UDC 544.57

APPLICATION OF ACOUSTIC CAVITATION WITH AI FOR FLUID ANALYSIS

Korolev I. S. (ITMO University)
Aliev T. A. (ITMO University)
Sazonova V. A. (ITMO University)
Supervisor – Dr. Ulasevich S.A. (ITMO University)

Introduction. Ultrasonic irradiation of liquids, such as water–alcohol solutions, results in cavitation or the formation of small bubbles. Cavitation bubbles are generated in real solutions without the use of optical traps making our system as close to real conditions as possible. Under the action of the ultrasound, bubbles can grow, oscillate, and eventually collapse or decompose [1]. We apply the mathematical method of separation of motions to interpret the acoustic effect on the bubbles. While in most situations, the spherical shape of a bubble is the most energetically profitable as it minimizes the surface energy, when the acoustic frequency is in resonance with the natural frequency of the bubble, shapes with the dihedral symmetry emerge [2]. Some of these resonance shapes turn unstable, so the bubble decomposes. It turns out that bubbles in the solutions of different concentrations (with different surface energies and densities) attain different evolution paths. While it is difficult to obtain a deterministic description of how the solution concentration affects bubble dynamics, it is possible to separate images with different concentrations by applying the artificial neural network (ANN) algorithm. An ANN was trained to detect the concentration of alcohol in a water solution based on the bubble images. This indicates that artificial intelligence (AI) methods can complement deterministic analysis in nonequilibrium, near-unstable situations [3].

Main part. The cavitation bubble dynamics was recorded using a high-speed camera Phantom Miro C110. The camera was fixed on a microscope Mikmed-6 (LOMO, Russia). The recording rate was 700 frames per second. The image resolution was 768 × 768 pixels. The image and video analyses were made using a Phantom CV 3.3 application. All measurements were performed three times for controlling the reproducibility of the measurements. The presented data were the average curves of three independent experiments. Among such methods is clustering visual images using artificial intelligence algorithms. While it is not possible to obtain a deterministic description of how the concentration of a solution affects bubble dynamics, it is still possible to separate images with different concentrations by applying the artificial neural network algorithm.

Conclusion. This demonstrates that AI methods can complement deterministic analysis in nonequilibrium, near-unstable situations. The model can be applied. For example, computer vision software can be installed on a computer with a microscope to automatically analyze bubbles in real time.

References:

1. Saint-Michel, B., & Garbin, V. (2020). Acoustic bubble dynamics in a yield-stress fluid. Soft Matter, 16(46), 10405-10418.
2. Dollet, B., Marmottant, P., & Garbin, V. (2019). Bubble dynamics in soft and biological matter. Annual Review of Fluid Mechanics, 51, 331-355.
3. Korolev, I., Aliev, T. A., Orlova, T., Ulasevich, S. A., Nosonovsky, M., & Skorb, E. V. (2022). When bubbles are not spherical: artificial intelligence analysis of ultrasonic cavitation bubbles in solutions of varying concentrations. The Journal of Physical Chemistry B, 126(16), 31613169.