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Modal analysis of a 3D gravitational liquid sheet

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Modal analysis of three-dimensional gravitational thin liquid sheet flows, interacting with unconfined gaseous environments located on both sides of the liquid phase, is performed in the present work. Numerical data of this relevant two-phase flow configuration are obtained through the single-phase formulation and the Volume-of-Fluid (VOF) technique implemented in the flow solver Basilisk [1]. This class of flows exhibits a variety of spatially and dynamically relevant structures, both in free and forced configurations, that are investigated through modal decomposition techniques, such as Proper Orthogonal Decomposition (POD), Spectral Proper Orthogonal Decomposition (SPOD) and Dynamic Mode Decomposition (DMD) [2]. Moreover, we employ also autoencoders to achieve the dimensionality reduction. By means of these methodologies, we explore the effect of two main governing parameters on the flow dynamics, namely the liquid sheet aspect ratio, $AR = W/H$, where H and W are the sheet inlet thickness and width, and the Weber number, $We = \rho_l UH/(2\sigma)$, in which U is the inlet liquid velocity, ρ_l the liquid density, and σ the surface tension coefficient. Finally, for the highest aspect ratio value considered ($AR = 40$), we investigate the forced dynamics of the system excited by a harmonic perturbation in transverse velocity component applied at the inlet section, comparing results with ones arising from a purely two-dimensional analysis of the flow [3]. The obtained results highlight the low rank behavior exhibited by the flow, suggesting that reduced order modeling could be particularly appealing to reduce complexity and computational effort in numerical simulation of this class of flows.

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