Overall structural equilibrium in Computational Methods Coupling Peridynamics with Classical Mechanics

Mirco Zaccariotto*[1], Tao Ni[2], Greta Ongaro[1], Pablo Seleson[3] and Ugo Galvanetto[1]

[*1]Department of Industrial Engineering, University of Padua, Padova, Italy
e-mail: mirco.zaccariotto@unipd.it, ugo.galvanetto@unipd.it
[2] College of Civil and Transportation Engineering, Hohai University, 210098, Nanjing, China
[3] Computer Science and Mathematics Division, Oak Ridge National Laboratory, USA

ABSTRACT

The pervasive presence of cracks in many structures, in particular in aerospace engineering, still represents a challenge for the engineer who wants to simulate the full structural life cycle. Since cracks do not satisfy the basic hypothesis of Classical Continuum Mechanics (CCM) i.e. the continuity of the domain where the problem is defined, in the last years many scientists have tried to equip CCM based methods, in particular the Finite Element Method (FEM), with the capability to simulate crack propagation.

Among the promising approaches well suited to model crack propagation there is that based on the theory of Peridynamics (PD) [1,2]. The PD based method does not assume continuous displacements, but it is not computationally efficient, due to the non-local nature of PD. Therefore, coupling of PD grids to FEM meshes in a way to obtain a numerical method that possesses the advantages of both computational techniques and avoids their pitfalls is the topic of a growing research effort [3-5].

An often-overlooked issue in the use of coupled computational methods is the verification of overall structural equilibrium: coupling different models of solid mechanics, to describe the mechanical behavior of a body, can affect the satisfaction of the equilibrium equations for the overall body. We will illustrate the problem through simple examples of statically determinate structures, partially discretized with a PD method and partially with a classical mechanics FEM approach. In our examples, using the coupling method presented in [5], the magnitude of the out of balance forces is small, compared to that of the acting forces, but it cannot be assumed to be a numerical error. We observe that even if the method described in [5] satisfies the usual numerical tests: rigid body motion, patch test, uniform strain cases, ... Our work will examine how the variation of the main features of the coupled model, such as position and size of the PD region, length of the coupling boundary, rate of change of the strains …, can affect the magnitude of the out of balance forces. Moreover, we will propose new criteria to reduce the magnitude of the out of balance forces.

The authors M. Zaccariotto and U. Galvanetto would like to acknowledge the support they received from University of Padua under the research project BIRD2017 NR.175705/17.

REFERENCES

[1] S.Silling, "Reformulation of elasticity theory for discontinuities and long-range forces", *J Mech. Phys. Solids*, Vol. **48**, pp.175–209, (2000).

[2] S. Silling, R.Leouchq, "Peridynamic theory of solid mechanics", *Adv. Appl. Mech.*, Vol. **44**, pp. 73–168, (2010).

[3] G. Lubineau, Y. Azdoud, F. Han, et al., "A morphing strategy to couple non-local to local continuum mechanics", *J. Mech. Phys. Solids*, Vol. **60(6)**, pp. 1088–1102, (2012).

[4] P. Seleson, Y.D. Ha, S. Beneddine, "Concurrent Coupling of bond-based Peridynamics and the Navier equations of classical elasticity by blending", *Int. J. Multiscale Comput. Eng.*, Vol. **13(2)**, 2015, pp. 91–113, (2015).

[5] M. Zaccariotto, T. Mudric, D. Tomasi, A. Shojaei, U. Galvanetto, "Coupling of FEM meshes with Peridynamic grids", *Comp. Meth. Appl. Mech. Eng.*, Vol. **330**, pp. 471–497, (2018).