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NON-EQUILIBRIUM EFFECTS ON GAS – FLUID INTERFACES

Abstract

Investigations of acute problems of heat and mass exchange accompanied by phase transitions need adequate modeling of evaporation, which is extremely important for the curved surfaces in the presence of strong heat fluxes. Working cycle of heat pipes is governed by the active fluid evaporation rate. Combustion of most widely spread hydrocarbon fuels takes place in a gas-phase regime. Thus, evaporation of fuel from the surface of droplets turns to be one of the limiting factors of the process as well. Evaporation under terrestrial conditions is strongly influenced by gravity induced thermoconvective flows. Those effects mask the influence of non-equilibrium processes in phase transitions making the proper understanding of the phenomenon very difficult in the ground-based experiments. Besides, non-equilibrium effects have a stronger manifestation under low gravity conditions for interfaces of high curvature. The aim of the present study is to develop a mathematical model for the non-equilibrium evaporation and to determine the applicability limits for the existing quasi-equilibrium models. The problem will be solved taking evaporation of small droplets as an example. Mathematical models for individual droplets evaporation incorporated in polydispersed mixtures modeling, are usually based on the assumptions of the equilibrium character of phase transitions. Comparison of theoretical and experimental data shows that this assumption being undoubtedly valid for large droplets and flat surfaces, brings to essential errors for small droplets. In the present paper processes of non-equilibrium evaporation of small droplets were investigated theoretically. The rate of droplet evaporation is characterized by a dimensionless Peclet number (Pe). A new dimensionless parameter I characterizing the deviation of phase transition from the equilibrium was introduced, that made it possible to investigate its influence on variations of the Peclet number and to determine the range of applicability for the quasi-equilibrium model. As it follows from the present investigations accounting for non-equilibrium effects in evaporation for many types of widely used liquids is crucial for droplets diameters less than 100 microns, while the surface tension effects essentially manifest only for droplets below 0.1 micron. The authors wish to acknowledge the support by Russian Foundation for Basic Research (Grant 09-08-000284).