Coupled SOL-core plasma simulations of the EU DEMO with a liquid metal divertor

Introduction

The EU-DEMO will need to exhaust extremely large heat fluxes, up to several tens of MW/m^2, during long pulses and in a high neutron fluence environment [1]. Current technology cannot provide solutions to reliably exhaust such important power loads and new concepts are under investigation. Among them, adopting liquid-metal (LM) plasma facing components, and in particular a Liquid Metal Divertor (LMD), is considered one of the most promising. Indeed: (i) LMs evaporate when exposed to the high plasma heat flux, so that the large latent heat becomes available to help the power exhaust; (ii) a LM surface does not undergo erosion since the surface material is continuously replaced; (iii) the LM vapor can efficiently radiate a fraction of the incoming SOL plasma power thus reducing the heat load impinging on the target via advection/conduction [2]. One of the potential showstoppers for using an LMD is the core plasma contamination associated with the presence of metal atoms. It is expected that using Li could lead to excessive plasma dilution, whereas using Sn could lead to intolerable plasma contamination.

At PoliTo, we have developed a suite of tools to numerically model liquid metal divertors. These tools have been applied both for studying a possible configuration for the Italian tokamak DTT ([3][4]) -which is going to be built in the next few years in Frascati-. We have also adapted existing complex edge plasma codes such as SOLPS-ITER for supporting the pre-conceptual design of an LMD for the longer-term EU-DEMO reactor [5]. At the moment, these tools include a model for the LM evaporating surface, the transport of the LM vapor in the SOL plasma, its interaction with the charged particles coming from the hot plasma core and its re-condensation over the actively cooled walls. Our calculations allow to estimate the flux of impurity atoms (Li/Sn) entering the core plasma, thereby giving a rough idea of the effect of the LM evaporation and transport on the core plasma performance, see Figure 1, but do not take into account in sufficient detail the core plasma region.

To obtain more quantitative information on the **effect of the impurities on the core plasma performance**, the SOL plasma models have to be coupled to core plasma codes. Promising candidates are STRAHL [6] and ASTRA [7], both developed and maintained at IPP Garching, which have been recently made available at PoliTo.

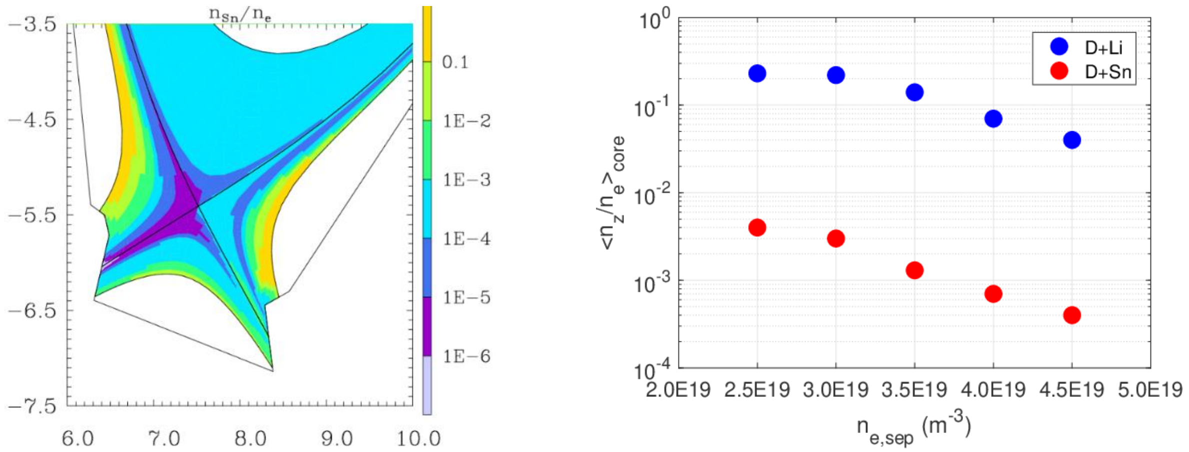

*Figure 1: **Left**: Sn concentration in the SOL and pedestal as calculated by SOLPS-ITER. **Right**: impurity concentration in the pedestal region as calculated by SOLPS-ITER.*

Aim of the work

The thesis work will start with a preparatory activity where the student will gain confidence with the core plasma physics implemented in STRAHL and ASTRA, possibly taking advantage of the availability of our contacts at IPP Garching. He will then run tutorial cases for the two codes, to become confident in using them before applying them to the case of interest for the thesis work.

The next step will consist in setting up a simulation where the impurity flux (Li or Sn) at the core boundary is fixed. This will allow to become confident with the different aspects associated to the transport of Li and Sn atoms in the core plasma.

After the successful completion of the above-mentioned steps, the student will run ASTRA simulations using as an input the SOLPS-ITER calculations, for a number of different plasma scenarios involving Li and Sn used as LMs. Based on the outcomes of these further calculations, the student will draw engineering conclusions which are relevant for two target design mentioned above.

Keywords: EU-DEMO, DTT, liquid metal divertor, power exhaust, impurities, core plasma, ASTRA

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