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Plasma exhaust and vacuum pumping on ITER & other devices

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The divertor system of a fusion device is always a compromise which has to meet power exhaust, particle exhaust and neutron shielding requirements at the same time. The design space of the tokamak particle exhaust function results from a number of requirements, such as geometrical parameters (for instance the divertor cassette configuration, and the position of the pumping port relative to the divertor), the effective pumping speed that can be provided, the intra- and inter-cassette gaps which define the recycle flow pattern of the divertor cassettes as well as from the presence of the dome which is mainly defined by neutron shielding. Hence, a feasible divertor design has to properly consider particle transport physics. Furthermore, since the neutral density in the private flux region (PFR) is expected to be high enough to justify viscous flow conditions, the corresponding gas collisionality increases and therefore a nonlinear (i.e. collisional) neutral particle transport treatment is required.

In that context, a numerical tool called DIVGAS (Divertor Gas Simulator) has been developed at Karlsruhe Institute of Technology (KIT). The DIVGAS code is based on the Direct Simulation Monte Carlo (DSMC) method. The aim of this code is to investigate and reliably describe the flow conditions in the particle exhaust of a fusion device. That said, DIVGAS takes into account all the physics and engineering aspects of plasma-wall interactions in the divertor, which influence the generation of neutral particles at the targets and consequently the overall flow behavior of the particle exhaust, including the attached vacuum system. For validation purposes, the DIVGAS code has been implemented to model the neutral gas flow in the JET sub-divertor. Moreover, DIVGAS has been applied for simulating the particle exhaust of ITER, JT60SA, AUG, EU-DEMO, DTT and recently of the stellarator W7-X.

This contribution will exemplify the main workflow which uses DIVGAS process to provide a self-consistent coupling between the sub-divertor volume and the vacuum systems. DIVGAS requires the total neutral flux (i.e fuel gas and impurities) in the PFR as input boundary condition. This information is usually provided by an edge plasma code. Additionally, the actual 2D/3D divertor geometry is introduced. The outcome of the simulation is given by the total pumped throughput, the recycle flow from the divertor to the core plasma, and the distribution of the neutral pressures in the whole sub-divertor area, which directly points to the required total pumping speed, distributed among a certain number of pumps located in the divertor pumping ports.

Based on the aforementioned workflow, this talk aims to highlight the impact of the main design drivers, illustrated by corresponding results, for various machines and divertor configurations (i.e. Single-Null, X, Super-X and liquid metal divertors) on the particle exhaust. In all cases, important design directions for achieving high pumping efficiency will be presented.

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