A cohesive interface formulation in large displacements

Guido Borino[1], Francesco Parrinello[1]
[1]*Dipartimento di Ingegneria Civile, Ambientale, Aerospaziale, dei Materiali, Universitá di Palermo, Italy*
E-mail: guido.borino@unipa.it, francesco.parrinello@unipa.it

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Mechanical interfaces are theoretical and computational tools able to properly reproduce the progressive decohesion along predefined surfaces [1]. Scientific literature is rich of interface models, developed under very different conctitutive framework, but mostly developed in small displacements, whereas a few of them assess the problem in a geometrically nonlinear setting.

In the present contribution interface formulation is rigorously developed in the large displacements regime. The relevant cohesive interface constitutive relations are defined in the local reference with normal and tangential axes to the middle surface in the current configuration. The interface is defined as a zero thickness layer with the traction vector acting between the two connected surfaces. Membrane forces are assumed negligible and separation displacement is assumed to remain small, at least up to full debonding. Under this constitutive hypothesis rotational equilibrium, discussed in [2], is implicitly verified. Geometric operators in the current configuration, such as the normal and tangential vectors to the middle surface and interface elongation, are defined as functions of nodal displacements. Corotational approach is also developed from the same formulation under the further hypothesis of small interface elongation. The nodal force vector and consistent tangent stiffness matrix are computed for a two-dimensional interface element. At difference with the available formulations, the present approaches show that symmetry condition of the geometric stiffness matrix is achieved both for the finite displacement interface and for the corotational one. As pointed out in [3], symmetry of the tangent stiffness is in itself a relevant property and we can also say that, even if Newton-Raphson methods works as well as with nonsymmetric tangent operators, symmetry typically produces higher rate of convergence and reduced computational time.

In order to have a realistic and accurate mixed mode fracture modeling, the proposed formulation has been realized inserting a coupling parameter, which allows to naturally produce two different fracture energies, in simple mode I and in a pure mode II. Because decohesion is just physical phenomenon where elastic ligaments are broken, the proposed model make use of only one single scalar damage variable. It is observed that in mixed loadings, the energy dissipated for unit length fracture is a value related to the mixity rate without any energy inconsistency.

The model is developed following a thermodynamic consistent framework, which means an a-priori satisfaction of the first and second principle of thermodynamics. A damage activation function and a damage potential function are defined, which, being different, frame the proposed model in the class of nonassociative damage models.

Either the finite displacements, or the symmetric corrotational formulations have been implemented in an open source finite element code FEAP [4] and some numerical simulations are presented. Features and effectiveness of the two formulations are shown and compared in terms of convergence rate.

References

[1] Parrinello, F., Marannano, G., Borino, G., “A thermodynamically consistent cohesive-frictional interface model for mixed mode delamination,” *Eng. Frac. Mech.*, **153**, 61-79 (2016).

[2] Vossen, B., Schreurs, P., van der Sluis, O., Geers, M., "On the lack of rotational equilibrium in cohesive zone elementsExact Nonlinear Plasma Oscillations," *Comp. Meth. Appl. Mech. Eng.ng.*, **254**, 146-153 (2013).

[3] Mosler, J., and Scheider I., "A thermodynamically and variationally consistent class of damage-type cohesive models," *J. Mech. Physics Solids*, **59** (8), 1647-1668 (2011).

[4] Zienkiewicz, O., . Taylor, R.L., *The Finite Element Method*, 5th Edition. Butterworth-Heinemann Press, (2000).