OCUURRENCE OF MICRO-BUBBLES DURING COALESCENT MOTIONS OF GAS-BUBBLES IN LIQUID

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Summary A new superposition method of Oseen's flow fields which is proposed here as a kind of the previous reflection method succeeds to estimate approaching motions of two equal-sized deformable gas-bubbles located vertically in series in a viscous liquid considering the hydrodynamic interactions between the gas-bubbles. The following phenomena are newly recognized by using high-speed video-camera and microscopes: (1) an occurrence of several number of micro-bubbles during a coalescent motion of two gas-bubbles observed at the final stage of the approaching motion of gas-bubbles rising freely in the viscous liquids, (2) an occurrence of several number of micro-bubbles during a coalescent motion of freely-rising motion of two bubbles between two sheets of vertically-set parallel plates in the viscous liquids, and (3) an occurrence of several micro-water-drops and micro-bubbles caused by a bursting motion of a single air-bubble at water surface.

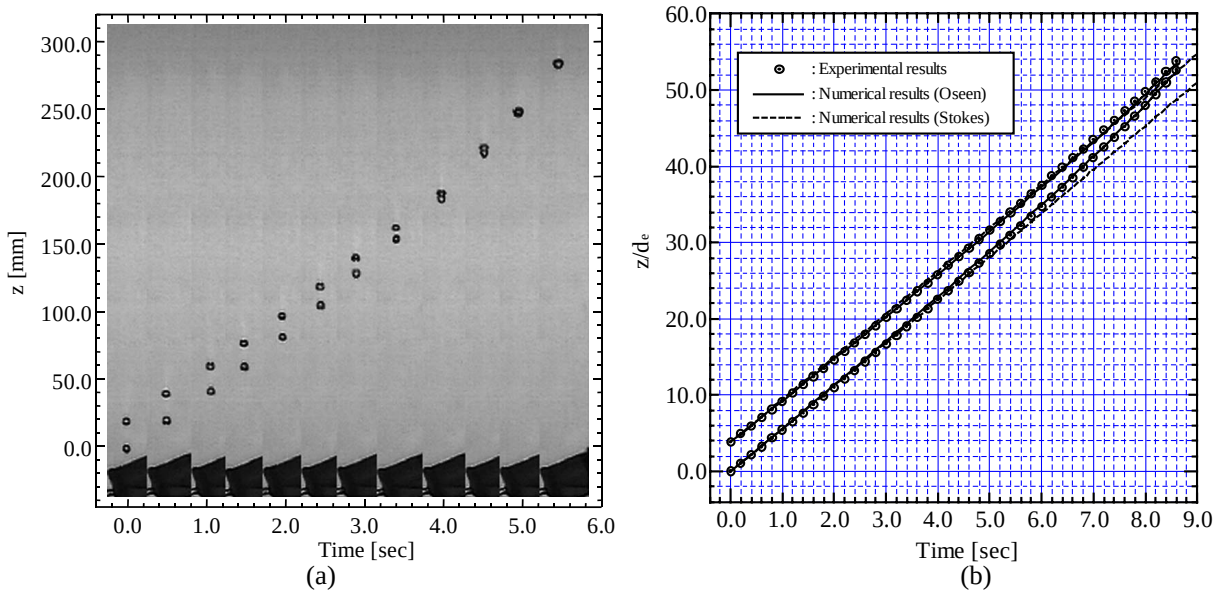
INTRODUCTION

The motion of gas-bubbles in liquid flows are not only a classical subject, but is directly related to many problems in industrial applications. Thus this subject has been treated theoretically and experimentally. However there are left rooms to study the motion of a cluster of deformable gas-bubbles in liquid considering the hydrodynamic interactions among gas-bubbles even if assuming at low Reynolds numbers.

RESULTS

FREELY-RISING MOTION OF GAS-BUBBLES IN LIQUID

A superposition method of Oseen's flow fields around deformable gas-bubbles is newly proposed here as a kind of the usual reflection method considering hydrodynamic interactions among gas-bubbles in liquid. This method succeeds to estimate the freely-rising motions of two equal-sized air-bubbles located vertically in series in a quiescent glycerol as shown in Figure 1. During this motion the following air-bubble approaches the preceding air-bubble even if they are equal-sized at the initial time. When the center-to-center distance reaches three times the equivalent diameter of the air-bubbles, the shape of the preceding air-bubble becomes oblate, while the following air-bubble becomes prolate. Then the two air-bubbles touch and coalesce finally. It should be noted that the numerical results obtained by using the usual Stokes's approximation fails to estimate this freely-rising motion even at the low Reynolds numbers such as Re=0.191.

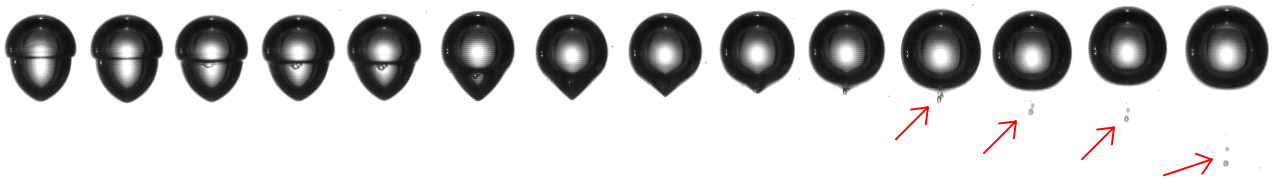


(a) (b)

Fig. 1: Freely-rising motion of two equal-sized air-bubbles located vertically in a quiescent glycerol in the case of M=73.4, Eo=7.39(Re=0.191, de=6.1mm); Fig.1(a) shows the video picture, while Fig.1(b) shows the experimental and numerical results.

