

**DRAFT MIGRATE-XX****A NUMERICAL STUDY OF INTERFACIAL TEMPERATURE JUMPS IN
THE EVAPORATION OF WATER****Aldo Frezzotti**

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KEY WORDS

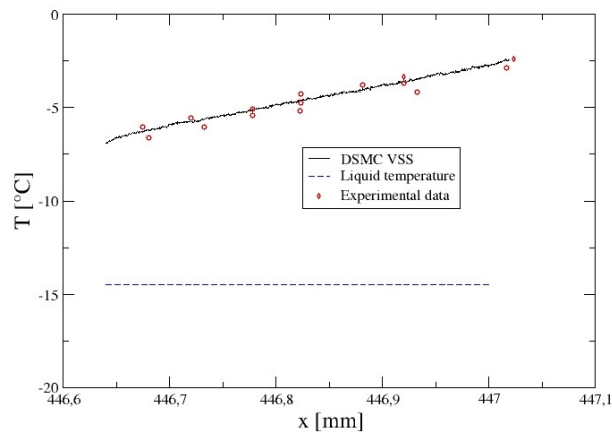
Kinetic theory, vapor- liquid interface, boundary conditions.

ABSTRACT

In 1999, Fang and Ward published a paper reporting measurements of large temperature jumps at the vapor-liquid interface, during the slow evaporation of purified water [1]. Temperature jumps in evaporation flows have also been observed in experiments adopting different setups [2] and working fluid [3]. The observed temperature jumps appeared as anomalous in that the vapor temperature, in proximity of the interface was found to be a few degrees *higher* than the liquid surface temperature, whereas it was expected to be slightly lower because of the vapor expansion in the evaporation flow. As pointed out in a few following papers [4, 2], such expectation is not correct, in principle. Actually, the temperature jump at the vapor-liquid interface is determined not only by evaporation mass flow rate but also by the heat flux [5]. The former gives a negative contribution to the temperature jump, in the case of evaporation. However, the latter gives a positive contribution when, as in the case of the experiment described in Ref. [1], a steep raise of the temperature is found outside the Knudsen layer, next to the interface. Although a clear, quantitative explanation of the observed jumps has not yet been given, the possible role of kinetic boundary conditions has been pointed out in Ref. [4] where a velocity dependent condensation coefficient, proposed by Tsuruta [6], has been adopted to study the influence of kinetic boundary conditions on temperature jumps. Although interesting, the analysis was affected by a few limitations. First of all, kinetic contributions have been taken into account only approximately, not by a consistent treatment of the Knudsen layer structure as done, for instance, by Soga [5] using a linearized kinetic model for a diatomic gas. Second, molecular internal degrees of freedom have not been taken into account. In principle, the latter approximation might have an important quantitative impact on the model predictions since the amount of internal energy stored in rotational motion of water molecules equals the translational contribution, in near equilibrium flows. The aim of the present work is to study the onset of temperature jumps at the vapor-liquid interface by a kinetic model, based on the Boltzmann equation [7] for a gas of rigid rotators with three rotational degrees of freedom. Molecular collisions are described by the Variable Soft Sphere (VSS) model [8] in combination with the Borgnakke-Larsen [9] statistical model to couple rotational and translational degrees of freedom. The (fundamental) role of boundary conditions at the interface is analyzed by a comparison of two different evaporation models. The first is a quite standard one, assuming an energy independent evaporation/condensation coefficient and Maxwellian distribution of spontaneously evaporated molecules [10]. The second one is Tsuruta's model, cited above, and already used by Bond and Struchtrup [4] to interpret experimental temperature jumps. The kinetic equation has



been solved numerically with the necessary accuracy by the Direct Simulation Monte Carlo method [11] thus providing results which are not affected by additional approximations beyond those intrinsic in the underlying physical models and in the flow geometry simplifications. As shown in the Figure below, matching kinetic theory predictions and experimental results is possible, provided the evaporation/condensation coefficient of water is very small (around 0.05) and specular reflection of molecules is assumed to occur at the vapor-liquid interface. Moreover, it is found that Tsuruta's model results are very close to those of the more standard energy independent evaporation/condensation coefficient. Since the boundary conditions setting that leads to agreement with experimental data appears as unrealistic, a deeper analysis of the experimental results and of the theoretical models is necessary.



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