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JETTING AND WAVE FORMATION IN A PERIODIC CYLINDRICAL OBSTACLE ARRAY UNDER IMPULSIVE SUBMERSION

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ABSTRACT

Free-surface dynamics play a crucial role in various engineering applications, including wave-energy devices and magnetized target fusion, where imploding liquid liners are used. Understanding the formation of disturbances, such as waves and jets, is essential for engineering design, as these phenomena can be either beneficial or detrimental depending on the application.

Previous studies have analytically and experimentally examined the initial free-surface disturbances caused by the submersion of a single cylindrical obstacle in a liquid under constant acceleration. A recursive numerical scheme is implemented to study cylinders of arbitrary size and motion. These studies found that the initial fill depth and free-surface acceleration determine whether jetting or gravity waves form. At high fluid velocities, where viscous and surface tension effects are minimal, modeling and experiments show good agreement. However, many practical applications involve periodic obstacle arrangements, which can significantly alter free-surface behavior.

This study investigates the effects of a horizontally periodic arrangement of cylindrical obstacles, as it better represents engineering scenarios such as the collapse of a liquid metal liner in nuclear fusion concepts. The objective is to experimentally and numerically determine how periodic superposition influences free-surface disturbances and assess whether an analytical model can accurately predict jet formation. The surface response to varying obstacle sizes, periodicity, and initial surface depths is measured using high-speed videography.

Experimental results reveal two primary effects of periodicity: grid focusing and surface tension smoothing. Grid focusing flattens the overall free surface while intensifying jet formation, whereas surface tension smoothing counteracts this effect, reducing jet strength at greater initial fill depths and for smaller obstacle spacing. The effects of both phenomena are isolated and verified using a Gaussian wave model and energetic analysis. The Gaussian wave model shows that decreasing obstacle spacing strengthens jetting, while energetic analysis incorporating surface tension effects predicts an inversion of this trend at large initial fill depths, aligning with experimental observations.

To assess predictive capabilities, experimental results are compared with an analytical model based on potential flow theory. While the model reasonably predicts free-surface behavior at higher obstacle spacing, it deviates when obstacle spacing is decreased due to increased surface tension effects and the breakdown of potential flow assumptions. Despite these limitations, the analytical model provides a conservative estimate for engineering applications where minimizing jetting is critical.