Fluid-Structure Interaction Algorithms

Olivier Pironneau*

* LJLL-UPMC (Sorbonne Université)
Place Jussieu, boite 187, F-75252 Paris
olivier.pironneau@upmc.fr, www.ann.jussieu.fr/pironneau

ABSTRACT

Fluid-Structure Interactions and Fluid-Fluid Interactions are numerically difficult because the geometry changes with time and because they require the coupling of variables of different physical origin such as velocities for the fluid part and derivative of displacements for the structural part.
At least two classes of problems have been investigated numerically extensively: blood flows [1] and free motions of objects in flows, whether self-propelled or passive and rigid or deformable [2].

A number of algorithms have been proposed, each with different coupling mechanisms. We shall review some of them and recall the mathematical results known for immersed boundaries [3], artificial density, fluid as solid, both with Finite Elements [4] or SPH [5], Eulerian/Lagrangian formulations [6], etc.
Algorithms that iterate between the structure and the fluid have usually restricted stability because of the "added mass effect"; we shall present a method that solves the fluid and solid variables in the same variational formulation by using a semi-linearization called "transpiration condition" [7]. The method is unconditionally stable for pipe flows. It will be illustrated with numerical results for blood flow and comparison with others methods [8].

REFERENCES

[1] L. Formaggia, A. Quarteroni, and A. Veneziani. Cardiovasuclar Mathematics. Springer MS&A Series. Springer-Verlag, 2009.
[2] J. Lighthill, Mathematical Biofluid dynamics, SIAM publication, Philadelphia, 1985.
[3] C. Peskin, The immersed boundary method. Acta Numerica, 11:479--517, 2002.
[4] M. Bergman, A. Iollo, Journal of Computational Physics 230 (2011) 329–348.
[5] J. H.M. Ever, I.A. Zisis, B. J. van der Linden, Manh Hong Duong. From continuum mechanics to SPH particle systems and back: Systematic derivation and convergence , ArXiv :1501.04512v1.
[6] P. Le Tallec and J. Mouro. Fluid structure interaction with large structural displacements. Comput. Methods Appl. Mech. Engrg 190, 3039-3067. 2001.
[7] T. Chacon, V. Girault, F. Murat, O. Pironneau, Analysis of a Simplified Coupled Fluid-Structure Model for Computational Hemodynamics, (submitted to SIAM-SINUM, 2014)
[8] M. Bukaca, S. Canic, R. Glowinski, J. Tambacac, A. Quainia. FSI in blood flow capturing non-zero longitudinal structure displacement. J. Comp. Physics 235 (2013) 515–541