

Numerical Simulation on Movement Behavior of Air Bubbles in Viscous Fluid

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Abstract. The computational geometry models of one bubble and two bubbles in viscous fluid were built. The Volume of Fluid model and pressure-velocity coupling solution method are used to solve the movement equation of air bubbles to investigate the movement, coalescence, and collapse of air bubbles. The results show at the beginning, the shape of the air bubble changes to ellipse from circle. The velocity of the air bubble greatly increases when the air bubble collapses; in the meanwhile the jet flow is produced. After the bubble collapses, the velocity of the oil decreases gradually. The movement velocity of two air bubbles is greater than that of one bubble.

Introduction

Hydro-viscous drive (HVD) theory applied to high-power mechanical equipment for speed regulation and soft start, has obvious energy-saving effects, which transmits power using viscosity of fluid [1]. This research field has been attracting many scholars from all over the world. Pär Marklund et al. [2, 3] studied torque, friction and lubrication of one pair of friction pair under the condition of boundary lubrication, and also made some experimental verification. Hong et al. [4] built mean surface roughness model and GT contact model, and proposed a calculation method for output rotation speed and torque under stable condition. Xie et al. [5, 6] built a revised Navier-Stokes equation based on the viscosity-temperature relationship, and investigated the effect of temperature, grooves, and deformed interface on capacity and torque of the oil film.

All of above scholars suppose the viscous fluid is single phase oil film. However, we found the air bubbles in the oil film will affect the transmission characteristics of the HVD. In this paper, the Volume of Fluid (VOF) model and pressure-velocity coupling solution method are used to solve the movement equation of air bubbles to trace the gas-fluid interface. Then, the movement, coalescence, and collapse of air bubbles in the viscous fluid are investigated in this paper.

Calculation Models

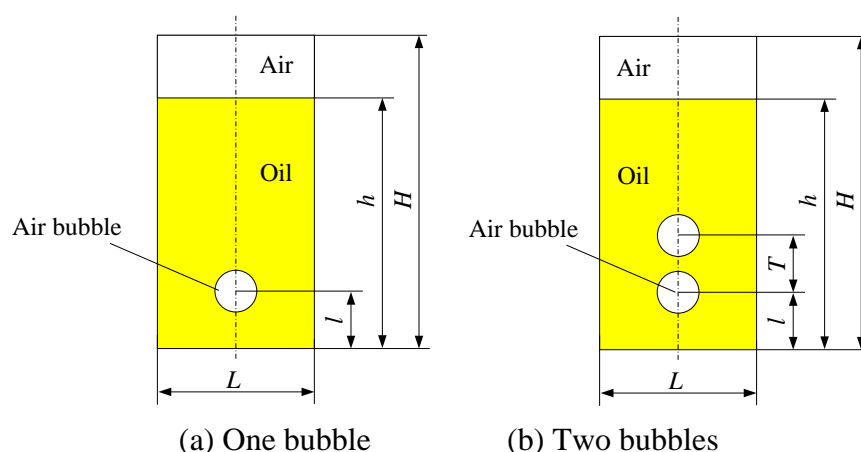


Fig. 1 Computational geometry model (a) One bubble, (b) Two bubbles

Fig. 1 is computational geometry model, in which the diameter of air bubble is 10mm. The parameters of the geometries are: L= 100mm, H= 200mm, l= 10mm, h= 150mm, T= 30mm.

Make assumptions that no wall slip, air bubble keep static in the oil. The initial velocity and pressure is 0, the shape of air bubble is circle, the calculation element size is 10-4m, and the unsteady calculation method is adapted. The properties of air bubble and oil are shown in Table 1.

Table 1 Properties of air bubble and oil

	Density (kg/m ³)	Specific heat J/(kg·°C)	Viscosity kg/(m·s)	Initial temperature (K)
Phase 1: Oil	881.6	2000	0.05458	300
Phase 2: Air	1.225	1006.43	1.7894e-5	300

