Variational formulation and numerical resolution of persistent adhesive contact in hyperelastic materials

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This contribution develops an energy-consistent variational and computational framework for hyper-viscoelastic contact problems involving unilateral contact, adhesion, and friction under large deformations. The formulation extends the classical persistent contact condition to cohesive regimes, ensuring a consistent transition between full adhesion, progressive decohesion, and complete separation.

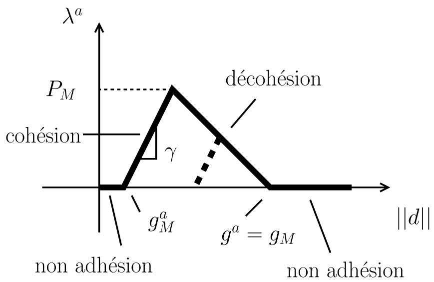

Figure 1: Normal adhesive traction λ_a versus adhesive gap $\|d\|$: cohesive (left), decohesion (middle), and non-adhesive (right) regimes.

Adhesion is described using a Talon–Curnier cohesive law, formulated as a projection-based relation driven by the accumulated interfacial elongation. The material behavior follows a Kelvin–Voigt hyper-viscoelastic model. The full formulation is expressed in the reference configuration, yielding a rigorous weak form and a straightforward finite element discretization. Let $\|d\|$ denote the adhesive gap, g^a the plastic interfacial elongation, and $s(g^a)$ the decreasing cohesive threshold; the normal adhesive traction is given by

$$\lambda^a = \mathrm{Proj}_{[0,\, s(g^a)]}\big(\gamma(\|d\| - g^a_0)\big), \tag{1}$$

where g^a_0 denotes the previous value of the elongation at the beginning of the time step, and $\gamma > 0$ is a penalty parameter. Time integration is performed using an implicit midpoint scheme that preserves the discrete energy balance. The resulting nonsmooth problem is solved efficiently using a semi-smooth Newton method combined with a Primal–Dual Active Set (PDAS) strategy, eliminating Lagrange multipliers and ensuring robust convergence. Numerical experiments demonstrate the accuracy, stability, and energy consistency of the proposed approach in reproducing complex adhesion and decohesion mechanisms.

References

[1] C. Talon and A. Curnier. A model of adhesion coupled to contact and friction. *European Journal of Mechanics A/Solids*, 22:545–565, 2003.

[2] M. Hintermüller, K. Ito, and K. Kunisch. The primal-dual active set strategy as a semismooth Newton method. *SIAM Journal on Optimization*, 13(3):865–888, 2002.