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THERMOCAPILLARY CONVECTION IN FREE LIQUID FILM - EFFECT OF LIQUID-FILM VOLUME RATIO ON FLOW PATTERNS

Abstract

We focus on thermocapillary convections in a free liquid film. The free liquid film is a film sustained by periphery, and has two free surfaces. A designated temperature difference is realized between both end walls, which results in non-uniform surface tension distribution over the free surfaces due to the temperature dependence of the surface tension. In 2003, an American astronaut, Dr. Donald Pettit, carried out a series of fluid physics demonstrations in the International Space Station. He observed a unique flow pattern in a free liquid film formed in a wire ring of about 10 cm in diameter by placing a heated soldering iron closer to the one end of the liquid film. He realized a flow in the film toward the soldering iron in spite of the negative temperature coefficient of the surface tension. The purpose of our study is to make clear the mechanism of flow patterns realized in the free liquid film due to the thermocapillary effect. We form a thin liquid film of 6-cSt silicone oil (Prandtl number Pr= 83.0) in a rectangular hole in the aluminum plate, and add designated temperature difference between the both end walls. We observe the temperature distribution over the upper free surface of the liquid film by an infrared camera. We simultaneously observe the convection field from beneath the liquid film by adding tracer particles inside the film with the digital Charge Coupled Device (CCD) camera. We carry out both a series of ground experiments and a series of parabolic flight experiments to take account of gravity effect on the flow patterns. Through the present study, we conclude that the dominant parameter to determine the flow pattern is the volume ratio of the liquid film. The volume ratio is defined as the ratio of the liquid film volume to the volume of the rectangular hole. We will discuss a mechanism to determine the flow pattern induced in the free liquid film by considering the growth of the thermal field over the free surface as well as the viscous effect in the film.