Calculation Results

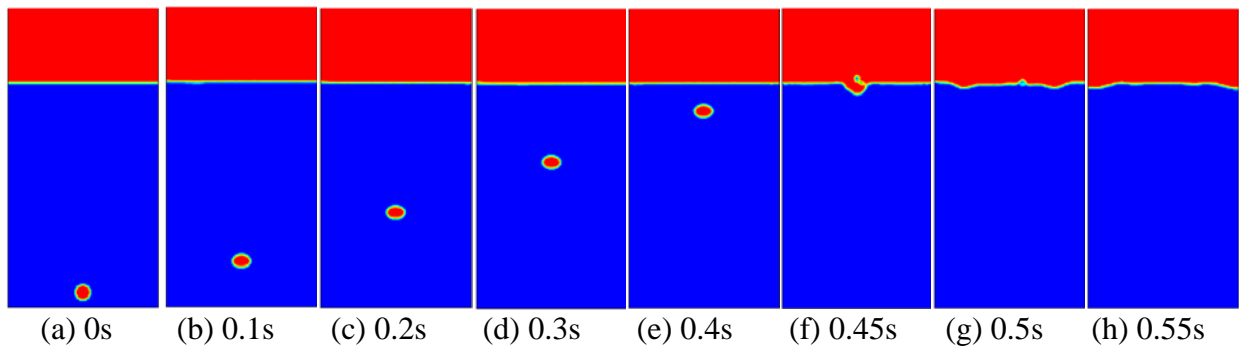


Fig. 2 Movement process of one air bubble in the oil

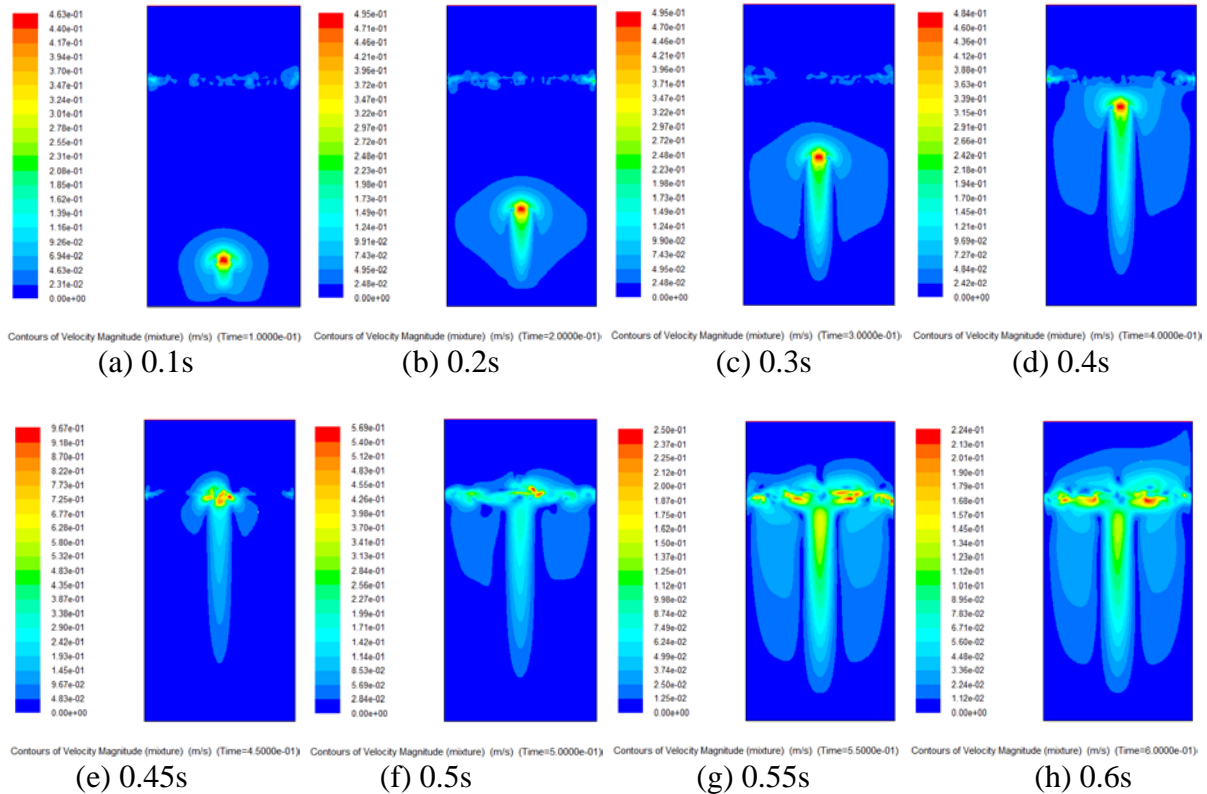


Fig. 3 Contours of velocity of one air bubble in the oil

Fig. 2 shows the movement of one air bubble in the oil, from Fig. 2 (a) to Fig. 2 (m). The figures also show the movement track, deformation and collapse of the air bubble. We can find the air bubble rise up under the action of pressure difference. At 0.1s the shape of the air bubble changes to ellipse

from circle. The bubble collapses at about 0.45s. From 0.5s to 0.6s, the surface of the oil exists a small fluctuation.

