VA 1: Rarefied gas dynamics and novel numerical approaches

Time: Monday 9:30–11:30 Location: H12

VA 1.1 Mon 9:30 H12

Direct Simulation Monte Carlo of diffusion pumps for the application in fusion reactors — •Tim Teichmann, Thomas Giegerich, and Christian Day — Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany

Active R&D is performed on developing of a continuously working pumping train for the future European demonstration fusion power plant (DEMO). Diffusion pumps operated with mercury have been identified as candidates for the high vacuum pumps. The numerical simulation of these pumps is challenging because they operate in a wide gas rarefaction range. A simulation framework based on the Direct Simulation Monte Carlo (DSMC) method has been established over the last years. The present talk aims to give an update on the present state of the simulations and their projected impact on the diffusion pump design for DEMO.

VA 1.2 Mon 10:10 H12

Transient modeling of the gas flows in the gas injection systems of fusion reactors — •Christos Tantos, Stylianos Varoutis, and Christian Day — Karlsruhe Institute of Technology, Karlsruhe, Germany

This work presents an assessment of the flow evolution inside the gas pipes of the gas injection system (GIS) of fusion reactors during a control action. A successful gas injection system design requires on the one hand the ability to meet the technical requirements under steady state conditions that are in line with the operating requirements of the reactor and on the other hand the appropriate prediction of the dynamic change of the system response times. In this framework, in the present work a state-of-the-art methodology has been utilized analyzing the transient behavior of the argon and deuterium-tritium gas flows in the GIS of DEMO (DEMOnstration Power Plant) fusion reactor. The applied methodology allows for an accurate description of the gas flow in the whole range of the gas rarefaction and compared to other widely applied particle-based approaches it requires low computational effort using an ordinary workstation. The main output of the present work, namely the delay time, representing the time it takes the flow to reach the outlet as well as the time needed to recover steady state conditions, is estimated in a wide range of the operating conditions and ratios length-to-diameter of the GIS tubes. The obtained data show that the response times of the GIS are unfeasibly high and this may have a strong impact on the design of the piping of the DEMO gas injection system.

VA 1.3 Mon 10:50 H12

The Regularized 13-Moment Equations for Rarefied Gas Simulations — •Manuel Torrilhon — RWTH Aachen University

The Regularized 13-Moment-Equations (R13) are using moment approximations for the Boltzmann equation in kinetic gas theory to describe gas flows when the Knudsen number - the ratio between mean free path and observation scale - becomes significant. Classical fluid theories like the constitutive laws of Navier-Stokes and Fourier are valid only close to equilibrium and fail for processes at Knudsen numbers as low as 0.05 because there are not sufficient particle collisions within the gas to maintain equilibrium.

The derivation of the R13-equations relies on the combination of moment approximations and asymptotic expansions in kinetic gas theory. The system has been shown to be stable and of high asymptotic accuracy yet using only a relatively small set of variables, namely density, velocity, temperature, stress deviator and heat flux - in total 13 fields. It has been demonstrated to succeed on the prediction of various nonequilibrium processes like shock waves or channel flows with Knudsen layers. The system of equations also exhibits desirable mathematical features like an entropy and is easy to use in numerical simulations. An overview of the equations and their features can be found in the review in Ann. Rev. Fluid Mech. 48, (2016), 429-458.

This talk will introduce the model and discuss recent developments like the efficient implementation in finite element frameworks, polyatomic collision models, and nonlinear extensions.