Effects of dynamic compressibility in a near-critical fluid: comparison with a perfect gas

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Media at parameters close to the gas-liquid critical point, usually called near-critical fluids, are studied. Such fluids exhibit anomalous physical properties related with asymptotic discrepancy of the constant-pressure heat capacity and isothermal compressibility and vanishing the thermal diffusivity at the critical point. Peculiarities in physical properties lead to interesting effects in dynamics and heat transfer and make near-critical fluids very attractive for modern technologies such as material processing, crystal grow, environmental remediation and many others.

Numerical simulations based on the full Navier-Stokes equations with two splitting of the pressure and the van der Waals equation of state are carried out. A 2D solver based on a finite-difference formulation is employed [1]. The scaling relations connecting the model criteria of similarity (contained in the governing equations) and the real criteria of similarity (actually characterizing near-critical dynamic phenomena) are derived. Using these relations, a near-critical fluid is compared with a model perfect gas to have the same physical properties except a high compressibility that allowed one to specify thermal effects caused by the adiabatic compression-expansion mechanism. Early, such relations were obtained for the conditions at the critical isohore [2] and used for some classical problems [3, 4]. In the present study, the scaling relations are extended to the random conditions. They are applied to the problem about dynamics and heat transfer in a near-critical fluid stimulated by one or two small thermal sources inside a cavity. From the comparison with a perfect gas, it is shown that adiabatic heating called the “piston effect” (PE) [5] reduces gravity-driven convection. A quantitative analysis of such phenomenon performed in a wide range of parameters is given. The ratio between the time scales of the PE and convection is evaluated. Conditions of the most influence of the PE on convection are defined.