3D Unsteady Benard-Marangoni Instabilities During The Evaporation Of The Volatile Sessile Drops

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Abstract

Our current research is focused on thermal Marangoni instabilities in sessile ethanol drops which develop spontaneously during evaporation. Our current problem for numerical model is 3D unsteady with moving interface of a sessile drop under forced evaporation and showing internal flow instabilities. The axi-symmetric model does not reproduce actual instabilities and it required the fine spatial and temporal resolutions to catch 3D instabilities. 3D unsteady Benard-Marangoni instabilities are first triggered in sessile drop and then grow with time.

To solve our problem, the governing equations have been implemented in the COMSOL Multiphysics® software. Along with the time-dependent governing equations for the fluid flow and heat transfer other boundary conditions have been implanted by using the weak contributions and weak constraints with that moving mesh for the interface velocity. A typical computational domain for the sessile drop consists(see fig. 1) of approximately 13,000 elements (approx. 732890 DOF), the typical computational time for the simulation on 64 cores of the Intel(R) Xeon(R) Gold 6142 CPU at 2.60 GHz,200Gb RAM takes around 2 days.

Our computations contribute to figure out the internal 3D flow structure in the drop and also to determine the driving mechanism and energy sources of the observed thermo-convective instability and thus clarifies its nature. They start with a uniform initial temperature field (at substrate heating temperature) in the drop and the imposed heating temperature at the substrate surface. Due to the latent heat of vaporization, the drop cools down from the liquid-gas interface, meanwhile, the temperature near the contact line remains higher due to heat conduction from the substrate through a thin layer of ethanol. This creates a vertical temperature gradient in the drop bulk and a tangential one along the drop surface near the contact line. These temperature gradients promote the development of thermocapillary Benard-Marangoni instability. In Fig. 2. we display the top view of the time evolution over the first 18s during the evaporation process of the sessile drop deposited on a heated substrate.

Figures used in the abstract

Figure 1 : Figure 1: Spatial discretization of the sessile drop domain mainly with hexahedral and prism meshes element showing cut view (top) and top view (bottom).

Figure 2 : Figure 2: 3D unsteady numerical simulation of an ethanol sessile drop evaporation evidencing Benard-Marangoni instabilities with cells merging then splitting.