Towards a new computational tool for multi-material dynamics

T.B.J. Di Giusto[a*], A.J. Gil[a], C.H. Lee[b], A. Huerta[c], M. Giacomini[c] and J. Bonet[d]

[a] Zienkiewicz Centre for Computational Engineering, Swansea University
e-mail: t.b.j.digiusto@swan.ac.uk, a.j.gil@swan.ac.uk

[b] Glasgow Computational Engineering Centre, University of Glasgow
e-mail: chunhean.lee@glasgow.ac.uk

[c] Laboratori de Càlcul Numèric (LaCàN), Universitat Politècnica de Catalunya
e-mail: antonio.huerta@upc.edu, matteo.giacomini@upc.edu

[d] University of Greenwich
e-mail: j.bonet@greenwich.ac.uk

ABSTRACT

The numerical simulation of nonlinear dynamics for multi-materials is regarded as one of the most challenging topics in computational mechanics. One example is the complex interaction of a highly deformable solid with a compressible fluid, a problem of interest in defence, aerospace, automotive and biomedical industries. Naturally, the specific choice of relevant (1) computational method or (2) formulation, can determine the robustness of the simulation and/or the quality of results.

Regarding (1), for instance, with the use of the classical standard low order Finite Element method, strains and stresses converge at a low rate (in comparison with displacements) and numerical instabilities can arise in the form of locking, spurious pressure oscillations and high frequency noise in the vicinity of shocks. As for (2), in a Lagrangian description, as nodes follow the path of their associated particles, this can lead to large distortions. On the contrary, Eulerian algorithms can better handle large strains, albeit costly and with some difficulty to set up (e.g. internal state variables). In this case, Arbitrary Lagrangian Eulerian (ALE, see Donea et al. [1]) descriptions aim to combine the pros and discard the cons of both individual approaches.

In this work, we start by introducing the framework developed by Lee et al. [4] and Haider [3], which consists on a cell centred Finite Volume Total Lagrangian method for large strain solid dynamics, where the linear momentum conservation equation is solved in conjunction with a series of geometric conservation laws (see Farhat et al. [2]) for the minors of the deformation, and upwinding stabilisation is introduced through an acoustic Riemann solver. The work will then introduce the steps planned for the enhancement of the existing solver towards the ultimate goal of solving fluid-structure interaction problems, namely, (1) ALE formulation for the fluid phase, in order to overcome current numerical limitations such as mesh entanglement, (2) the use of a more advanced Roe's Riemann solver for improved shock capturing capabilities and (3) the incorporation of a more sophisticated thermo-mechanical model.

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