Efficient Linear Finite Element Scheme for Fluid–Structure Interaction: Partitioned vs Monolithic Approach

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We compare two efficient linear finite element schemes for non-linear fluid–structure interaction between an incompressible viscous fluid and an elastic plate or shell, formulated in the arbitrary Lagrangian–Eulerian (ALE) framework on a fixed reference domain. Both methods employ backward Euler time discretization and a low-order spatial discretization with P1-bubble/P1 elements for the fluid and P1 elements for the structure. The semi-implicit monolithic scheme from [1] advances the coupled system by a single linear solve per time step and dissipates the total energy at the discrete level. The partitioned scheme from [2] updates fluid and structure sequentially without sub-iterations while preserving a discrete energy estimate, even for large deformations with a convection term.

We establish optimal first order convergence with respect to the time step and mesh size and confirm it numerically in strongly deforming regimes. Figure 1 illustrates representative large-deformation snapshots together with the observed timestep convergence. Finally, we compare efficiency: the monolithic scheme reduces cost relative to a fully implicit solve [1], and the partitioned variant further lowers per-step cost while maintaining comparable accuracy. The approach naturally extends to fully non-linear bulk elasticity models, including compressible neo-Hookean and Saint Venant–Kirchhoff materials.

References

[1] S. Schwarzacher, B. She, K. Tůma: *Stability and error estimates of a linear numerical scheme approximating nonlinear fluid-structure interactions*. Numerische Mathematik 157.3: 1023-1077, 2025.

[2] B. She, T. Tian, K. Tůma: *Stability and error estimates of a linear and partitioned finite element method approximating nonlinear fluid-structure interactions*, arXiv preprint arXiv:2601.02847, 2026.