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Topological structure evolvement of flow and temperature fields in deformable drop Marangoni migration in microgravity. (English) Zbl 1227.80039

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Summary: Using the level-set method and the continuum interface model, the axisymmetric thermocapillary migration of a deformable liquid drop immerged in an immiscible bulk liquid with a temperature gradient is simulated numerically with constant material properties of the two phases. Steady terminal state of the motion can always be reached. The dimensionless terminal migration velocity decreases monotonously with the increase of the Marangoni number. Good agreements with space experimental data and most of previous numerical studies in the literature are evident. The terminal topological structure of flow field, in which a recirculation identical to Hill's vortex exists inside the drop, does not change with the Marangoni number. Only slight movement of the location of vortex center can be observed. On the contrary, bifurcations of the terminal topological structure of temperature field occur twice with increasing Marangoni number. At first, the uniform and straight layer-type structure of temperature field at infinitesimal Reynolds and Marangoni numbers wraps inside of the drop due to convective transport of heat as the Marangoni number increases, resulting in the emergence of an onion-type local cooler zone around the center of the drop beyond a lower critical Marangoni number. Expanding of this zone, particularly in the transverse direction, with the increasing of the Marangoni number leads to a cap- or even shell-type structure. The coldest point within the liquid drop locates on the axis. There is a middle critical Marangoni number, beyond which the coldest point will jump from the rear stagnation into the drop, though the topological structure of the temperature field does not change. The second bifurcation occurs at an upper critical Marangoni number, where the shell-type cooler zone inside drops ruptures from the central point and then a torus-type one emerges. The coldest point departs from the axis, and the so-called "cold-eye" appears in the meridian. It is also found that the inner and outer thermal boundary layers along the interface may exist both inside and outside the drop if $Ma > 70$. But the thickness decreases with the increasing Marangoni number more slowly than the prediction of potential flow at large Marangoni and Reynolds numbers. A velocity shear layer outside the drop is also introduced formally, of which modality may be affected by the convective transports of heat and/or momentum.

MSC:

80A20 Heat and mass transfer, heat flow (MSC2010)
76T10 Liquid-gas two-phase flows, bubbly flows
76R10 Free convection
80M25 Other numerical methods (thermodynamics) (MSC2010)
76M25 Other numerical methods (fluid mechanics) (MSC2010)

Keywords:

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