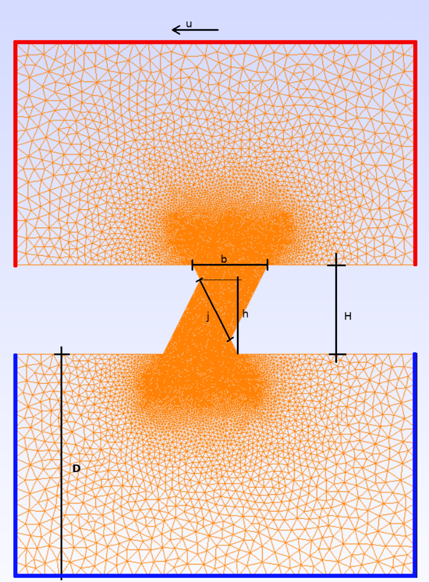
cohesive law

- $\sigma_{eff} > \sigma_c$
  with $\sigma_{eff} = \sqrt{\sigma_n^2 + \frac{\tau^2}{\beta^2}}$
- $\delta_I = \sqrt{\beta^2 \Delta_t^2 + \Delta_n^2}$
- $\delta_{II} = \sqrt{\frac{\beta^2}{\kappa^2} \Delta_t^2 + \Delta_n^2}$





Adhesive wear modeling



Mesh and loading features

- Dynamic loading
- Top: $u_x = u_0 + v_x \cdot \Delta_t$, $u_y = 0$
- Bottom: $u_x = 0$, $u_y = 0$
- slender geometry: $\frac{h}{b} = 1$
- bulky geometry: $\frac{h}{b} = 0.5$

Material and loading parameters

Material parameters

- Aluminum 7075-T6 [11]
- Elastic behavior

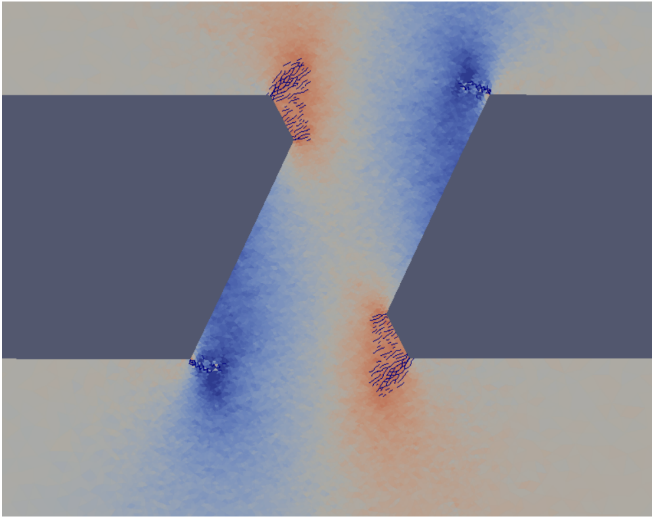
Cohesive element parameters

- $\kappa = \frac{G_{c,II}}{G_{c,I}}$
- β weight expressing tangential opening contribution

Loading parameters

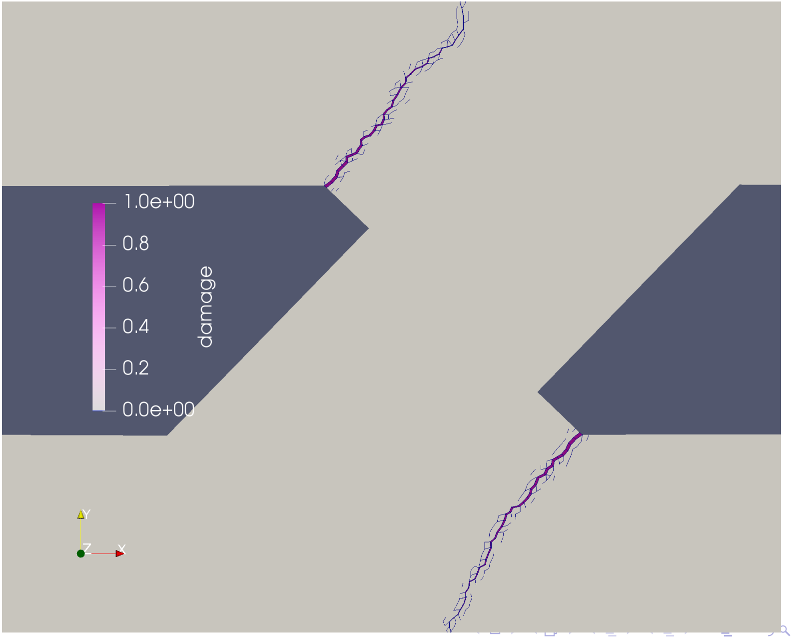
- Initial displacement u_0 and velocity $v_0(\mathbf{x})$ to reduce elastic phase
- Sliding velocity $v_x = 10[m/s]$
- Time step $\Delta_t = k \cdot \Delta_{t,stable}$; $k = 0.1$

