ΑΝΑΚΟΙΝΩΣΗ - ΠΡΟΣΚΛΗΣΗ
ΔΗΜΟΣΙΑ ΥΠΟΣΤΗΡΙΞΗ ΔΙΔΑΚΤΟΡΙΚΗΣ ΔΙΑΤΡΙΒΗΣ
Νικόλαου Βασιλειάδη,
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Προσκαλούμε τους μεταπτυχιακούς και προπτυχιακούς φοιτητές μας, τα μέλη Δ.Ε.Π., τους διδάσκοντες του Τμήματος και κάθε ενδιαφερόμενο, στη δημόσια υποστήριξη της Διδακτορικής Διατριβής του κ. Νικόλαου Βασιλειάδη με τίτλο:

GASEOUS TRANSPORT PHENOMENA IN RAREFIED CONDITIONS VIA DETERMINISTIC AND STOCHASTIC METHODS WITH APPLICATIONS IN VACUUM AND FUSION ENGINEERING

The scientific field of theoretical and computational gaseous transport phenomena in rarefied conditions, is steadily attracting considerable attention. These phenomena are far from local equilibrium and their basic interpretation and modeling are based on kinetic theory, as described by the Boltzmann equation (BE). They are of major importance in many industrial processes and technological applications, including microelectromechanical systems (MEMS), semiconductors, rarefied aerosol flows and vacuum engineering (e.g. particle accelerators and fusion reactors).

In the present work, sophisticated and advanced deterministic and stochastic kinetic modeling is developed on the basis of the well-established Discrete Velocity Method (DVM) and the Direct Simulation Monte Carlo (DSMC) method, respectively. The developed software is validated in several benchmarks and implemented to tackle diverse subjects related to gaseous transport phenomena under rarefied conditions.

The advanced deterministic kinetic modeling includes the solution of the linearized BE in slab geometry, the investigation of rarefied gas flows coupled with gas injection and suction and the advancement of the in-house gas network code for simulating gas distribution systems of arbitrary complexity operating under any vacuum conditions.

The computational solution of the linearized Boltzmann equation for the hard-sphere intermolecular potential is validated by computing the gas heat conductivity and viscosity, as well as, by solving the planar fully-developed Poiseuille and thermal creep rarefied gas flows. Then, the developed software is implemented to simulate the planar oscillatory pressure driven fully-developed rarefied gas flow in the whole range of gas rarefaction and oscillation frequency. The results include the amplitudes and phases of all macroscopic distributions and overall quantities (e.g. bulk velocity, flow rate) and are compared with corresponding ones, available in the literature, based on the BGK model. The range of validity of the BGK solution is established. It is noted that, this is the first in-house code solving the linearized Boltzmann equation.

Several rarefied gas flows coupled with gas injection and suction have been considered. The flow configurations include, the fully-developed pressure and temperature driven rarefied gas flows between parallel permeable plates with gas injection and suction through the bottom and top plates respectively, as well as, the fully-developed rarefied gas flow over a permeable plate with downward suction, driven by the free stream parallel to the plate. These three flow setups are of theoretical and technological interest in porous media

and adsorption/desorption processes and although they have been thoroughly investigated in the hydrodynamic regime, they have never been considered before under rarefied conditions. Modeling is based on the Shakhov (S) kinetic model and the BE. The full-range acceleration scheme is introduced to speed up the slow convergence of the iteration map of the kinetic equations in the slip and hydrodynamic regimes. Novel results are presented for the mass and heat flow rates in the Poiseuille and thermal creep type flows and for the boundary layer thickness in the half space flow. The S model results are in excellent agreement with the BE ones, justifying the use of kinetic models in rarefied gas flows with gas injection and suction.

The in-house steady-state gas network code has been advanced by developing robust algorithms for extracting the network loops and pseudoloops and simulating arbitrary number of pumps. In addition, by developing a hybrid time-dependent gas network code, which implements the steady-state one at each time step, modeling and simulation of the transient behavior of gas distribution networks of any complexity in the whole range of the Knudsen number, is feasible. The time-dependent algorithm is benchmarked in two prototype problems. The upgraded steady-state and the developed time-dependent software are implemented to simulate the ITER fusion reactor primary pumping system, one of the most complex ones, worldwide, during the burn and dwell phases, respectively. In both cases, various pumping scenarios are investigated and useful results are provided for the pumped throughput and the temporal evolution of the torus pressure. It is concluded that, in both phases, the pumped throughput depends almost linearly on the number of operating cryopumps. In the dwell phase, the target torus pressure is achieved in the whole range of the outgassing decay index only when all six available cryopumps are employed.

The advanced stochastic kinetic modeling includes the implementation of the Monte Carlo (MC) uncertainty propagation analysis method to gas distribution systems and the advancement of the in-house DSMC solver to simulate the transport of spherical solid particles in rarefied gases. The upgraded steady-state network code is employed to demonstrate the implementation of the MC uncertainty analysis methodology to gas distribution systems. The uncertainty of the output quantities such as the pumped throughput, due to the uncertainty of the input quantities, such as the pipe radius, pipe length, pressure and pumping speed measurements, have been determined.

The in-house three-dimensional DSMC solver is appropriately modified to simulate the transport of spherical solid particles in a rarefied gas for arbitrary complex geometries. A two-way coupling between the gas and the solid particle transport is implemented. More specifically, both the solid particle transport and the surrounding gas flow are governed by the solid-gas collisions. In addition, several advancements, including the implementation of subcells and the Variable Soft Sphere (VSS) intermolecular potential, are emploed. The capabilities of the developed code are demonstrated based on three benchmarks, namely, thermophoresis, as well as, translational and rotational Brownian motion. The thermophoresis benchmark considers the thermophoretic force exerted on a rigid spherical particle suspended in a rarefied gas between two parallel plates kept at slightly different temperatures. The translational and rotational Brownian motion considers the random translational and rotational movement, respectively of a solid particle suspended in a free-molecular gas bath. In all cases, the outputs of the developed aerosol code are in excellent agreement with available computational and theoretical results.

Overall, it is believed, that the present work will be useful, at certain extend, to the rarefied gas dynamics community and support the design and optimization of applications, devices and systems in MEMS, vacuum engineering and fusion technology.

Παρασκευή, 7 Μαΐου 2021, ώρα 11:00 (διαδικτυακή τηλεδιάσκεψη μέσω e:Presence)