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MODELING OF IMPINGING VISCOELASTIC DROPLETS USING ALE-FEM

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Numerical computations of impinging viscoelastic droplets are highly demanded in several scientific, engineering and industrial applications such as spray cooling, spray coating, ink-jet printing, medicinal/pharmaceutical sprays and pesticide deposition. The flow dynamics of a Newtonian droplet impinging on a horizontal surface has extensively been investigated in the literature. However, the influence of viscoelasticity on the impact and spreading of a droplet on a flat substrate is receiving growing attention only in the recent years [1, 2]. The time-dependent incompressible Navier–Stokes equations are used to describe the fluid flow in the liquid droplet, whereas the viscoelasticity in the moving droplet is described by the Giesekus [3] constitutive equation.

An arbitrary Lagrangian–Eulerian (ALE) [4] formulation with finite elements is proposed to solve the time-dependent incompressible Navier–Stokes equation and the Giesekus [3] constitutive equation in the time-dependent domain. In particular, a three-field formulation based on the Local Projection Stabilization (LPS) [5] is proposed for the computations of impinging viscoelastic droplets. The stabilized scheme allows us to use equal order interpolation spaces for the velocity and the viscoelastic stress, whereas inf-sup stable finite elements are used for the velocity and the pressure. In the ALE approach, the surface force is incorporated into the model very accurately since the free surface and the liquid-solid interface are resolved by the computational mesh. Further, the spurious velocities which might arise due to the approximation errors of the pressure and the surface force can be suppressed by using this approach. In addition, we use the tangential gradient operator technique to treat the curvature in a semi-implicit manner. This technique allows us to include the contact angle into the model weakly. Further, the Navier-slip boundary condition is used on the liquid-solid boundary to ease the singularity at the moving contact line. The governing equations are solved in a monolithic approach with 3D-axisymmetric configuration.

The proposed numerical scheme is implemented in the finite element code ParMooN [6]. In addition to the mesh convergence study, an array of parametric studies are performed with different Weissenberg numbers, Newtonian solvent ratios, Reynolds numbers and equilibrium contact angles to demonstrate the effect of viscoelasticity on the flow dynamics of the droplets on wetting surfaces.

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