

Abstract

The dynamics of a single cavitation bubble play a crucial role in a wide range of scientific and engineering applications, including underwater acoustics, erosion, and surface damage mitigation. In the present work, a controllable low-voltage underwater electrical-discharge system is developed to generate repeatable single cavitation bubbles over a wide range of maximum radii. The discharge energy is precisely controlled through a relay-based capacitor network, enabling systematic investigation of bubble growth and collapse dynamics under varying electrical, material, and ambient conditions.

High-speed imaging is employed to quantify bubble radius evolution and nucleation characteristics, while synchronised hydrophone measurements are used to analyse the associated acoustic emissions. The influence of circuit parameters, electrode resistance, and electrode material on bubble repeatability and maximum radius is examined. A voltage sensing module is incorporated to establish a correlation between the electrical energy delivered during discharge and the potential energy of the generated cavitation bubble.

The study further investigates bubble dynamics under reduced ambient pressure, with emphasis on accurately reconstructing early-stage expansion and estimating internal pressure evolution using physics-based models. Bubble–surface interactions are examined near solid boundaries with controlled wettability, including hydrophilic, hydrophobic, superhydrophilic, and superhydrophobic surfaces. The effect of surface wettability on collapse symmetry, acoustic signatures, and cavitation-induced erosion is analysed.

Keywords: Cavitation bubble dynamics, low-voltage electric discharge system, Hypobaric, Surface wettability, Acoustic radiation, Erosion, superhydrophilic, superhydrophobic