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Free response of a gravitational liquid sheet by means of three-dimensional Volume-of-Fluid simulations

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Direct numerical simulations of gravitational thin liquid sheet flows, interacting with unconfined gaseous environments located on both sides of the liquid phase, are performed through the Volume-of-Fluid (VOF) technique [1]. The global unsteady dynamics of the three-dimensional non-parallel flow is analyzed by perturbing the initial steady configuration by means of a Gaussian bump in the transverse velocity component. In particular, the work is focused on the determination of the free (natural) response of the system, which is characterized by means of Fast Fourier Transform (FFT) of numerical data performed along the gravity (vertical) direction. The effect of two governing parameters of the flow dynamics, namely the liquid sheet aspect ratio, $AR = W_i^\star/H_i^\star$, and the Weber number, $We = \rho_l U_i^\star H_i^\star/(2\sigma)$, is investigated, where $H_i^\star$ and $W_i^\star$ are the sheet inlet thickness and width, respectively, $U_i^\star$ the inlet liquid velocity, ρ_l and σ the liquid density and surface tension coefficient. In supercritical conditions (i.e., for $We > 1$), three flow configurations with different aspect ratios are analyzed, namely $AR = 10$, 25 and 40, providing also comparisons with results arising from a simplified linear one-dimensional model, which has been already validated against two-dimensional numerical simulations of the same configuration [2]. Finally, for the highest AR value considered in the analysis, the supercritical-to-subcritical flow transition is numerically investigated by varying the Weber number below the critical value $We = 1$ [3].

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