University of Victoria | Graduate Studies

Notice of the Final Oral Examination
for the Degree of Master of Applied Science

of

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BSc (University of Hannover, 2014)

“Modeling Evaporation in the Rarefied Gas Regime by Using Macroscopic Transport Equations”

Department of Mechanical Engineering

Wednesday, April 11, 2018
10:00 A.M.
Engineering and Computer Science Building
Room 468

<u>Supervisory Committee:</u>
Dr. Henning Struchtrup, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Brad Buckham, Department of Mechanical Engineering, UVic (Member)

<u>External Examiner:</u>
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<u>Chair of Oral Examination:</u>
Dr. Lynne Siemens, Department of Mechanical Engineering, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

Due to failure of the continuum hypothesis for higher Knudsen numbers, rarefied gases and microflows of gases are particularly difficult to model. Macroscopic transport equations compete with particle methods such as DSMC to find accurate solutions in the transition regime. Due to growing interest in micro ow applications, such as micro fuel cells, it is important to model and understand evaporation in this ow regime.

First, for gaining a better understanding of evaporation physics, a non-steady simulation for slow evaporation in a microscopic system, based on the Navier-Stokes-Fourier equations, is conducted. The one-dimensional problem consists of a liquid and vapor layer (both pure water) with respective heights of 0.1mm and a Knudsen number of Kn=0.01 where vapor is pumped out. The simulation allows for calculation of the evaporation rate within steady and non-steady-state.

The main contribution of this work is the derivation of new evaporation boundary conditions for the R13 equations, which are macroscopic transport equations with proven applicability in the transition regime. The approach for deriving the boundary conditions is based on an entropy balance, which is integrated around the liquid-vapor interface. The new equations utilize Onsager relations, linear relations between thermodynamic fluxes and forces, with constant coefficients that need to be determined.

For this, the boundary conditions are fitted to DSMC data and compared to other R13 boundary conditions from kinetic theory and Navier-Stokes-Fourier solutions for two steady-state, one-dimensional problems. Overall, the suggested fittings of the new phenomenological boundary conditions show better agreement to DSMC than the alternative kinetic theory evaporation boundary conditions for R13.

Furthermore, the new evaporation boundary conditions for R13 are implemented in a code for the numerical solution of complex, two-dimensional geometries and compared to Navier-Stokes-Fourier (NSF) solutions. Different ow patterns between R13 and NSF for higher Knudsen numbers are observed which suggest continuation of this work.