Generalized Robin-Neumann explicit coupling schemes for fluid-structure interaction

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We deal with the coupled problem describing the interaction between a viscous incompressible fluid and a viscoelastic structure. Standard explicit coupling schemes based on Dirichlet-Neumann interface conditions are known to be unconditionally unstable whenever the amount of added-mass effect is large. This explains why research during the last decade mainly focused on alternative strategies, such as implicit or semi-implicit, which require a higher computational effort. Stable explicit coupling schemes have recently been proposed in the literature, based on a Robin-Robin interface coupling paradigm derived from Nitsche's method. The main issue in these methods is accuracy, which demands restrictive CFL conditions or correction iterations.

In this talk we will present a family of Robin-Neumann explicit coupling schemes. In the case of the coupling with a thin-walled structure, the methods involve an explicit interface Robin condition for the fluid, which is intrinsically consistent (see [1]). The implicit treatment of the sole solid inertia ensures added-mass free stability whereas the explicit treatment of the solid viscoelastic contributions enables the fluid-solid splitting. We show, in particular, that the resulting scheme with first-order extrapolation provides unconditional stability and optimal first-order accuracy. In the case of the coupling with a thick-walled structure (see [2]), we show that a consistent generalized-Robin interface condition can be recovered at the space semi-discrete level through a mass-lumping approximation in the solid. The resulting interface condition for the fluid is similar to the thin case but involves a different interface mass operator (hence the terminology *generalized*-Robin). The methods preserve the stability properties of the thin-walled case. As regards accuracy, the splitting introduces an error perturbation whose leading term scales as $\mathcal{O}(\tau^{2^{r-1}} h^{-\frac{1}{2}})$, where h denotes the space discretization parameter and $r \in \{0, 1, 2\}$ the extrapolation order. Note that for $r = 1$ the method converges under a standard hyperbolic-CFL condition, without the need of correction iterations. A 3/2-CFL condition is required to achieve first-order optimal accuracy. The $h^{-\frac{1}{2}}$ loss is due to the non-uniformity of the discrete solid viscoelastic operator and not to the mass-lumping approximation.

The presentation will mainly focus on the thick-walled case: generalized Robin-Neumann coupling, mass-lumping approximation, specificities of the error analysis (compared with the thin-walled case). Several numerical examples will illustrate the theoretical results.

Références

[1] Fernández, Miguel Angel and Mullaert, Jimmy and Vidrascu, Marina, *Explicit Robin-Neumann schemes for the coupling of incompressible fluids with thin-walled structures*, Computer Methods in Applied Mechanics and Engineering, 10.1016/j.cma.2013.09.020, 2013.

[2] Fernández, Miguel Angel and Mullaert, Jimmy and Vidrascu, Marina, *Generalized Robin-Neumann explicit coupling schemes for incompressible fluid-structure interaction: stability analysis and numerics*, Research Report, RR-8384, 2013.

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