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Simulating Jet Propulsion Through a Flexible Nozzle Using solids4foam

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Abstract

Fluid-structure interaction (FSI) describes the coupled response between a moving fluid and a deformable solid, where the motion and loading in each domain directly influence the other. Such interactions occur across biological and engineering systems, including bio-inspired jet propulsion mechanisms. In this study, a flexible nozzle inspired by squid-like pulsatile propulsion is computationally investigated to examine how structural compliance affects jet formation and vortex evolution. A strongly coupled, partitioned FSI model is developed using `OpenFOAM` and `solids4Foam`. The incompressible laminar flow is solved in the internal nozzle passage and surrounding fluid domain using a moving-mesh formulation, while the nozzle wall is modeled as a finite-strain neo-Hookean solid in a Total Lagrangian framework. A prescribed inlet velocity pulse is applied to generate a starting jet, and the wall flexibility is controlled through the effective stiffness parameter $Eh = 100$. The results show that nozzle deformation modifies the instantaneous exit geometry, altering the near-exit velocity field, shear-layer roll-up, and downstream vortex-ring evolution. Compared with the rigid nozzle case, the flexible configuration produces a stronger jet response, indicating that structural compliance is an important design variable in pulsatile jet-based propulsion systems.