Deformation of Water Bells When Breaking the Membrane

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When a vertically downward water jet strikes a horizontally placed disk, it forms a unique axisymmetric water film called a “water bell.” This water bell can undergo a dramatic and irreversible transformation when the liquid film is ruptured after a change in the flow rate. To investigate the effects of pressure on the deformation, two types of water bells were introduced: a "closed" bell, which does not allow air exchange across the film unless it is ruptured, and an "open" bell, where the inside and outside are connected via a tube. The deformation phenomena, especially the deformation of an open water bell, which exhibits diverse behavior under different conditions, have not been sufficiently studied. In this research, the deformations of both conditions were quantitatively analyzed. First, an experimental system was developed, and the numerical reproduction of the water bell shape closely matched the experimental results. Subsequently, a theoretical model was proposed to explain the deformation of both bells. The corresponding numerical simulations demonstrated good agreement with the experimental observations, thereby validating the model. Furthermore, a simplified approximation of the phenomenon clarified the parameter dependence of the deformation. The parameter dependence indicated that both the dramatic deformation of the water bells and the variability in the deformations of the open bell stem from the high sensitivity of the volume to internal pressure. This study contributes to the control of the water bell system and enhances the understanding of its unique behaviors.

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