Fig. 3 shows the contours of velocity of one air bubble in the oil. It can be seen that from 0.1s to 0.4s, the velocity of the air bubble increases gradually, the value greatly increases at 0.45s, because at this moment the air bubble collapses, and jet flow is produced. Then, the velocity of the oil decreases gradually.

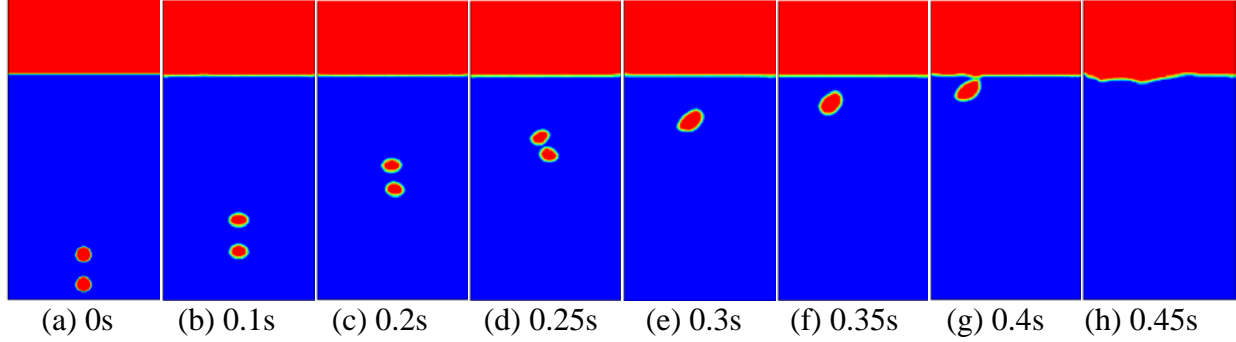


Fig. 4 Movement process of two air bubbles in the oil

Fig. 4 shows the movement of two air bubbles in the oil. The figures also show the movement track, deformation, coalescence and collapse of the air bubble. It can be seen that from 0.1s to 0.25s, with the rise of the air bubbles, the distance between two bubbles reduce gradually. At 0.3s two air bubbles merges into one new bigger air bubble, continue rising. Until 0.4s the new bubble touches the surface of the oil, the collapse time is between 0.4s and 0.45s.

