boltzplatz
numerical plasma dynamics

Kinetic Simulation of a Helical-type Molecular Drag Pump

Plasma Kinetic Code PICLas STUTTGART

boltzplatz offers services around the simulation software PICLas, originally developed by the University of Stuttgart.

Direct Simulation Monte Carlo

The Direct Simulation Monte Carlo method in PICLas is suitable for rarefied gas flows and has a multitude of features:

- 1D, 2D, axisymmetric (including a radial weighting) and 3D simulations
- Mesh independence with on-the-fly octree-based mesh refinement and a nearest neighbour algorithm
- Broad range of available species from electrons to polyatomic molecules such as CO_2 and CH_4

Application areas of DSMC range from atmospheric entry and in-space propulsion to terrestrial applications such as micro-channel flows and vacuum pumps.

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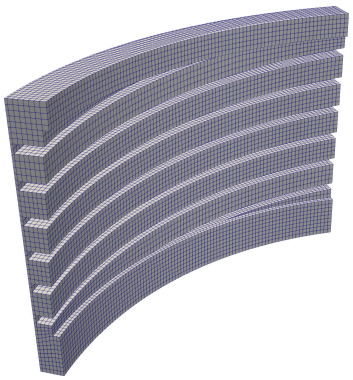
Numerical simulations of vacuum pumps can be utilized to predict the pumping performance of new concepts and optimize existing products without the need for expensive experimental campaigns and prototypes. The application case presented in the following is investigated with the Direct Simulation Monte Carlo (DSMC) method within PICLas.

Numerical setup

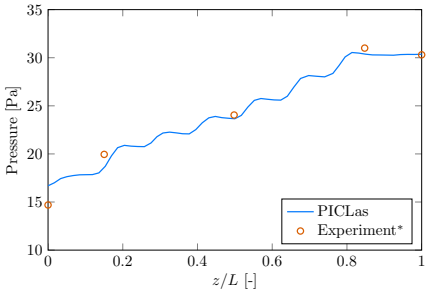


The setup is a single stage helical-type (Holweck) molecular drag pump in the transitional flow regime. The rotor has a diameter of $169\,\mathrm{mm}$ and a height of $41\,\mathrm{mm}$. The simulation domain extends $11\,\mathrm{mm}$ below (outlet) and $5\,\mathrm{mm}$ above (inlet) the rotor. The clearance to the outer stator cylinder is $0.5\,\mathrm{mm}$. The number of grooves is six, allowing to exploit rotational symmetry with a $60°$ slice. The simulation is performed in the rotational frame of reference. The test gas is diatomic nitrogen (N_2). The discretized geometry is shown on the left and further details on the experiment are provided by Kim et al. (2008). The boundary conditions are summarized below, where a fixed outlet pressure and a constant mass flow at the inlet are defined.

p_{out} [Pa]	$\dot{m}_{\mathrm{in}}$ [sccm]	T_{in} [K]	ω_{rot} [rpm]	T_{wall} [K]
30.3	66	297	24 000	293.15

Experimental measurements

The experimental measurements from the literature have been performed by Kim et al. (2008) at five different points along the outer cylinder height, where p_{out} corresponds to P_5 in the publication. The pressure measurements are compared to the simulation results, where good agreement can be observed. Thus, predictive simulations can be performed to investigate new concepts and gain detailed insights into the pumping mechanisms in the transitional flow regime. Besides a single, helical-type stage, it is possible to simulate a disk-type molecular drag pump (Siegbahn) as well as multiple stages within a turbomolecular pump.



Reference:

- Kim, D.-H., Kwon, M.-K., Hwang, Y.-K., & Abe, T. (2009). A Study on the Pumping Performance of a Helical-type Molecular Drag Pump. AIP Conference Proceedings 1141–1146. https://doi.org/10.1063/1.3076453