SOLPS-ITER simulations of the GyM linear plasma device

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1. Introduction

In the context of magnetic confinement fusion research, understanding and controlling plasma-material interaction (PMI) is a key point for the realisation of future fusion device, such as ITER. Since the conditions foreseen in ITER have never been obtained before, there is the need to study PMI in ITER-relevant regimes both numerically and experimentally. Linear plasma devices are widely adopted as material-testing facilities, being able to generate ITER-relevant plasmas in a compact and cost-effective fashion. On the numerical aspect, dedicated codes have been developed by the fusion community addressing the modelling of edge plasmas (e.g. SOLPS [1]) and plasma material interaction (e.g. ERO [2]). Edge plasma codes are widely used for the modelling of present-day tokamak devices, but are scarcely applied to linear machines. To bridge this gap, in this contribution, we show the first results concerning the application of the SOLPS-ITER [3] code to the medium-flux linear plasma device GyM [4] (figure 1). As a starting point, simplified argon plasmas were simulated, considering only one charged state (Ar^+) and the neutral atom. The atomic nature of the Ar gas offers a simplified picture to apply the code, in absence of the complexity related to molecular species. A detailed sensitivity scan on several code free parameters (such as puffing, pumping efficiency, absorbed power, etc.) is first performed. Simulations results are then compared to experimentally available data, showing a remarkably good quantitative and qualitative agreement between numerical simulations and experimental data.

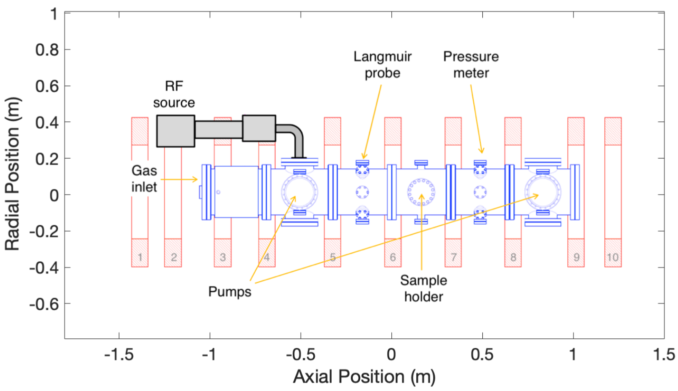

Figure 1: Schematic drawing of the linear plasma device GyM

2. Modelling of GyM

SOLPS is a suite of codes for the simulation of edge plasma transport, among which the main packages are B2.5 and EIRENE codes. B2.5 solves a set of 2D conservation equations describing the plasma as a collection of interacting fluid, flowing in the direction along the magnetic field and diffusing across the field lines. EIRENE is a Monte Carlo code solving the kinetic equation for the transport of neutral atoms, molecules and molecular ions inside the plasma.

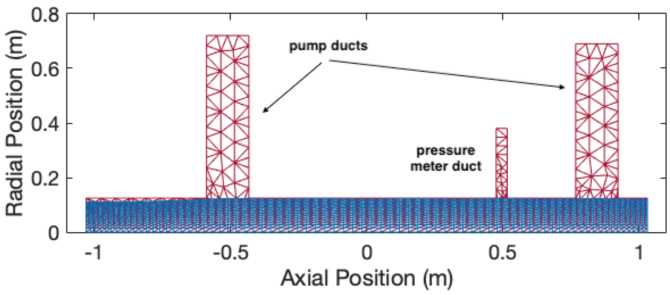

Figure 2: SOLPS-ITER computational grids. B2.5 field-aligned mesh in blue and EIRENE mesh in red.

The first input to be provided to the code are the 2D computational meshes for B2.5 and for EIRENE. The B2.5 grid is a quadrilateral grid, aligned with the magnetic field lines. It must extend from target-to-target and no intersection with e.g. lateral walls is allowed. The Eirene grid is made of triangles and can cover the whole 2D cross-section of the device. The ducts connecting the main chamber to the pumps are included in the simulation domain. An example of such two grids is shown in figure 2 for the case of GyM.

In GyM, plasma is generated and sustained exploiting resonant energy coupling between the electron cyclotron frequency and a 2.45GHz RF source. Modelling of the plasma source and heating in this contribution is done considering only ECH mechanism. Although also upper and lower hybrid resonances should be in principle considered, their dependence on the plasma density complicates the modelling, since the density distribution is not kwon a priori. For this reason they are neglected for the moment. When an EM waves at 2.45GHz in injected in a magnetised plasma the resonance conditions is satisfied one the B-field reaches 0.0875T, as shown in figure 3 for different values of the magnetic field. ECH is modelled in the code as an imposed external source in the electron energy equation. The true spatial

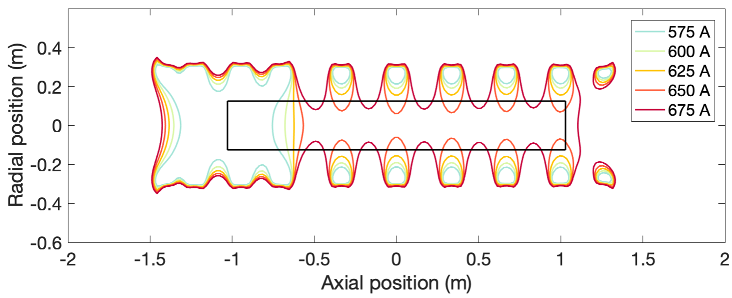

Figure 3: ECR conditions for different magnetic field strengths. The black box represents GyM vacuum chamber.

distribution of the source should be better investigated. Here it is assumed to be radially constant, with an axial gaussian shape centered at the resonance location.

