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Cavitation Inception and Bubble Dynamics in Vortical Flows

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Abstract

The liquid in the core of a vortex can be at a significantly lower pressure than the surrounding fluid, and possibly in tension. Small bubbles (nuclei) exposed to this tension can rapidly enlarge to fill the radial extent of the vortex core and then grow along the vortex axis. Such vortex cavitation can readily occur in the shed vortices of lifting surfaces or in turbulent shear flow such as jets and wakes. Incipient and developed vortex cavitation bubbles can exhibit complex dynamics as the bubble interacts with the surrounding flow. As the bubble changes volume within the vortex core, the vorticity distribution of the surrounding flow is modified, which then changes the pressures at the bubble interface. This coupling can produce volume oscillations with a period of the order of the vortex time scale, $\tau_V = 2\pi r_c / u_{\theta max}$, where r_c is the vortex core radius and $u_{\theta max}$ is its maximum tangential velocity of the vortex. However, the volume oscillation amplitude and frequency are quite sensitive to variations in the vortex properties, the rate and magnitude of the local pressure core pressure, and the nuclei's critical pressure. The axial and radial growth of elongated cavitation bubbles is also strongly coupled, especially near the axial extents of the bubble. Such complex growth, oscillation, and collapse of vortex cavitation bubbles can lead to both broadband and tonal sound emissions. Moreover, it is possible to understand the formation and dynamics of vortex cavitation as the result of vortex dynamics, vortex breakdown, and vortex-vortex interactions. And, finally, it may be possible to mitigate the inception of vortex cavitation on lifting surfaces through both passive and active means.

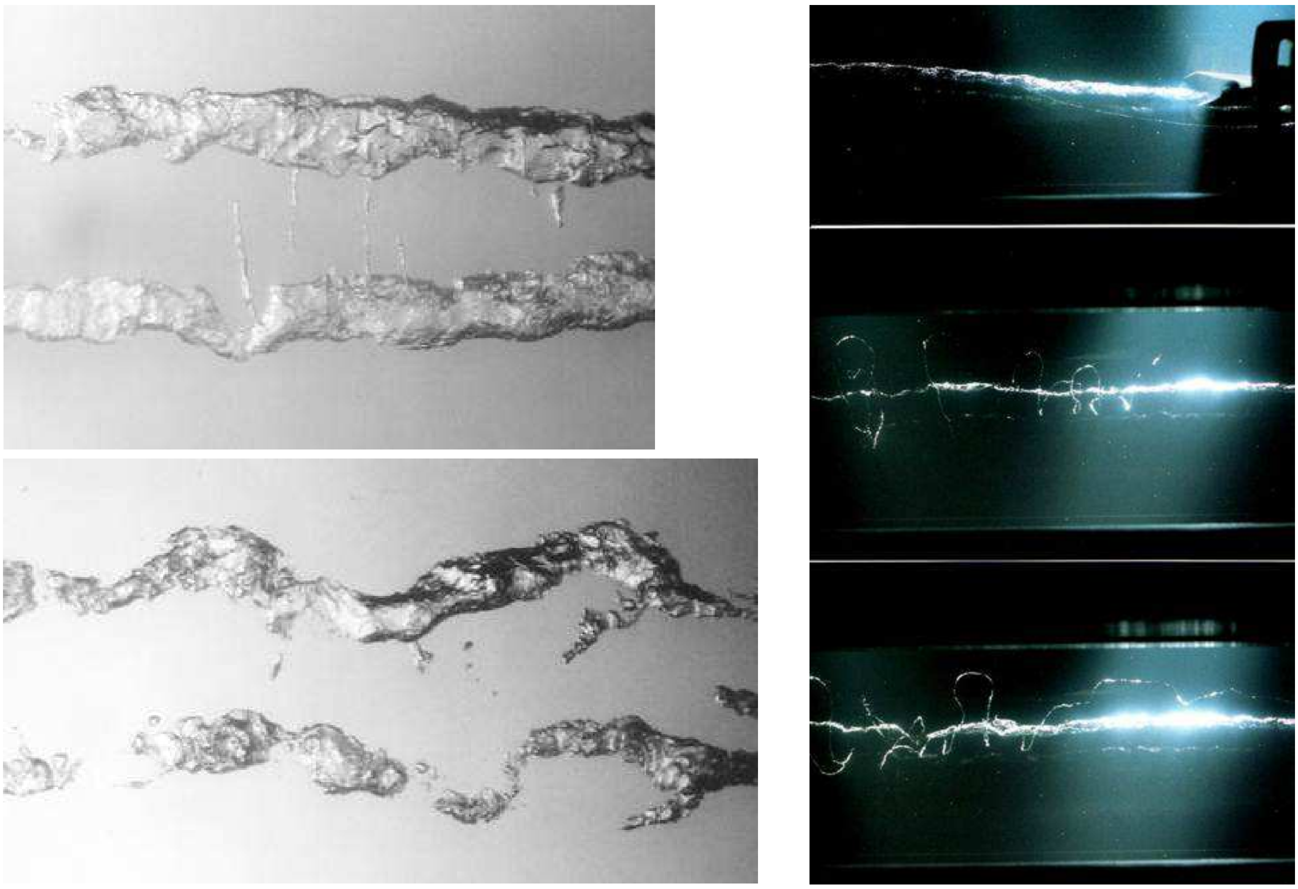

Figure 1: Images of cavitation in vortical flows.