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Cavitation Inception and Bubble Dynamics in Vortical Flows

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The liquid in the core of a vortex can be significantly lower than the surrounding pressure, 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.