NUMERICAL SIMULATION OF BUBBLE DYNAMICS NEAR THE FREE SURFACE

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The strong interaction between the submerged oscillating bubble and the free surface will cause complex phenomena [1]. The dynamics of the collapsing bubble and the free surface is severely dependent on γ_f, which stands for the non-dimensional bubble-free surface distance scaled with the maximum bubble radius. When γ_f is sufficiently small, the bubble will burst at the free surface [2]. The present study performs the simulation using the compressible two-phase flow solver implemented in OpenFOAM. OpenFOAM is now a popular tool utilized for simulating bubble dynamics. The excellent examples are the work of Han *et al* [3] studying the dynamics of the laser-induced bubble pairs, the work of Koch *et al* [4] calculating the growth and collapse of the bubble with mass conservation improved, the work of Moezzi-Rafie *et al* [5] investigating the flow physics of the bubble implosion and the work of Lechner *et al* [6] researching on the pressure and tension waves from bubble collapse near a solid boundary. VOF method is utilized and it allows to simulate the complex physical phenomena, like splitting and coalescence of the bubble, smoothly without artificial interference. The adiabatic equation of state for the gas and the Tait equation for the water are adopted, which leads to the closure of the Navier-Stokes equations with energy equation omitted. Complex dynamic behaviors of the bubble and free surface are well predicted.

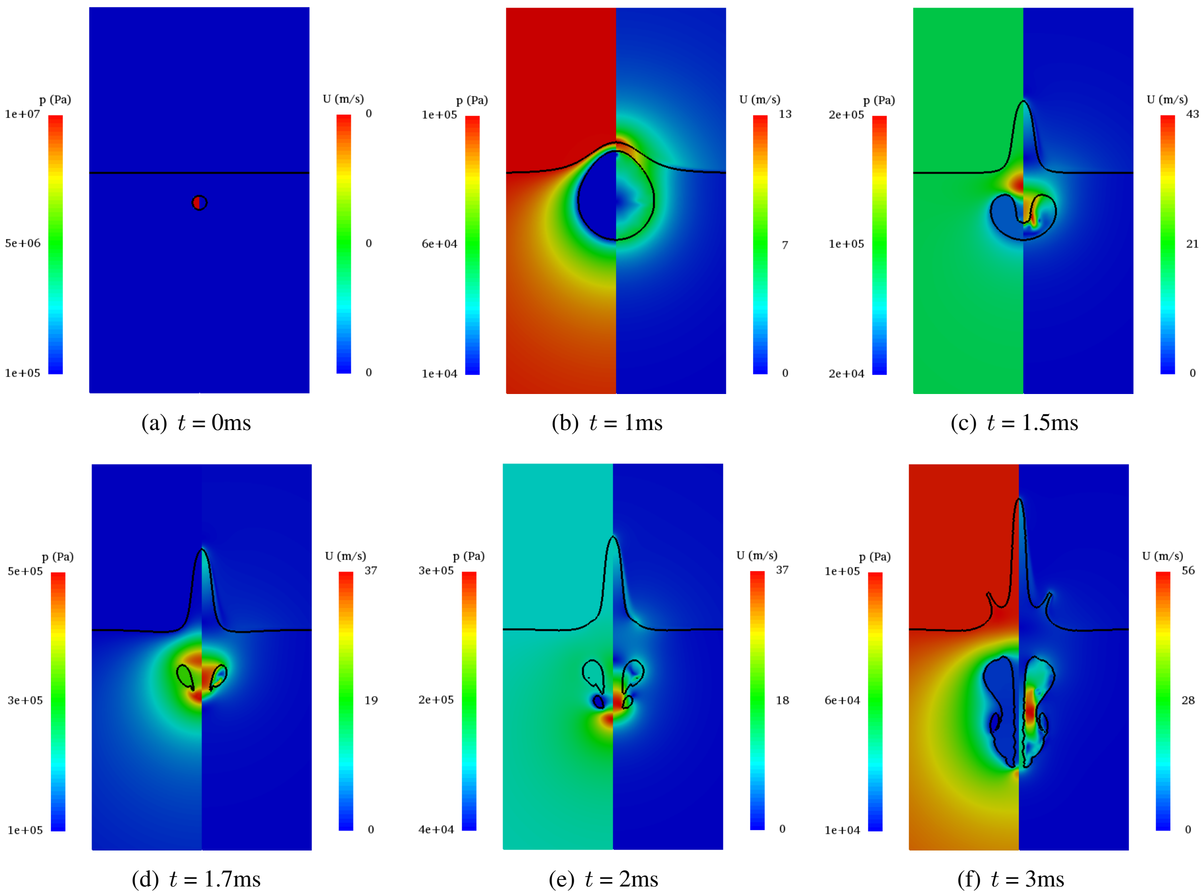
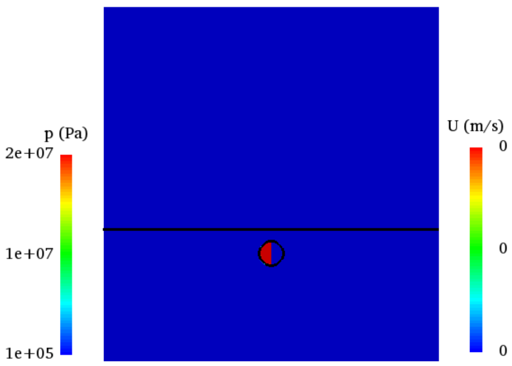


