Eulerian numerical approach for flows with immersed solids treated as constraints: elastic case and rigid-body limit

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ABSTRACT

In this work we describe a numerical formulation to deal with flows in which solids are immersed. The key idea is to consider the general equations of continuum mechanics written in an Eulerian reference system and treat the solids as restrictions in terms of the strain rate tensor. Thus, the flow equations for Newtonian fluids are written with the constraint that in the region occupied by the solid the constitutive equation to be applied is that of this solid. The main advantage of this approach is that the rigid body limit can be dealt with in a clean way, simply by imposing that the strain rate tensor be zero in the solid region. The inconvenience is that in some cases it might be involved to obtain the constitutive equation for the solid expressed in terms of the strain rate tensor, and the transport of some variables might be required. Nevertheless, this is not difficult in the case of incompressible Neo-Hookean materials considered in this work, which is a summary of [1,2]

The restriction in the flow equations to introduce the rheological behaviour of the solid is imposed by means of a Lagrange multiplied of tensor nature. This can be understood as an extra stress that enforces the constitutive equation of the solid, easily including the rigid body case. Therefore, the unknowns of the problem are the velocity and the pressure over the whole computational domain and this extra stress on the regions occupied by the solid.

The resulting three-field problem is approximated in time using finite differences and in space using finite elements. In order to avoid the need to satisfy the inf-sup compatibility conditions for the three variables in play, we use a stabilized finite element method that allows one to use arbitrary interpolations for all variables. The design of this formulation in order to achieve optimal convergence in space is also explained.

REFERENCES

[1] E. Hachem, S. Feghali, T. Coupez and R. Codina, "A three-field stabilized finite element method for fluid-structure interaction: elastic solid and rigid body limit", submitted.

[2] E. Hachem, S. Feghali, R. Codina and T. Coupez, "Immersed stress method for fluid structure interaction using anisotropic mesh adaption", *Int. J. Numer. Methods Engrg.,* Vol. **94**, pp. 805-825 (2013)