A First Order Hyperbolic Framework for Large Strain Computational Solid Dynamics: An upwind finite volume method

Chun Hean Lee[1*], Antonio J. Gil[1], Jibran Haider[1], Osama Ibrahim[1], Javier Bonet[2]

[1]Swansea University
Zienkiewicz Centre for Computational Engineering, College of Engineering, Swansea University, Bay Campus, SA1 8EN, United Kingdom
{c.h.lee, a.j.gil}@swansea.ac.uk

[2]University of Greenwich
London, SE10 9LS, United Kingdom
j.bonet@greenwich.ac.uk

ABSTRACT

Current commercial codes (e.g. PAM-CRASH, ANSYS AUTODYN, LS-DYNA, ABAQUS, Altair HyperCrash) used in industry for the simulation of large-scale solid mechanics problems (e.g. crash, contact, impact, fracture) are typically based on the use of classical low order Finite Element displacement based formulations. However, it is well-known that these formulations present a number of shortcomings, namely (1) reduced order of convergence for strains and stresses in comparison with displacements; (2) high frequency noise in the vicinity of shocks or sharp spatial gradients and (3) numerical instabilities associated with shear locking, volumetric locking and pressure checker-boarding.

In order to alleviate these, a first order hyperbolic system of conservation laws was introduced in terms of the linear momentum and the deformation gradient tensor of the system [1, 6-8]. Current research focuses on the development of a **TO**tal Lagrangian **U**pwind **C**ell centred Finite Volume Method for **H**yperbolic conservation laws (**TOUCH** [1]) in the open source code OpenFOAM. Two different strategies have been incorporated in order to ensure the satisfaction of the underlying involutions of the system, that is, that the deformation gradient tensor must be curl-free throughout the deformation process. In addition, the use of a discrete angular momentum projection algorithm and a monolithic Total Variation Diminishing Runge-Kutta time integrator is utilised in order to guarantee the conservation of angular momentum. For computational efficiency, an adapted artificial compressibility approach is also introduced for truly incompressible materials [2, 5].

A series of challenging numerical examples are examined in order to assess the robustness and accuracy of the proposed algorithm, benchmarking it against an ample spectrum of alternative numerical strategies developed by the authors in recent publications [2-6, 8]. The overall scheme shows excellent behaviour in bending dominated nearly incompressible scenarios, yielding an equal order of convergence for velocities and stresses.

References

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