Conservative coupling method between an inviscid compressible fluid flow and a fracturing structure

Maria Adela Puscas[1, 2, 3], Alexandre Ern[1], Christian Mariotti[2], Laurent Monasse[1], Christian Tenaud[3]

[1] Université Paris-Est, CERMICS, ENPC
77455 Marne la Vallée cedex, France
email: {puscasa, ern, monassel}@cermics.enpc.fr

[2] CEA-DAM-DIF 91297 Arpajon, France
email: {adela.puscas, christian.mariotti}@cea.fr

[3] LIMSI-CNRS, 91403 Orsay, France
email: {adela.puscas, christian.tenaud}@limsi.fr

ABSTRACT

Key Words: Fluid-structure interaction, finite volume, immersed boundary, conservative method, fracturing structure

We present a conservative method for the three-dimensional interaction between an inviscid fluid and a fracturing structure. On the fluid side, we consider an inviscid Euler fluid in conservative form discretized using a high-order monotonicity-preserving Finite Volume method with a directional operator splitting [1]. On the solid side, we consider a fracturing deformable solid discretized with a Discrete Element method [2]. A conservative explicit coupling algorithm between the inviscid fluid and the three-dimensional deformable, but non-fracturing, solid has been developed in [3], where an immersed boundary technique is employed through the modification of the Finite Volume fluxes in the vicinity of the solid. Herein, we extend the results to the fracturing deformable case.

During the process of fracturing, vacuum between solid particles can occur due to the fact that the velocity of the crack propagation can be larger than the speed of sound in the fluid. This leads to fluid cells where the fluid pressure and the density are very low, close to zero. A numerical challenge is to compute the solutions of the Euler equations in domains adjacent to regions of vacuum. In order to solve the Riemann problem in the presence of vacuum, we combine the usual calculation of the fluid fluxes [1] with the Lax-Friedrichs numerical flux near the vacuum area.

The computational cost of the fluid and solid methods lies mainly in the evaluation of fluxes on the fluid side and of forces and torques on the solid side. Both methods being time-explicit and computationally expensive, we use a coupling algorithm based on an explicit time-marching procedure. As in the non-fracturing case, the method yields conservation of mass, momentum and energy of the system, and also exhibits important consistency properties, such as conservation of uniform movement of both fluid and solid as well as the absence of numerical roughness on a straight boundary. We present numerical results assessing the method in the case of a fracturing deformable solid with large displacements coupled with a compressible fluid flow.

REFERENCES

[1] V. Daru and C. Tenaud. High-order one-step monotonicity-preserving schemes for unsteady compressible flow calculations. *Journal of Computational Physics*, 193:563–594, 2004.

[2] L. Monasse and C. Mariotti. An energy-preserving Discrete Element Method for elastodynamics. *ESAIM: Mathematical Modelling and Numerical Analysis*, 46:1527–1553, 2012.

[3] M.A. Puscas and L. Monasse. A three-dimensional conservative coupling method between an inviscid compressible fluid flow and a deformable structure, submitted.