Buoyancy-driven Path Instabilities of an Air Bubble Rising in Water and Aqueous Polymer Solutions of a Hele-Shaw Cell

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Hele-Shaw セル中に水、あるいはポリ N－イソプロピルアクリルアミド（PNIPAM）水溶液を満たし、その中を浮力でもって上昇する単一の泡のダイナミクスを泡の面積、温度を変えて検討したので報告する。溶液の種類に依らず、泡はその形状（扁平楕円体）を大きく変化させずに、単調振動しながら上昇し、泡の上昇速度は泡の面積と共に増加し、一定値に近づくことが分かった。上昇速度が一定になる泡の面積は水よりも PNIPAM 水溶液の場合が大きくなった。また、その面積を越えると、泡の周囲長が振動し始める、すなわち泡の不安性が起こることも分かった。そして、その振動の振幅は PNIPAM 水溶液のほうが水に比べて小さくなった。流体力学的無次元パラメータであるストローハル数 St の値が 0.2 を越えると、周囲長は振動し始めることが明らかになった。従って、St の値の 0.2 が非定常流れを起こす閾値であることも知られており、St の値は Hele-Shaw セル中の液体を上昇する泡の不安定性を制御する因子になると考えられる。

Keywords : Path Instabilities, Hele-Shaw Cell, Bubble, Aqueous Polymer Solutions, Strouhal Number

The buoyancy-driven path instabilities of an air bubble rising in water and in aqueous poly(N-isopropyl acryl amide) (PNIPAM) solutions of a Hele-Shaw cell made from two parallel rectangle Plexiglas plates (25cm x 5cm x 1.5 cm), separated by a 0.15 cm thick Plexiglas plate spacer were investigated as functions of bubble size and temperature. The experimental temperatures were varied at 16.0, 25.0, 31.3, and 34.8 °C and changes in the bubble size, namely a bubble area S were performed from 0.1 to 1.0 cm^2. The motion of the center of the bubble outline is a zigzag path, irrespective of the fluid and the bubble size. When the bubble size is increased, the periphery length L of the bubble is fluctuated. Thus, changes in the bubble shape are evaluated by plots of the periphery length L as a function of rising time. When the distances that the bubble traveled along the centerline of the path for the bubble rising in the fluids are plotted against the necessary time, the data points can be fitted to a straight line for all bubbles, leading to the steady-state rising velocity U. The resulting U value increases with an increase in the bubble size and gradually tends to a plateau value, irrespective of the fluid. The value of S which the U value approaches the plateau one for water is smaller than that for the PNIPAM solution. Above the S value, the L value zigzag vibrates, irrespective of the fluid. Thus, it can be considered that the plateau velocity U causes the instability of the L value, namely path instability occurs. Strouhal number St is defined by (fd/U), where f is the frequency of the zigzag path and d is related to $d = 2\ (S/\pi)^{1/2}$: the resulting St value gradually increases and it somewhat steeply increases with increasing S for the St values larger than 0.2, irrespective of the fluid. Thus, the value of St can be regarded as a controlling parameter for the buoyancy-driven path instabilities of a bubble in a fluid of Hele-Shaw cell.