Mid-Term situation

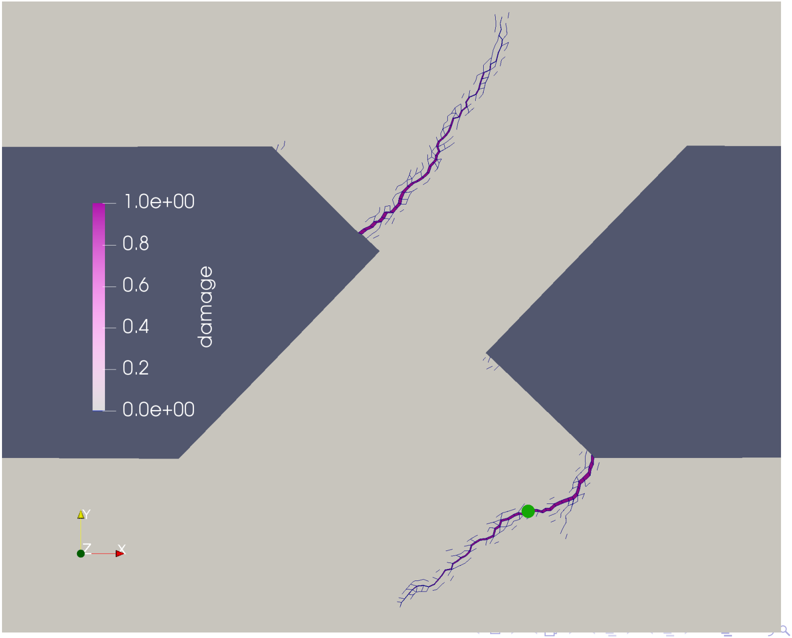


- Mesh size scaling
- Increase mode $|II|$ toughness: $\beta = 5$, $\kappa = 5$

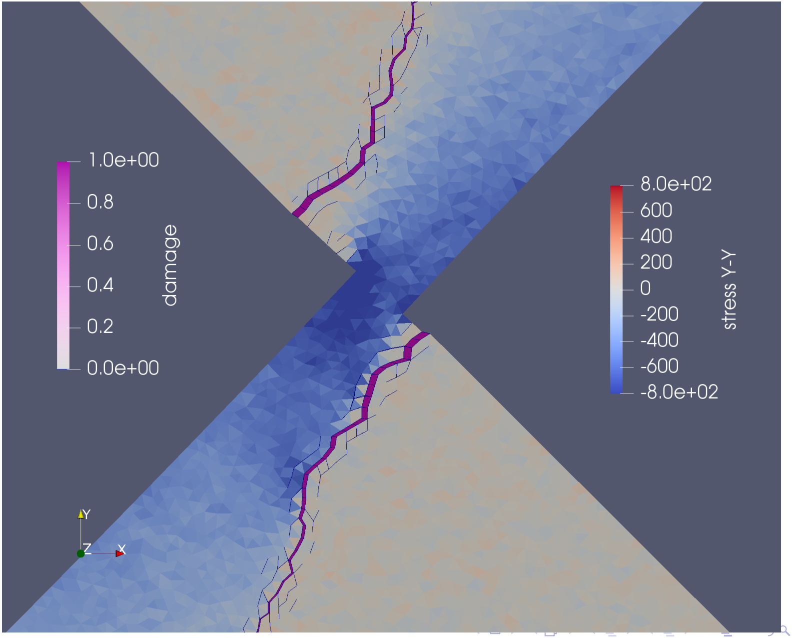
h/b = 0.5 ; J=0.8



