Void Fraction Measurement In Boiling Channels Using Acoustic Transducers

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Abstract

In nuclear reactors, thermal management and controlled heat exchange are pivotal to ensuring efficient and safe operation. Void fraction, defined as the ratio of vapor/gas volume to liquid volume, is a critical key performance indicator (KPI) for boiling phenomena and coolant dynamics. This study aims to characterize the dimensions and implicitly the volume of voids based on their interaction with acoustic pressure waves. Wood A.B. [1] initially observed this phenomenon, and subsequent studies have analytically [2] and experimentally [3] validated these observations. We seek to extend these findings by evaluating the performance of these techniques in accurately measuring the diameter of a singular bubble and thereby scaling it to also account for clusters of bubbles.

In our model, the Acoustics, Structural Mechanics, and AC/DC modules have been employed. A monopole source with known origin and strength is propagated through a fluid medium containing a singular bubble. A piezoelectric transducer, positioned orthogonally to the propagation direction of the wave, measures the intensity of the pressure wave. The existence of bubbles in the fluid increases the attenuation constant significantly [4]. The differential intensity between the source wave and the transduced wave serves as an indicator of the vapor volume within the fluid.

Reference

[1] Wood, A. B. et al, "A Textbook of Sound", G Bell and Sons Ltd, London, 1946

[2] Hyun Jin Park et al, "Monitoring of Void Fraction and Bubble Size in Narrow-Channel Bubbly-Flows Using Ultrasonic Pulses With a Super Bubble-Resonant Frequency", IEEE Sensors Journal, Vol. 21, No. 1, January 1, 2021

[3] Kerry W. Commander et al, "Linear pressure waves in bubbly liquids: Comparison between theory and experiments", The Journal of the Acoustic Society of America. 85, 732–746 (1989)

[4] Jing Han et al, "Study on measurement of sound attenuation coefficient in bubble wake by pool", E3S Web of Conferences 206, 03013 (2020)

