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# Simulation of 2D Cavitation Bubble Growth Under Shear Flow by Lattice Boltzmann Model

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**Abstract.** Natural cavitation is defined as the phenomenon of the formation of vapor bubbles in a flow due to the pressure falls below the liquid's vapor pressure. The inception of the cavitation bubble is influenced by many factors, such as impurities, turbulence, liquid thermal properties etc. In this paper, we simulate a 2D cavitation "bubble" growth under shear flow in the inception stage by Single-Component-Multiphase Lattice Boltzmann Model (SCMP LBM). An empirical boundary condition sensitive 2D bubble growth rate, $R \sim e^t$, is postulated. Furthermore, the comparison is conducted for bubble behavior under different shear rates. The results show that the cavitation bubble deformation is coincident with prior droplet theories and the bubble growth decreases slightly with the flow shear rate.

**AMS subject classifications**: 76T10, 76M28, 65Z05

**Key words**: Bubble dynamics, cavitation, lattice Botlzmann methods, Rayleigh-Plesset equation.

## 1 Introduction

Natural cavitation is defined as the phenomenon of the formation of vapor bubbles in a flow due to the pressure falls below the liquid's vapor pressure, which can cause the falling of fluid machinery performance [1,2], *or* drag reducing for high speed underwater vehicles [3]. In the past decades, numerous efforts were contributed to the cavitation bubble inception [4,5], which can be treated as the initial condition for the bubble evolution. However, the study shows that the cavitation inception is more complex than we

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described at the beginning of this paragraph. It is influenced by the number and qualities of the nuclei in the liquids, the flow structure, thermodynamic parameters etc. And different inception forms were found, including bubble band, bubble ring, traveling bubble, traveling patch, fixed patch, and developed attached cavitation [4].

In addition to the experimental and scaling analyses, numerical simulation is conducted widely as a powerful tool for the cavitation study. Coupling with the thermodynamic models Vortmann et al. [6] applied the volume of fluid method to predict typical effects of cavitations. By finite volume method, Chau et al. [7] studied the hydrodynamic characters of foils. Particular emphasis was placed by Kunz et al. [8] on solve two-phase Reynolds Averaged Navier-Stokes equations (RANS), which included prediction strategy, flux evaluation, limiting strategies etc. The capabilities of the method were further validated through a comparison between axisymmetric and 3D RANS simulations by the same group [9]. Senocak and Shyy [10] applied a pressure-velocity-density coupling scheme to handle the large density ratio cavitating flow. Seo et al. [11] proposed a density-based homogeneous equilibrium model with a linearly-combined EOS to predict cavitating flow noise. To capture the acoustic waves in two-phase flow, the central compact finite difference scheme was implemented. Lu et al. [3] compared different cavitation models numerically. Ventilated and natural cavitation flows were studied. Besides the class of surface capture methodologies, as mentioned above, surface tracking methods were applied as well, where the interfaces are treated as time dependent boundaries of computational domain [12].

For the traditional partial differential equation based numerical simulation, two major obstacles should be combatted. The first one is the numerical scheme. Since across the interface, phase properties, such as density and viscosity, vary steeply, the numerical schemes should be designed carefully to prevent the nonphysical oscillations. Limiting strategies, filtering techniques or sophistical interface updating algorithms should be applied. Secondly, the phase transition model should be postulated correctly according to the thermodynamic fundamentals.

In recent decades, lattice Boltzmann methods (LBM) emerged as an attractive CFD method, which bases on the mesoscale particle dynamics [13–15]. Some sophistical flow phenomena, such as interfacial flow, reactive flow, are simulated successfully by combined with certain particle properties, whose motion is simply divided into "collision" and "stream" loops. Shan and Chen [16] postulated a long range interaction, by which the liquid phase transition and interfacial tension were simulated perfectly. Swift [17] coupled Cahn-Hilliard free energy formula with LBM, where phase separation and two-phase flow modeling were validated to be feasible. The key issue of the two models is to reproduce the non-ideal gas EOS. Later on, multiphase LBM were applied in many fields [18–21]. Yuan and Schaefer [22] compared different EOS with Chen-Shan's model. Sukop [23] validated the capability of LBM to simulate the cavitation problems by Shan-Chen's model. 2D bubble evolution (growth or collapse) were reported.

In this paper, our first goal is to demonstrate the feasibility of LBM on cavitation simulation further. With LBM, we also intend to study the 2D cavitation bubble growth