11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

APPLICATION OF VARIATIONALLY CONSISTENT SELECTIVE MASS SCALING TO HIGHER ORDER AND ISOGEOMETRIC FINITE ELEMENTS IN EXPLICIT DYNAMICS

Anne-Kathrin Schäuble[1], Anton Tkachuk[2] and Manfred Bischoff[3]

[1] University of Stuttgart, Institute for Structural Mechanics,
Pfaffenwaldring 7, 70550, Stuttgart Germany
schaeuble,tkachuk,bischoff@ibb.uni-stuttgart.de, ibb.uni-stuttgart.de

Key Words: *Selective mass scaling, explicit dynamics, isogeometric finite elements*

The primal goal of this contribution is the investigation of selective mass scaling techniques for higher order and isogeometric finite elements. They allow an increase of the critical time step size for explicit time integration without substantial loss in accuracy in the lower modes. Neither consistent nor lumped mass matrices lead to satisfactory results for *p*-FEM and isogeometric analysis in explicit dynamics: due to the large fill-in, a calculation with consistent mass is computationally too intensive, a calculation with lumped mass deteriorates accuracy. Here, recently proposed variationally based selective mass scaling is applied to higher order 2D- and 3D-finite elements and 2D-NURBS elements.

For low order FEM, scaling of inertia for explicit time integration is a common procedure. Since the 70s, conventional mass scaling (CMS) is applied, where artificial mass is added only to the diagonal terms of the lumped mass matrix and thus the diagonal form of the mass matrix is preserved [1]. However, translational and rotational inertia of the structure increases, which may cause non-physical phenomena. Algebraic selective mass scaling (ASMS) adds artificial terms both to the diagonal and non-diagonal terms, which results in a non-diagonal mass matrix, but at least allows the preservation of the translational mass. Both CMS and ASMS lack a rigorous variational formulation and consequently their application to higher order and isogeometric FE is not straightforward.

Variationally based selective mass scaling (VSMS) was recently proposed in [4,5]. Starting point of the method is a parametrized variational principle of elastodynamics, which can be interpreted as penalized Hamilton's principle which imposes relations between the independent fields. Here, a simplified two-field formulation with independent variables for displacement and velocity is considered. A consistent discretization of the principle results in a parametric family of mass matrices. The method does not only allow derivation of mathematically consistent mass matrices, but also facilitates systematic control of specific properties like preservation of inertia, reduction of the highest frequencies or accuracy in the lowest modes.

For the efficiency and accuracy of VSMS for higher order and isogeometric finite elements, the choice of ansatz spaces is crucial. Based on implementations of higher order 2D and 3D elements (e.g. ten-node tetrahedra) different shape functions for velocity discretization are discussed. The efficiency of the proposed approach is investigated by numerical examples.

Application of VSMS to isogeometric finite elements using shape functions based on non-uniform rational B-splines (NURBS) is not trivial. It is analyzed if and how particular properties of B-splines, like higher continuity and positivity are advantageous. Numerical results obtained with 1D and 2D isogeometric finite elements are compared with results obtained with existing mass scaling methods [1-3]. The numerical examples imply that a considerable reduction of the critical time step can be obtained with VSMS also for isogeometric finite elements.

REFERENCES

[1] S. W. Key, Z. E. Beisinger. The transient dynamic analysis of thin shells by the finite element method. In Proc. 3rd Conf. on Matrix Meth. in Struct. Mech., 1971.

[2] L. Olovsson, K. Simonsson and M. Unosson, Selective mass scaling for explicit finite element analyses. *Int J Num Meth Engrg*, Vol. 63, pp. 1436–1445, 2003.

[3] H. Askes, D. Nguyen and A. Tyas. Increasing the critical time step: micro-inertia, inertia penalties and mass scaling. *Comp Mech.*, Vol. 47, pp. 657–667, 2011.

[4] A. Tkachuk and M. Bischoff, Variational methods for selective mass scaling. *Comp Mech.*, Vol. 52, pp. 563–570, 2013.

[5] A. Tkachuk and M. Bischoff. Applications of variationally consistent selective mass scaling in explicit dynamics. In Proc. of the 4th ECCOMAS Thematic Conference on Comput Meth. in Struct Dynamics and Earthquake Engrg., 2013.