OCCURRENCE OF MICRO-BUBBLES DURING THE COALESCENCE OF TWO BUBBLES

In the coalescent motion of the two air-bubbles, a crack occurs on the interfacial plane between the two air-bubbles. Then several number of micro-bubbles are left behind the coalesced air-bubble as shown in Fig.2. Fig.2 is obtained by using high-speed video-camera with 10000 frames/s which is moved vertically with the same speed as the rising speed of the center of the two air-bubbles.



t=0.00 t=0.01 t=0.02 t=0.03 t=0.04 t=0.09 t=0.14 t=0.19 t=0.24 t=0.29 t=0.34 t=0.44 t=0.54 t=0.64

Fig.2 Occurrence of micro-bubbles during coalescence of two air-bubbles in glycerol

OCCURRENCE OF MICRO-BUBBLES DURING COALESCENCE OF TWO AIR-BUBBLES IN GLYCEROL BETWEEN TWO PARALLEL PLATES WITH NARROW SPACING

Several number of micro-bubbles are generated from the trailing edges of the upper air-bubble at the final stage of the coalescent motion as shown in Fig.3.

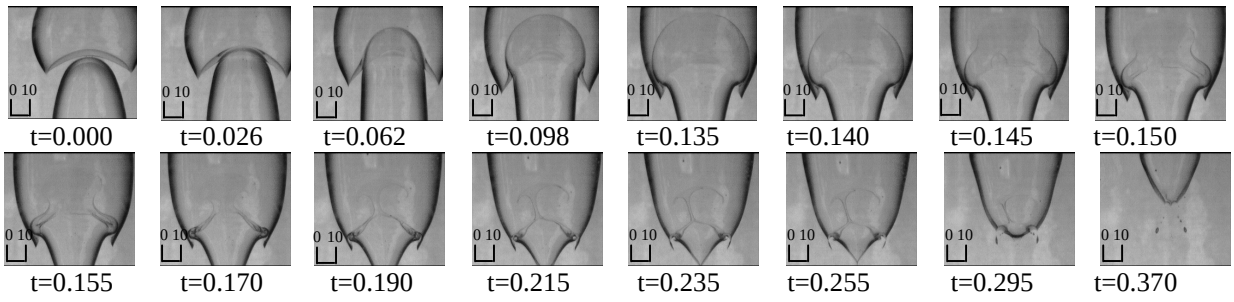


Fig.3: Occurrence of several micro-bubbles during the coalescent motion of two air-bubbles in glycerol between two parallel plates with narrow spacing (Re=0.314, We=0.870)

OCCURRENCE OF SEVERAL NUMBER OF MICRO-DROPS AND MICRO-BUBBLES IN THE BURST OF A SINGLE AIR-BUBBLE AT LIQUID SURFACE

Several number of micro-drops and micro-bubbles occur after a single air-bubble is bursted at water surface as shown in Fig.4, while only several micro-bubbles occur at glycerol surface as shown in Fig.5.

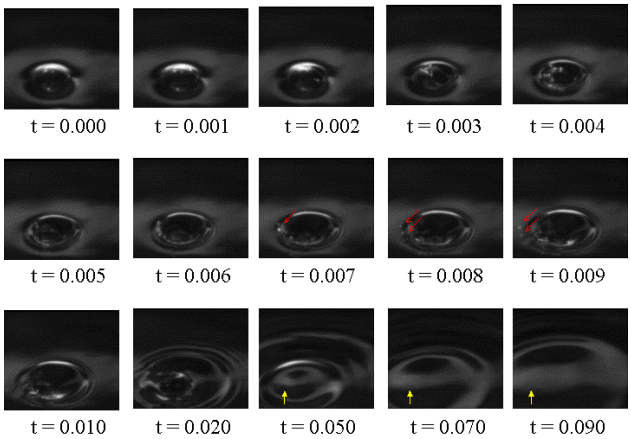


Fig.4 Occurrence of micro-water-drops and micro-bubbles at water surface (d=9.88mm, We=2.94, Re=2.91)

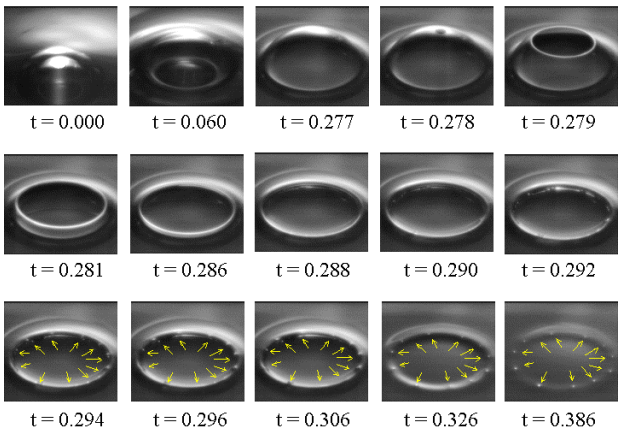


Fig.5 Occurrence of micro-bubbles at glycerol surface (d=23.41mm, We=3.91, Re=2.61)

CONCLUSIONS

The superposition method of Oseen's flow fields describes well the approaching motion of two equal-sized gas-bubbles rising freely in series in the viscous liquid at low Reynolds numbers. The phenomena of occurrence of micro-bubbles are recognized in the coalescence of two gas-bubbles in viscous liquids and in the burst of a single gas-bubble at water surface.