Non Smooth Fracture Dynamics (NSFD)

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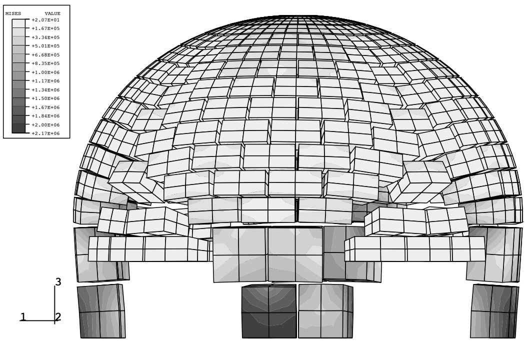
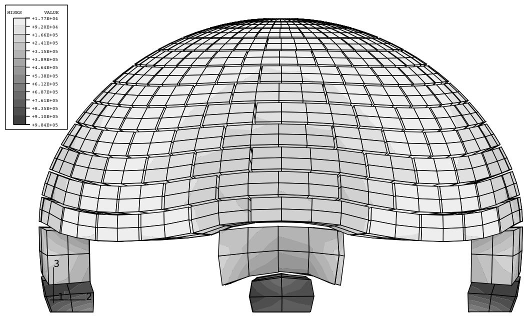


(a) An example without cohesion - Transient response(magnification=2.0E+04)



(b) With cohesion, equilibrium state (magnification=3E+06)

Figure 1: A masonry dome on 4 pilars under gravity load

We present in this work a modeling approach and an associated numerical strategy both devoted to complex mechanical surface interactions. This approach together with the dedicated numerical strategy are referred as *Non Smooth Fracture Dynamics* (NSFD).

From an applied point of view, this work concerns the comprehension, the prediction and the numerical simulation of dynamic fracture for a wide variety of materials and structures. The main contribution is the ability to predict an entire fracture process: crack initiation, growth, propagation of microcracks, coalescence, propagation of a microcrack, final rupture and post fracture behavior (e.g. frictional contact between created fragments after fracture).

The NSFD approach is based on three main features:

1. a surface-volumetric multibody approach using mixed boundary conditions between each volumetric finite elements and/or rigid bodies,
2. the development of a generic formulation of cohesive zone type models coupled to various physical phenomena as wear or dry friction, and
3. a specific nonsmooth dynamical framework associated to implicit time-stepping schemes. In particular, this last feature allows a convenient numerical treatment of nonsmooth events such as impacts and unilateral constraints and permits larger time-steps when dealing with nonsmooth mechanics.

The associated mathematical formulation is based on pioneering works of [1] and [2] (see [3] for further details) and the coupling with cohesive zone type models derives from the method proposed in [4, 5]. The numerical strategy rests on algorithms and code architecture proposed by [6].

The efficiency of the NSFD approach is illustrated on static or dynamic fracture of non linear homogeneous materials (elasticity, viscosity, plasticity and coupling) as well as heterogeneous materials. Research of equivalent fracture properties can be done extending this approach to periodic homogenization [7]. The fracture of functionally graded materials and the surface damage in a large collection of bodies as masonry belong to the scope of the method [8, 9].

References

[1] *Unilateral contact and dry friction in finite freedom dynamics*, J.-J. Moreau, in: J.-J. Moreau, P. Panagiotopoulos Editors, Non Smooth Mechanics and Applications, Vol. 302 of CISM - Courses and Lectures, Springer, Vienna, 1–82, 1988.

[2] *The non-smooth contact dynamics method*, M. Jean, Computer Methods in Applied Mechanics and Engineering 177, 235–257, 1999.

[3] *Numerical Methods for Nonsmooth Dynamical Systems: Applications in Mechanics and Electronics*, volume 35 of *Lecture Notes in Applied and Computational Mechanics*. V. Acary B. Brogliato. Springer Verlag, 2008.

[4] *Non-smooth contact dynamics approach of cohesive materials*, M. Jean, V. Acary, Y. Monerie, Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 359 (1789), 2497–2518, 2001.

[5] *Nonsmooth fracture dynamics using a cohesive zone approach*. V. Acary, Y. Monerie. INRIA Research Report 6032, `http://hal.inria.fr/inria-00110560/fr/`, 2006.

[6] *Une plateforme de développement dédiée à la modélisation des problèmes d'interaction*, F. Dubois, M. Jean, in: M. Potier-Ferry, M. Bonnet, A. Bignonnet Editors, 6ème colloque national en calcul de structures, Vol. 1, Giens, 111–118, 2003.

[7] *Two field multibody method for periodic homogenization in fracture mechanics of nonlinear heterogeneous materials*, F. Perales, S. Bourgeois, A. Chrysochoos, Y. Monerie, Engineering Fracture Mechanics 75 (11), 3378–3398, 2008.

[8] *Nonsmooth fracture dynamics of functionally graded materials*, F. Perales, Y. Monerie, A. Chrysochoos, Journal De Physique. IV : JP 134, 367–372, 2006.

[9] *Numerical modeling of three dimensional divided structures by the non smooth contact dynamics method: Application to masonry structure*. V. Acary, M. Jean. In *The Fifth international Conference on Computational Structures Technology 2000*,B.H.V. Topping, editor, pp. 211–222. Civil-Comp Press, 6-8 September 2000.