Parametric model order reduction approach for quasi-static non-linear mechanical problems using an industrial code: application to an elasto-plastic material

E.Agouzal[1,2,3], JP. Argaud[1], M.Bergmann[2,3], G.Ferté[1], and T.Taddei[2,3]

[1]*Electricté de France (EDF) R&D; 91120, Palaiseau, France,*
[2]*IMB, UMR 5251, Univ. Bordeaux; 33400, Talence, France*
[3]*Inria Bordeaux Sud-Ouest, Team MEMPHIS; 33400, Talence, France*

We present our work on parametric model order reduction (pROM) for a generic class of parametric mechanical problems with internal variables in a non-linear quasi-static framework. This work is the result of a collaboration between the MEMPHIS team of Inria Bordeaux Sud-Ouest and the R&D departments of EDF. Within the engineering studies performed by EDF, engineerqs might have to run simulations repeatedly for slightly different configurations, which are associated with different physical or geometric model parameters (parametric study). However, successive evaluations for non-linear mechanical problems can lead to prohibitive computational costs.

We implement an hyper-reduced reduced-order model (ROM) based on an industrial FEM code (Code Aster). We develop an adaptive algorithm based on a POD-Greedy strategy [2]. Since the differential operator is nonlinear, we develop an hyper-reduction strategy based on empirical quadrature (EQ): our approach relies on the construction of a reduced quadrature to speed up online assembly costs of the ROM. This strategy relies on recasting the EQ problem ([1], [3]) as a sparse representation problem over all integration points, or elements. Moreover, we introduce an error indicator correlated to the approximation error, whose evaluation is cost-efficient in terms of computational time.

As an illustration and validation of our methodology, we present numerical results for a plate with a hole under traction with a elastoplastic behaviour, with physical variable parameters (strain hardening or elasticity coefficients).

References

[1] C. Farhat, T. Chapman, and P. Avery. Structure-preserving, stability, and accuracy properties of the energy-conserving sampling and weighting method for the hyper reduction of nonlinear finite element dynamic models. *International journal for numerical methods in engineering*, 102(5):1077–1110, 2015.

[2] B. Haasdonk and M. Ohlberger. Reduced basis method for finite volume approximations of parametrized linear evolution equations. *ESAIM: Mathematical Modelling and Numerical Analysis*, 42(2):277–302, 2008.

[3] M. Yano and A. T. Patera. An lp empirical quadrature procedure for reduced basis treatment of parametrized nonlinear pdes. *Computer Methods in Applied Mechanics and Engineering*, 344:1104–1123, 2019.