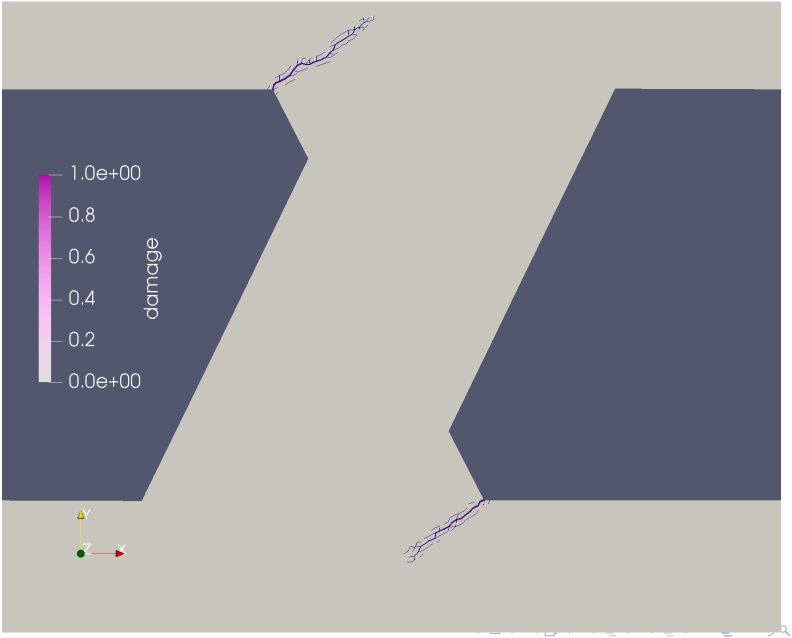
h/b = 0.5 ; J=0.5



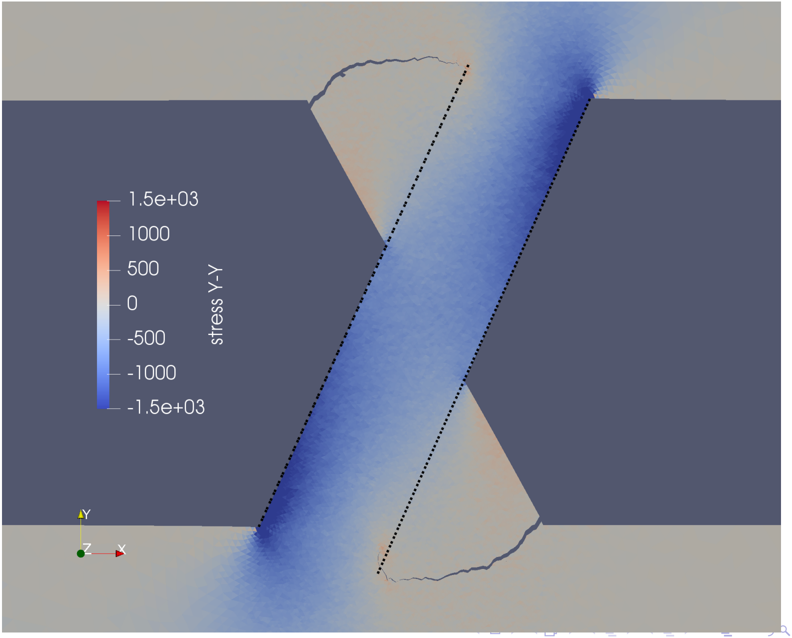
h/b = 0.5 ; J=0.1


1.0e+00
0.8
0.6
0.4
0.2
0.0e+00
damage
8.0e+02
600
400
200
0
-200
-400
-600
-8.0e+02
stress Y-Y
Y
Z
X

