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On-demand nuclei seeding in a Venturi tube - why do nuclei in hydrodynamic process tend to develop to attached cavitation?

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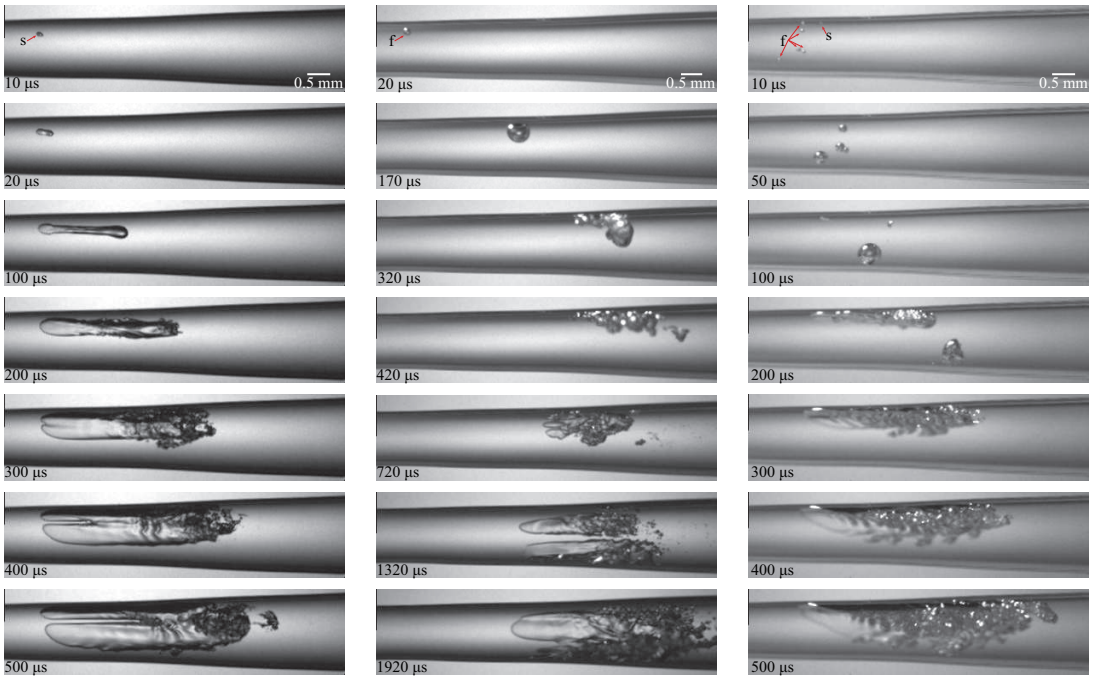
Within a fluid flow, cavitation generally develops as attached cavities on the wall surface, which is commonly terms as attached cavitation. While much research has focused on understanding the stability and consequences of attached cavities, the mechanism leading to its formation and why hydrodynamic cavitation tends to manifest in this form remain largely unexplored. To address this, we introduced a novel on-demand nuclei seeding method using a pulsed laser sheet to locally heat the water flow within a Venturi tube on impurities. This method generates nanobubbles as cavitation nuclei in a non-intrusive way with spatio-temporal control. High-speed imaging revealed cavitation from freestream and surface nuclei, see Fig. 1. We found that these initial cavitation bubbles most of the time evolve into attached cavitation, which persist over time. For surface nuclei, cavitation bubbles tend to remain attached at their original location. However, their top regions elongate downstream due to the pressure and flow, accompanied by rapid volumetric growth, eventually forming a macroscopic attached cavity. For cavitation bubbles induced by freestream nuclei, they travel with the flow and may generate new surface nuclei upon making contact with the tube wall. When both freestream and surface nuclei are present, both compete, yet surface nuclei-induced cavitation bubbles consistently prevail that develop into attached cavities. We propose a simple theoretical model to explain the competition between different cavitation bubbles.



(a) Surface nuclei (b) Freestream nuclei (c) Surface & freestream nuclei

Figure 1: Formation of an attached cavity in the divergent section of a Venturi channel recorded with a high-speed camera. (a) Surface nucleus "s" growing into an attached cavity. (b) Free stream nuclei "f" expands and upon contact to the boundary nucleates the attached cavity. (c) Competition between freestream and surface nuclei. The Venturi flow is directed from left to right.

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