8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

Explicit time-stepping of fluid-structure problems arising in blood flows

Erik Burman[1] , ***Miguel A. Fernández**[2]

[1]University of Sussex
Brighton, UK–BN1 9RF, UK
E.N.Burman@sussex.ac.uk

[2]INRIA, RC Paris-Rocquencourt
F–78153 Le Chesnay Cedex, France
Miguel.Fernandez@inria.fr

Key Words: *Fluid-structure interaction, Explicit coupling, Nitsche's method, Blood flows simulation.*

ABSTRACT

The efficient numerical simulation of fluid-structure interaction problems involving a viscous incompressible fluid with a moderate fluid-structure density ratio is a difficult task. Blood flow simulations in deformable arteries is a popular example. Indeed, in such situations, *explicit* coupling schemes, *i.e.* that only involve the solution of the fluid and the structure once (or just a few times) per time step, are known to give rise to numerical instabilities [2,7].

In practice, these instabilities have been overcome mainly through the use of *implicit* coupling schemes (see *e.g.* [4,5,6,9,10] and the references therein), leading to a fully coupled problem at each time step, the solution of which often requires a huge computational effort. Other approaches suggest the use of *semi-implicit* coupling schemes [3,12], involving a reduced fully coupled problem.

Recently, in [1] we have proposed a (stabilized) explicit coupling scheme, based on Nitsche's method [11,8], whose stability properties are independent of the fluid and structure density ratio. Stability is obtained thanks to the dissipative structure of the Nitsche coupling and a stabilization term giving control of the time fluctuations of the interface fluid load.

In this talk, we will discuss some recent results on the numerical analysis of this new explicit coupling scheme. In addition, some numerical experiments will illustrate the behavior of our approach when applied to the simulation of blood flows in large arteries.

REFERENCES

[1] E. Burman and M.A. Fernández. "Stabilized explicit coupling for fluid-structure interaction using Nitsche's method". *C. R. Acad. Sci. Paris Sr. I Math.* **345**(8), 467–472, 2007.

[2] P. Causin, J.-F. Gerbeau and F. Nobile. "Added-mass effect in the design of partitioned algorithms for fluid-structure problems". *Comput. Methods Appl. Mech. Engrg.*, **194**(42–44), 4506–4527, 2005.

[3] M.A. Fernández, J.-F. Gerbeau and C. Grandmont. "A projection semi-implicit scheme for the coupling of an elastic structure with an incompressible fluid". *Internat. J. Numer. Methods Engrg.*, **69**(4), 794–821. 2007.

[4] S. Deparis, M. Discacciati, G. Fourestey and A. Quarteroni. “Fluid-structure algorithms based on Steklov-Poincaré operators”. *Comput. Methods Appl. Mech. Engrg.*, **195**(41-43), 5797–5812, 2006.

[5] M.A. Fernández and M. Moubachir. “A Newton method using exact Jacobians for solving fluid-structure coupling”. *Comp. & Struct.*, **83**, 127–142, 2005.

[6] C.A. Figueroa, I.E. Vignon-Clementel, K.E. Jansen, T.J.R. Hughes, C.A. Taylor. “A coupled momentum method for modeling blood flow in three-dimensional deformable arteries”. *Comput. Methods Appl. Mech. Engrg.*, **195**(41–43), 5685–5706, 2006.

[7] C. Förster, W.A. Wall and E. Ramm. “Artificial added mass instabilities in sequential staggered coupling of nonlinear structures and incompressible viscous flows”. *Comput. Methods Appl. Mech. Engrg.*, **196**(7), 1278–1293, 2007.

[8] P. Hansbo. “Nitsche’s method for interface problems in computational mechanics”. *GAMM-Mitt.*, **28**(2), 183–206, 2005.

[9] P. Le Tallec and J. Mouro. “Fluid structure interaction with large structural displacements”. *Comput. Meth. Appl. Mech. Engrg.*, **190**, 3039–3067, 2001.

[10] D.P. Mok, W. A. Wall and E. Ramm. “Partitioned analysis approach for the transient, coupled response of viscous fluids and flexible structures”. In W. Wunderlich, editor, *Proceedings of the European Conference on Computational Mechanics*. ECCM’99, TU Munich, 1999.

[11] J. Nitsche. “Über ein Variationsprinzip zur Lsung von Dirichlet-Problemen bei Verwendung von Teilräumen, die keinen Randbedingungen unterworfen sind”. *Abh. Math. Sem. Univ. Hamburg*, **36**, 9–15, 1971.

[12] A. Quaini and A. Quarteroni. “A semi-implicit approach for fluid-structure interaction based on an algebraic fractional step method”. *Math. Models Methods Appl. Sci.*, **17**(6), 957–983, 2007.