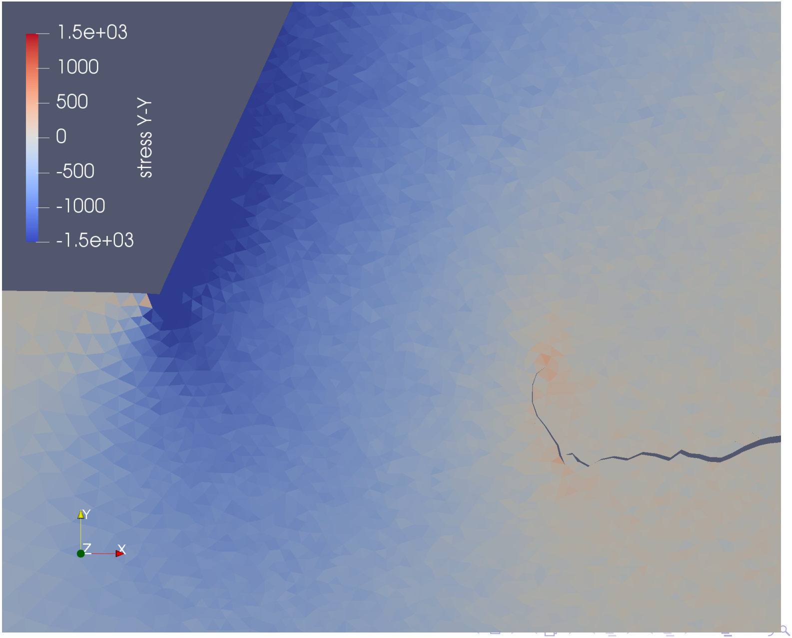
h/b = 1 ; J=0.8



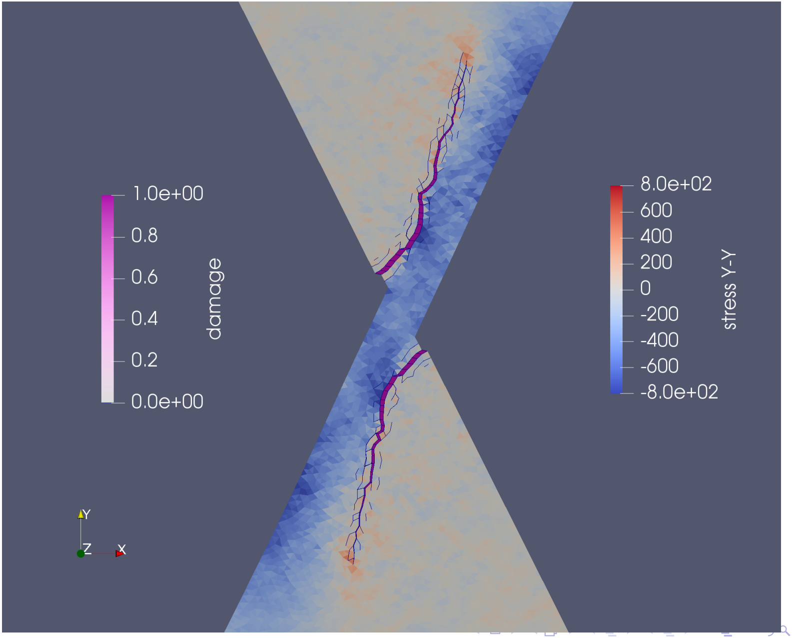
h/b = 1 ; J=0.5



h/b = 1 ; J=0.5



h/b = 1 ; J=0.1


1.0e+00
0.8
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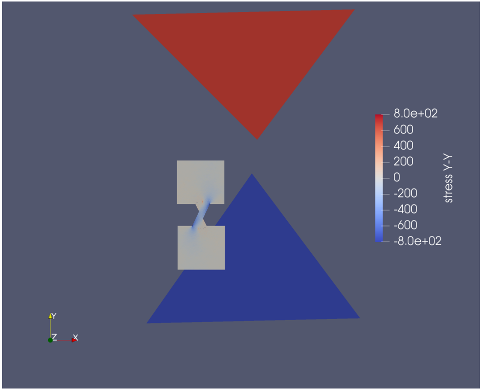
damage
8.0e+02
600
400
200
0
-200
-400
-600
-8.0e+02
stress Y-Y
Y
Z
X

Further development



Limitations of the model

- Plastic dissipation
- Boundary conditions
- Mesh dependence of the crack path
- Element detachment near the crack

Outline

Outcomes from previous studies

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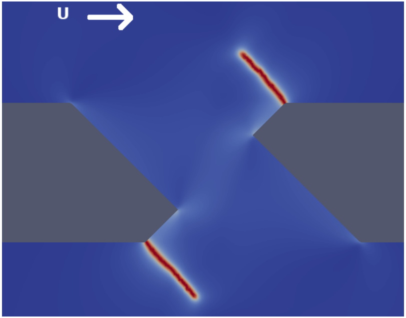

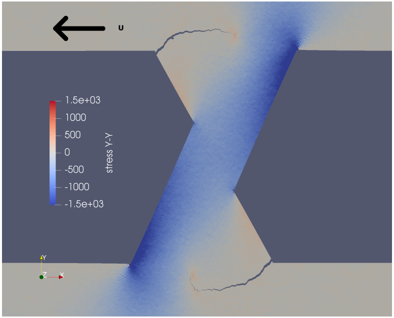

Model features

Crack nucleation and growth modeling needs mesh independence, plastic behavior and large deformations

A single model that includes all features ?