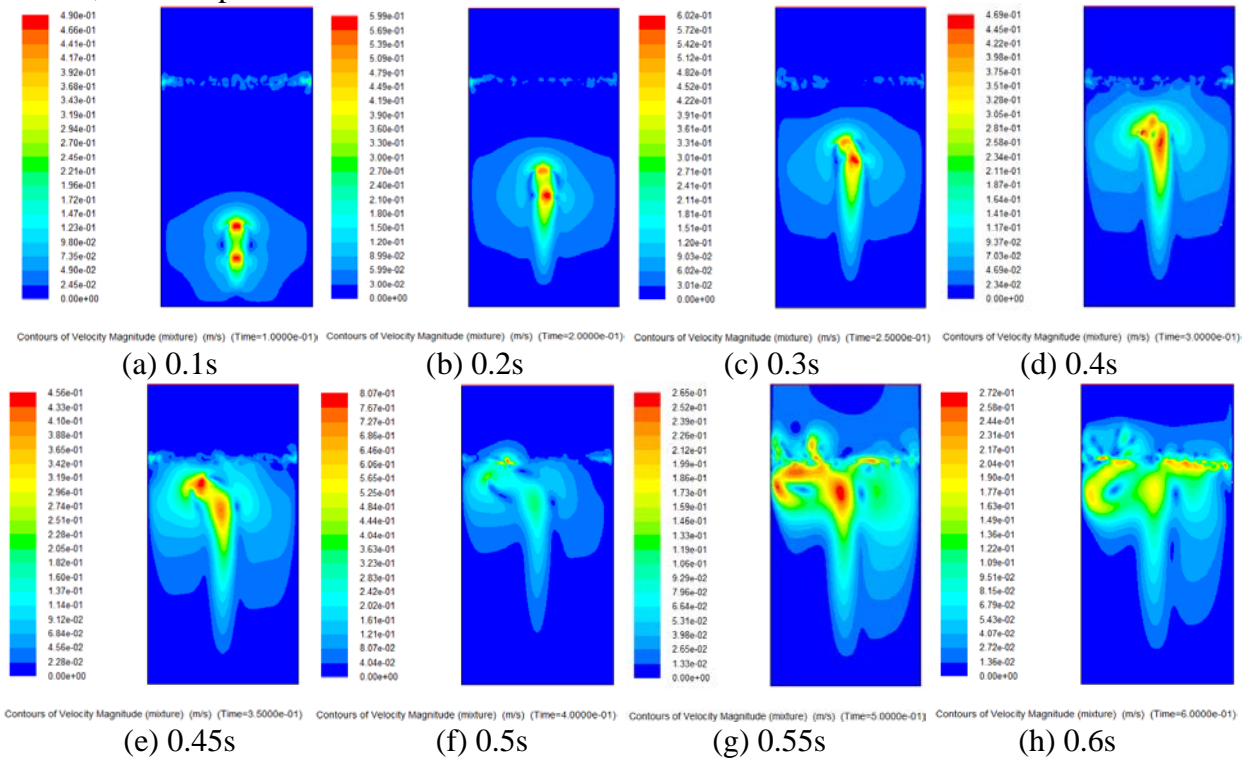


Fig. 5 Contours of velocity of two air bubbles in the oil

Fig. 5 shows the contours of velocity of two air bubbles in the oil. It can be seen that from 0.1s to 0.4s, the velocity of two air bubbles is greater than that of one bubble. And the velocity of the lower bubble is greater than that of the upper one, because the wake flow of the upper bubble enhance the velocity of the lower bubble. From 0.45s to 0.6s, the velocity of the oil decreases gradually after the bubble collapses.

Fig. 6 shows the variation of velocity of air bubble with time. It can be seen that the mean velocity of two bubbles is greater than that of one bubble before collapse. The collapse velocity of one bubble is 0.967m/s, while we did not capture the collapse time of two bubbles. From Fig. 6 we can find that

the collapse time is between 0.4s and 0.45s, and we are sure the collapse velocity must be higher than 0.967m/s.

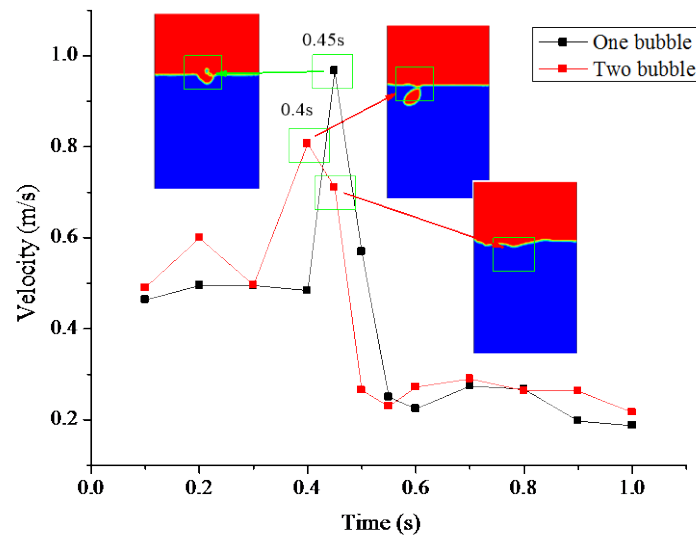


Fig. 6 Variation of velocity of air bubble with time

Conclusions

In this paper, the computational geometry models of one bubble and two bubbles were built. The VOF model and pressure-velocity coupling solution method are used to solve the movement equation of air bubbles to trace the gas-fluid interface. Then, the movement, coalescence, and collapse of air bubbles in the viscous fluid are investigated. We found that at the beginning, the shape of the air bubble changes to ellipse from circle. The velocity of the air bubble greatly increases when the air bubble collapses; in the meanwhile the jet flow is produced. After the bubble collapses, the velocity of the oil decreases gradually. The movement velocity of two air bubbles is greater than that of one bubble.

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