Paper ID: 14031
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student

MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (A2)
Fluid and Materials Sciences (2)

Author: Mr. Takumi Watanabe
Tokyo University of Science, Japan, a7508151@rs.tus.ac.jp

NON-LINEAR FLOW FIELDS AND THEIR TRANSITION PROCESS IN HANGING DROPLET DUE TO THERMOCAPILLARY EFFECT

Abstract

We focus on thermocapillary-driven convection in a hanging droplet with experimental approaches. We realize several flow patterns in the droplet by increasing the temperature difference between the sustaining rod and droplet tip, that is, we have a transition of the flow field from a two-dimensional steady flow to three-dimensional time-dependent 'oscillatory' ones. The oscillatory flow is accompanied with a thermal wave traveling over the free surface at a constant frequency. Such a thermal wave induced by the thermocapillary effect is known as the hydrothermal wave (HTW) after Smith Davis (1983). We pay our attention to this phenomenon to find out the correlation between the convective field inside the droplet and the HTW by imposing a range of temperature differences. We make a comparison with on-orbit experiments carried out on the Japanese Experimental Module 'KIBO' aboard the International Space Station, to measure the scale effect. The droplet is formed on the top rod facing downward, and the bottom plate is placed beneath the droplet. In order to realize a designated temperature difference, the top rod is heated and the bottom plate is cooled at designated temperatures. In the terrestrial experiments, we use two kinds of top rods, whose diameter is of 2.0 and 3.0 mm. We employ 2 and 5-cSt silicone oil as the test fluids. In the on-orbit experiments, the diameter of the rod is of 30.0 mm. We employ 5 and 20-cSt silicone oil as the test fluids. We visualize the flow field in the droplet by suspending gold-coated acrylic particles in the fluid, and observe the flow patterns with two high-speed cameras. We simultaneously measure the surface temperature with an infrared camera. In the present research, we evaluate two things; the transition point of the flow inside the droplet, and the fundamental frequency of the oscillatory flow after the transition. As for the transition point, we detect it as functions of the aspect ratio and size of the droplet, and of the Prandtl number of the test fluid. It is found that transition point is well described with the droplet aspect ratio, and that the higher aspect ratio of the droplet, the lower the transition point. As for the fundamental frequency, we find that the frequency is linearly increased as the intensity of thermocapillary effect. We introduce a non-dimensional frequency to include the effects of the droplet scale and the Prandtl number of the test fluid.