Recent publication [10]

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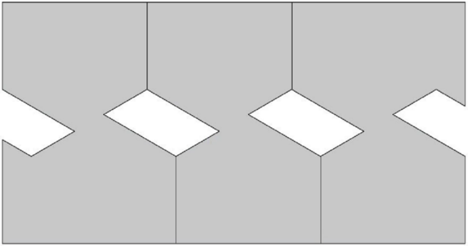
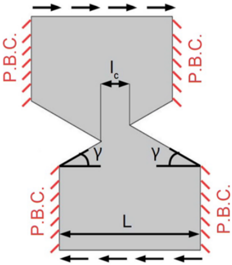
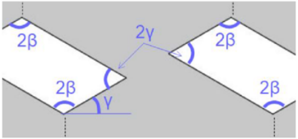
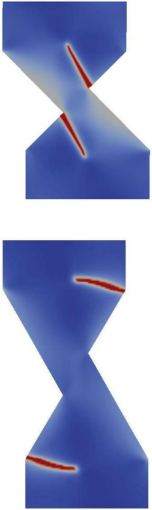

(a)



(b)



(c)



Plasticity in phase-field models

Uncoupled models Damage starts to grow after ultimate yield stress is mobilized [2]

Coupled model Coupling between plastic models and damage models [3]

Higher order phase-field formulation Phase-field formulation is extended to account for non-linear ductile fracture. Needs shape functions $\in C^3$ [4]

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Internal energy density for coupled models

$$W_{PD} = \overbrace{g(d)\psi_e(\epsilon - \epsilon^p)}^{\text{E}} + \overbrace{h(d)\psi_p(\alpha, \nabla\alpha)}^{\text{H}} \quad \text{free energy}$$
$$+ \underbrace{\Delta_f(d, \nabla d)}_{\text{F}} + \underbrace{p(d)\Delta_p(\alpha)}_{\text{P}} \quad \text{dissipated work}$$

State variables

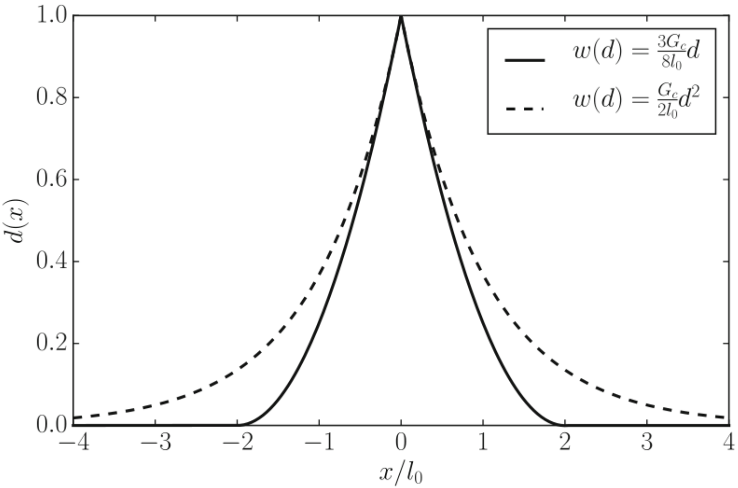
Damage field

- $d(\mathbf{x}, t) \in [0, 1]$
- $\dot{d} > 0$

Accumulated plastic strain

- $\alpha(\mathbf{x}, t) = C_N \int_0^t ||\dot{\epsilon^p}|| d\tau$
- $\dot{\alpha} > 0$

Fracture energy [8]



fracture energy density functional

$$\Delta_f(d, \nabla d) = w(d) + w_0 l_0^2 |\nabla d|^2$$

Goal of the masters thesis

Model implementation (March-May)

- Complete derivation of the plastic-damage model for FEM
- Model implementation within *Akantu*

Adhesive wear simulations (Mai-August)

- Comparative study using phase-field and cohesive elements
- Investigation of the influence of asperity height to width ratio ($\frac{h}{b}$) and junction length (J) on the crack patterns
- More complex geometries

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