# FEMxDEM multi-scale modelling with second gradient regularization

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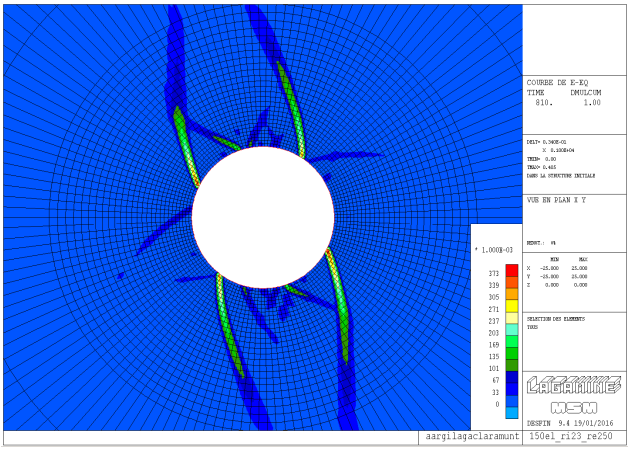
## ABSTRACT

The multi-scale FEMxDEM approach is an innovative numerical method for geotechnical problems, using at the same time the Finite Element Method (FEM) at the engineering macro-scale and the Discrete Element Method (DEM) at the scale of the microstructure of the material. The link between scales is made via computational homogenization. In this way, the continuum numerical constitutive law and the corresponding tangent matrix are obtained directly from the discrete response of the microstructure [1,2,3].

In the proposed paper, a variety of operators, rather than the tangent consistent for the Newton-Raphson method, is tested in a challenging attempt to improve the poor convergence performance. The independence of the DEM computations between the different elements is exploited to develop a parallelized code using an OpenMP paradigm. At the macro level, a second gradient constitutive relation is implemented in order to enrich the first gradient Cauchy relation bringing mesh-independency to the model. The second gradient regularization, together with the speedup provided by the parallelization allows by first time to the FEMxDEM model to be applied to real scale problems with the desired mesh refinement.

Some results are given exhibiting the above findings with emphasis on aspects related to strain localisation.




## REFERENCES

[1] Nitka, Michał, et al. "Two-scale modeling of granular materials: a DEM-FEM approach." *Granular Matter* 13.3 (2011): 277-281.

[2] Nguyen, Trung, et al. "FEM× DEM modelling of cohesive granular materials: Numerical homogenisation and multi-scale simulations." *Acta Geophysica* 62.5 (2014): 1109-1126.

[3] Guo, N., and Jidong Z. A coupled FEM/DEM approach for hierarchical multiscale modelling of granular media. *International Journal for Numerical Methods in Engineering* 99.11 (2014): 789-818.