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PhD Public Defense

First principles study of the static arrangement of a plasma facing component in the form of a Capillary Porous System (CPS)

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Abstract

The present PhD dissertation focuses on the modelling of alternative plasma facing components (PFCs) in the form of liquid metals in order to circumvent problems generated by plasma-wall interaction, namely handling the excessive heat and electric current loads generated in the bulk of the reactor and directed towards the divertor. The free surface PFCs constitute one of the most critical technological challenges of future fusion reactors. Out of the proposed liquid metal concepts, this PhD dissertation deals with the jet/drop curtain and, primarily, the Capillary Porous System (CPS) concepts.

Regarding the jet/drop concept pertaining to the ISTTOK experiments, the simplified model developed in the context of the present study, provides a proof of principle explanation for the observed deflection from the original trajectory in a Tokamak environment. Furthermore, this PhD dissertation is an attempt, through first principles studies, to describe the major phases of the CPS operation. More specifically, it models-explains what happens during the preparation phase, that is to say before the machine is "turned on". Subsequently, it delves into the replenishment process of liquid metal, following its depletion due to a large external heat load, identifying the interplay between the different forces that act towards pushing liquid lithium out of the porous matrix or resist its motion. Finally, the current PhD dissertation studies extensively the static arrangement of the liquid metal film that rests onto the CPS outer surface, as a function of the reservoir overpressure, the substrate nature and topography, external field forces and wetting properties of the working liquid metal on the substrate.

It was thus seen for realistic reservoir overpressures, i.e. approaching vacuum conditions, that micron or even submicron coatings are established as a result of the balance between pressure and adhesive forces. In this regime, the pore size and mesh topography start playing an important role in the static arrangement. Furthermore, a threshold reservoir overpressure exists beyond which a static arrangement with the liquid metal coating the CPS is not possible. In the presence of a magnetic field and an incoming electric current the above static arrangement is modified within each pore due to the Maxwell stresses that develop, while the interface with plasma is pushed out of the pore as the magnetic pressure increases.