4. EIRENE stand-alone simulations

The EIRENE code can also be run in the so called standalone mode: the neutral transport is computed on a fixed plasma background provided as input. These simulations have been performed to fix the pumping efficiency, which is a free code parameter. In particular, the recycling coefficient of the pumping surfaces has to be fixed. To do so, EIRENE simulations have been performed without plasma present. In figure 4 we plot the simulated Ar pressure for different values of the Ar puffing strength (measured in sccms), for a recycling coefficient of 0.99862. This was first fixed by matching the experimental pressure for a given value of the particle puff. One can see that the pressure increase linearly with the puffing strength, as can be expected. On the same figure, we show the corresponding values of the experimentally measured pressure. One can notice a good agreement between the simulated and the experimental curve, with slight deviations occurring at higher values of the particle puff.

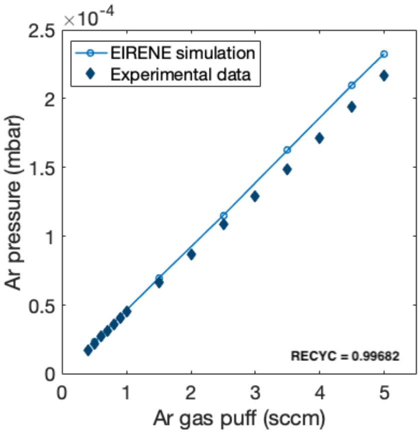

Figure 4: Comparison between ssimulated and experimental pressure as a function of gas puff.

5. B2.5-EIRENE coupled Ar simulations

An analysis of the effects of the pumping efficiency and power absorption efficiency has been performed exploiting the B2.5-EIRENE coupled mode. For a fixed absorbed power by the electrons, an increase in the pumping efficiency results in a decrease of the plasma density and an increase in the electron temperature. This can be expected, since an increased pumping efficiency leads to less neutrals in the systems. Analogously, if the pumping efficiency is fixed and only the absorbed power is increased, one notice a corresponding increase in the plasma density with only minor change (slight decrease) of the

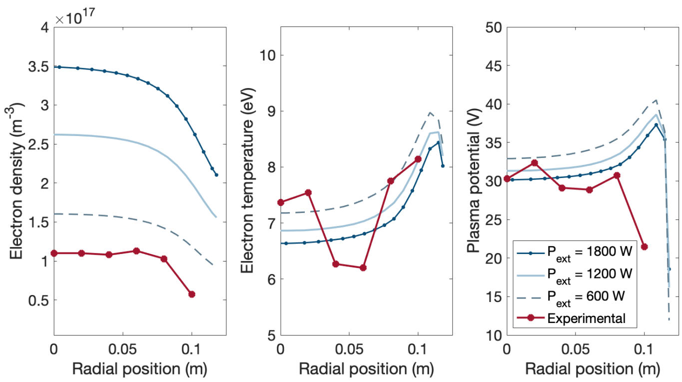

Figure 5: Comparison between radial profiles of electron density and temperature from B2.5-EIRENE simulations and experimental data.

electron temperature. Finally, using the pumping efficiency obtained through EIRENE standalone simulations by matching experimental pressure readings, we performed a B2.5-EIRENE coupled simulations trying to match simulated radial profiles of the electron density and temperature to that available experimentally. To do so, the power absorption efficiency was properly varied. From these studies, the power absorption efficiency is estimated to be around 30%. Results are shown in figure 5. A good qualitative and quantitative agreement is obtained between experimental measurements and simulated profiles, with the sole exception of the electron density where a factor of 2 difference exists.

6. Conclusions and perspectives

The SOLPS-ITER code has been successfully applied to simulate Ar plasmas in the medium-flux device GyM. Detailed sensitivity analysis of the pumping efficiency and power absorption have been performed in B2.5-EIRENE coupled mode and these free parameters have been fixed in order to match the experimental data. A good qualitative and quantitative agreement is observed for the radial profiles of electron density and temperature, with discrepancies compatible with the experimental error.

Future perspectives of this work are related to the extension of the simulations also to deuterium plasmas. Once a satisfactory agreement with the available experimental data is obtained, the code will be used for predictive simulations of the new gyrotron source (28 GHz with 15kW power). Finally, the SOLPS-ITER simulated plasma background will be used as input for the material transport code ERO2.0, to perform an integrated modelling of PMI0-related experiments in GyM.

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