A novel dual time stepping method for Fluid Solid Interaction (FSI) problems with large deformations

Alberto Coccarelli[1], Dimitris Parthimos[1], and Perumal Nithiarasu[2]

[1]Institute of Cancer and genetics, School of Medicine, Cardiff University, UK
[2]Zienkiewicz Centre for Computational Engineering, College of Engineering, Swansea University, UK

ABSTRACT

Despite recent findings [1] on the superiority of monolithic approaches to FSI over the segregated ones, there are many advantages that make the latter a valuable alternative [2]. For example, in a staggered approach, individual solution strategies can be employed independently to fluid flow and solid dynamics and they can be coupled through a robust interface coupling methods. This allows researchers to employ well established solution methods without radically changing the solution strategies for fluid or solid.

In the present work, a novel, segregated framework for solving fluid structure interaction (FSI) problems with large deformation is presented. The model is based on two independent, well established solvers able to provide a robust and accurate FSI solution. The fluid is modelled using the incompressible Navier-Stokes equations in Arbitrary Lagrangian Eulerian (ALE) coordinates. The solid is assumed to be under large deformation regime and a neo-Hoookean constitutive model has been adopted. The flow equations are solved by the Characteristic Based Split method with artificial compressibility (AC-CBS) introduced by Nithiarasu [3]. In this method, pressure is decoupled from velocity calculations and low order elements can employed without violating the Babuska-Brezzi condition. Solid dynamics equations have been solved in time through the well known α method.

The global fluid-solid scheme consists of a dual time stepping method for flow solution. This framework is then coupled to the Aitken method proposed in [4]. The traction vectors computed at fluid-solid interface nodes are passed on to the solid system by using the algorithm proposed by Farhat et. al [5] that uses non-conforming meshes. We evaluate the framework's performance by employing two versions of CBS method: a matrix free dual time stepping method, in which all variables are computed explicitly within a real time step and a quasi-implicit method in which viscous and pressure terms are evaluated in an implicit way via appropriate symmetric matrices. The results indicate that the quasi-implicit form is faster.

References

[1] Küttler U., Förster Ch. Gee M., Comerford A., and Wall WA. Coupling strategies for biomedical fluid-structure interaction problems. *International Journal for Numerical Methods in Biomedical Engineering*, 26:305–321, 2010.

[2] A.E.J. Bogaers. *Efficient and robust partitioned schemes for fluid-structure interactions*. Ph.d dissertation, The University of Cape Town, Cape Town, South Africa, 2015.

[3] P. Nithiarasu. An efficient artificial compressibility (ac) scheme based on the characteristic based split (cbs) method for incompressible flows. *International Journal for Numerical Methods in Engineering*, 56(13):1815–1845, 2003.

[4] Küttler U. and Wall WA. Fixed-point fluid-structure interaction solvers with dynamic relaxation. *Computational Mechanics*, 43:61–72, 2008.

[5] C. Farhat, M. Lesoinne, and P. Le Tallec. Load and motion transfer algorithms for fluid/ structure interaction problems with non-matching discrete interfaces: Momentum and energy conservation, optimal discretization and application to aeroelasticity. *Comp. Meths. Appl. Mech. Engng*, 157:95–114, 1998.