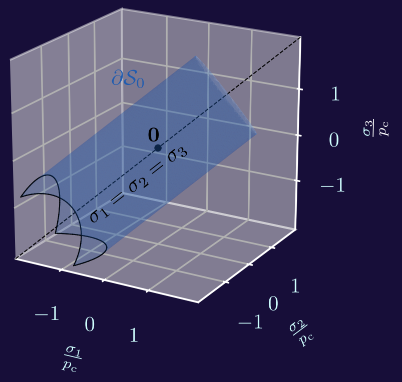
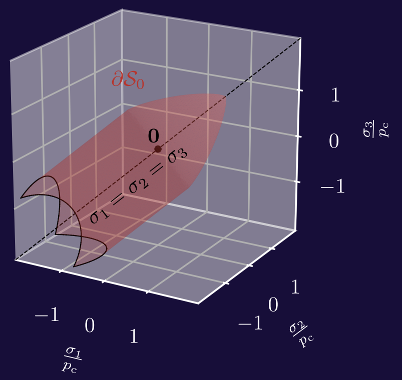
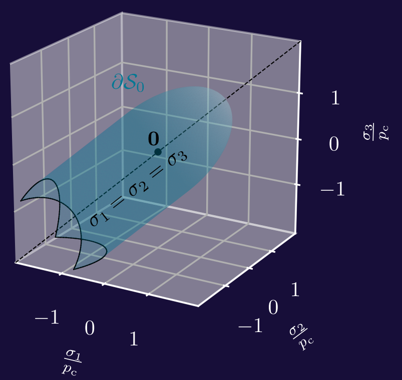
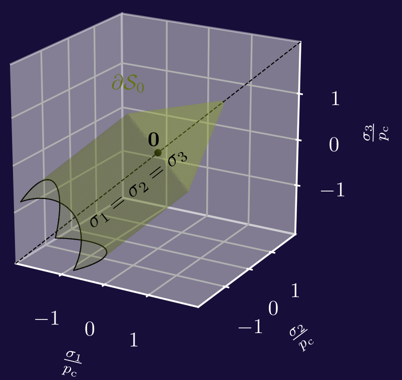
Recent results on variational phase-field modeling of cohesive fracture









Laura De Lorenzis

ETH Zurich

25th of June

2 p.m. - Amphitheatre Pôle de Mécanique

Variational phase-field models of brittle fracture have been quite successful for studying Griffith-type crack propagation in complex scenarios. However, as approximations of Griffith's theory—which does not incorporate a strength criterion—these models lack flexibility in prescribing material-specific strength surfaces. Consequently, they struggle to accurately capture crack nucleation under multiaxial stress conditions.

In a recent paper [1], we proposed a variational phase-field model that approximates cohesive fracture and accommodates an arbitrary (convex) strength surface, independent of the regularization length scale. This formulation results in sharp cohesive cracks and naturally enforces a sharp non-interpenetration condition. It satisfies strain hardening for a sufficiently small ratio of the regularization length to the material's cohesive length, whereas stress softening and "crack-like" residual stresses are fulfilled by construction. In [1], we investigated the model in one and three dimensions, establishing first- and second-order stability results.

More recently [2, 3], we have made further progress in different directions. From the modeling standpoint, we have clarified pros and cons of different strength criteria, including those considered in [1] and [4], and we have compared the results of the second-order stability analysis in [1] with the partially contradictory results in [4] and with numerical experiments. From the computational standpoint within the finite element method, we now solve for the eigenstrain locally by means of closed-form or one-dimensional numerical iterative solutions, which enables the straightforward extension of codes based on phase-field models of brittle fracture to the new framework. Finally, we have extended the model to dynamics [4] and examined the main features of its behavior regarding interaction of elastic waves with pre-existing cracks and crack propagation. The talk summarizes these recent advancements.

[1] F. Vicentini, J. Heinzmann, P. Carrara, L. De Lorenzis (2026), Variational phase-field modeling of cohesive fracture with flexibly tunable strength surface, Journal of the Mechanics and Physics of Solids, 207, 106424.
[2] G. Illiano, F. Vicentini, L. De Lorenzis (in preparation).
[3] J. Heinzmann, F. Vicentini, P. Carrara, L. De Lorenzis (in preparation), Variational phase-field modeling of dynamic cohesive fracture.
[4] B. Bourdin, J. Marigo, C. Maurini, and C. Zolesi (2025), A variational approach to fracture incorporating any convex strength criterion. arXiv:2506.22558.