Figures used in the abstract

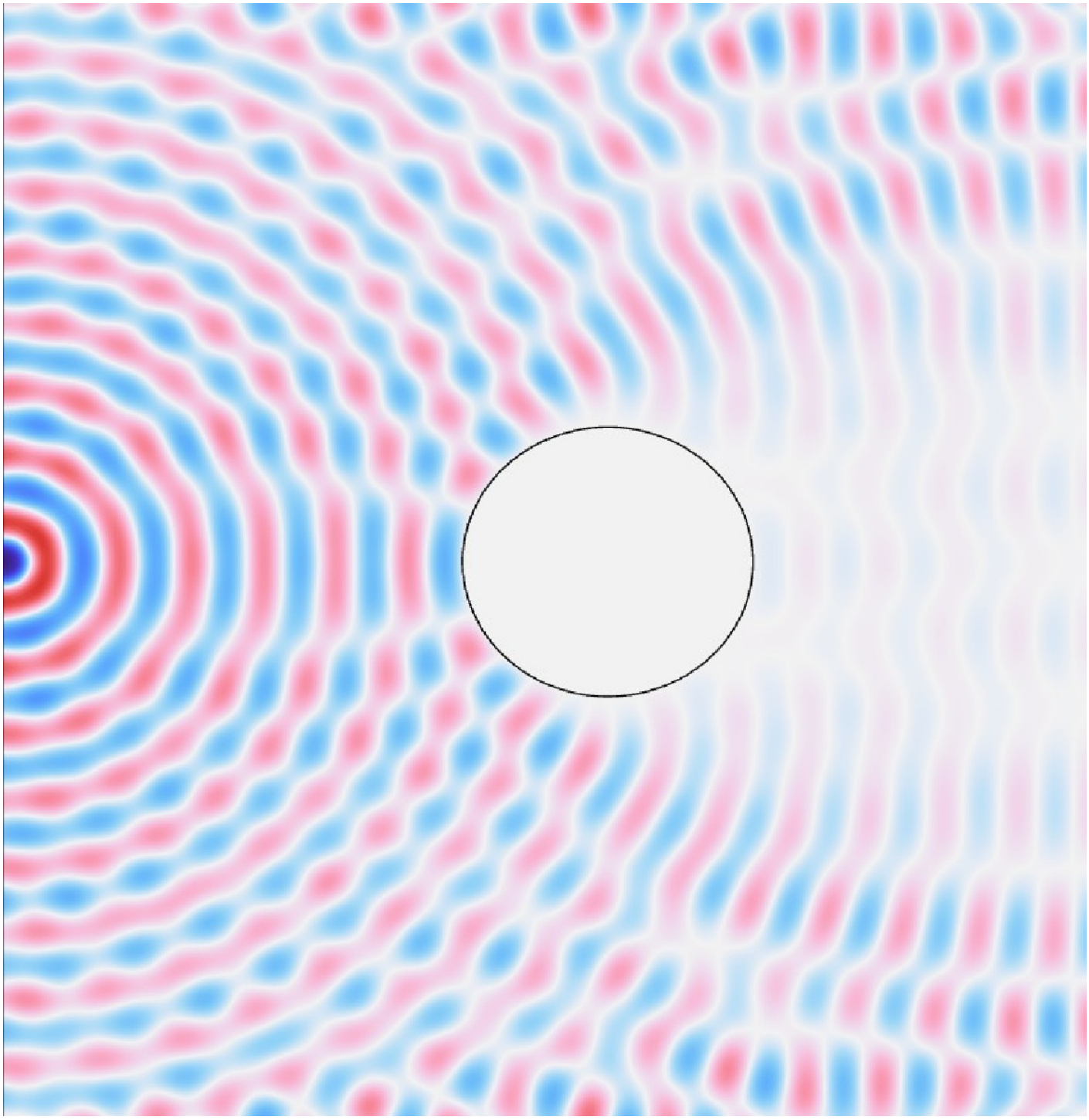

Figure 1 : Acoustic Wave (Freq 5000 Hz) Pressure in the void and fluid(water) mixture

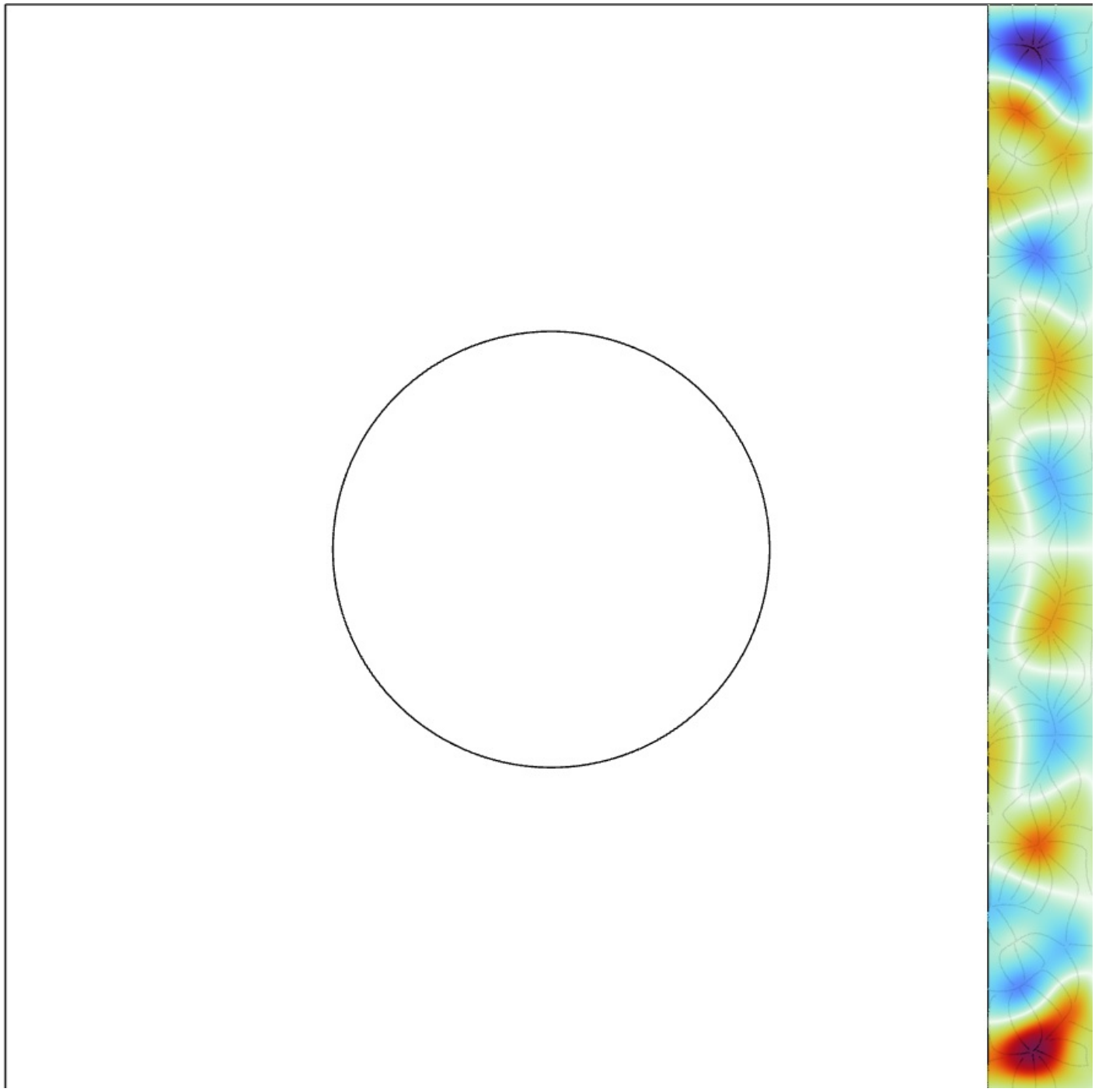

Figure 2 : Electric Potential Distribution in Piezo Transducer