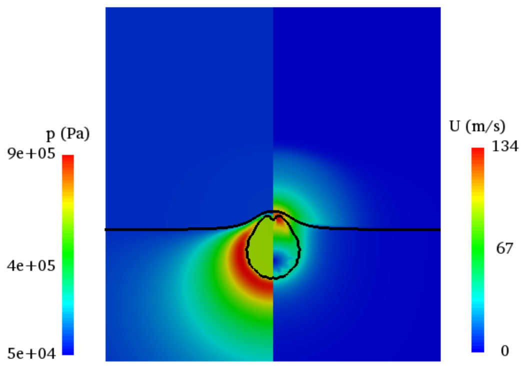
Figure 1: Bubble oscillating near the free surface

Fig. 1 shows the dynamic behaviors of a bubble initially located 8.1mm below the free surface. The initial bubble radius is 1.9mm and the initial bubble pressure is 10MPa in Fig. 1(a). The free surface is pushed upward by the expanding bubble.

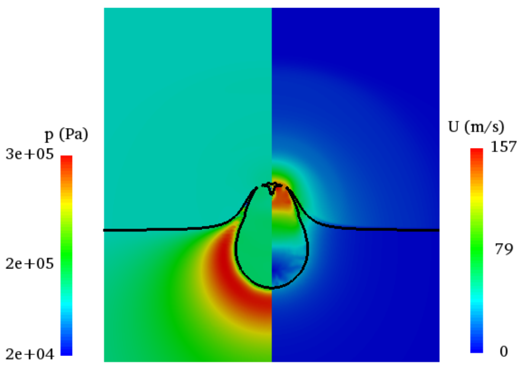
The bubble cannot maintain its spherical shape due to the attraction by the free surface, as shown in Fig. 1(b). When the bubble starts to collapse, a high pressure region is induced between the top of the bubble and free surface. The bubble is repelled by the free surface, leading to a downward liquid jet, as shown in Fig. 1(c). The liquid jet impacts on the opposite side and a toroidal bubble is generated. The toroidal bubble goes through splitting and coalescence during its rebounding phase, as shown in Fig. 1(d) and Fig. 1(e). The water spike grows continuously along with the oscillation of the bubble. An interesting phenomenon called "crown spike" can be observed in Fig. 1(f).
Fig. 2 shows the case of the bursting of the bubble near the free surface. In Fig. 2(a), the initial radius of the bubble radius is 5mm and the initial bubble pressure is 20MPa. The initial bubble-free surface distance is 10mm. As shown in Fig. 2(b), there is still a free surface hump as the bubble expands. The water layer between the top of the bubble and the free surface breaks up when it is thin enough, as shown in Fig. 2(c). The cavity generated by the bursting continues to expand with inertial effect, as shown in Fig. 2(d).



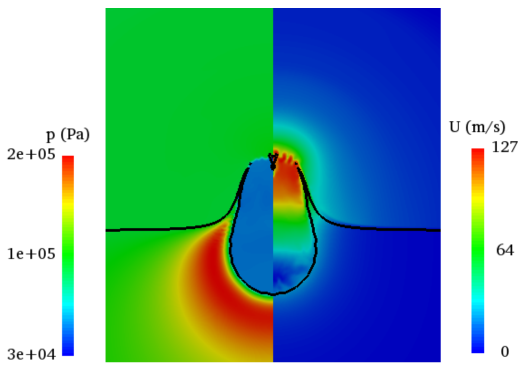
(a) $t = 0$ms



(b) $t = 0.1$ms



(c) $t = 0.2$ms



(d) $t = 0.3$ms

Figure 2: Bubble bursting at the free surface

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