ENERGETICS

DTT/DENERG - 3-D modeling and simulation of plasma-wall interactions in DTT

Funded By	CONSORZIO PER L'ATTUAZIONE DEL PROGETTO DIVERTOR TOKAMAK TEST DTT S.C. A R.L. [P.iva/CF:15408721007] Dipartimento DENERG
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Context of the research activity	With nuclear fusion getting close to reactor conditions, the plasma chamber elements are getting exposed to an increasingly harsh environment. To properly design such critical components, 3D details should be considered when assessing the expected plasma-wall interactions. However, the currently most consolidated plasma modelling tools assume toroidal simmetry. This project aims at developing a relevant 3D edge-plasma simulation capacity, to help the design of nuclear fusion reactors.
	The new generation of nuclear fusion devices is being designed to bridge the gap between currently operating experiments and full power production systems. Within this context, they will face unprecedented challenging requirements including, among others, (i) exhausting power levels of tens to hundreds of MW, with available surfaces of the order of 1 m2 or less (the so-called Power Exhaust, PEX, problem); (ii) withstanding high fluence of 14 MeV neutrons onto the plasma facing components; (iii) preventing the occurrence of disruptions and implementing effective mitigation strategies. This challenging goal requires synergy among analysis of all the available experimental databases, realization of new dedicated experiments and predictive theoretical modeling of the expected reactor environment, with considerable focus on Plasma Facing Components (PFC). Several edge plasma modeling tools were developed over time. The currently most advanced one is the SOLPS-ITER code, which includes a rich (and being continuously updated) collection of detailed physical models for the plasma fuel, impurities, and neutral gas within the reactor. For historical reasons, while much emphasis is given by the code on the edge plasma region close to the core (the so-called near SOL, with typical extension a few power decay lengths ¿q), the far SOL, directly contacting the PFC along the first wall, suffer from some lack of details. Among others, while the core and near-SOL regions are, with very good approximation, toroidally symmetric (2D), the outer wall introduces 3D geometrical details, which are not within the capability of SOLPS-ITER. In recent years, the EMC3 code was developed, aiming specifically at overcoming this limitation, enabling three-dimensional studies of the plasma-wall contact region. This offers unique, so

Objectives	far, opportunities to study in detail highly critical components like, e.g., the antennas located close to the plasma for heating purposes. On the other hand, the physics features of EMC3 are currently limited with respect to SOLPS-ITER, which remains the preferred tool whenever full geometrical details can be overcome. With this project, we aim at combining both tools to study in detail plasma-wall interaction processes for the upcoming generation of fusion reactors. In this context, there are two ideal candidates for applications of the study. One of them, DEMO, is the central focus of the European fusion development strategy. The other is the Italian DTT experiment. In particular, the latter, being specifically designed to develop and test effective PEX solutions, will provide challenging and exciting environment for testing the 3D modeling capacities under development. Focusing first on DTT, we will implement a proper modeling sequence. As a first step, the SOLPS-ITER code will be employed to produce global edge plasma scenarios (establishing conditions for plasma detachment, estimating the extension of the power decay length, producing maps of radiated power from the SOL and proper transport coefficient profiles). Within the DTT geometrical structure, the capability of SOLPS-ITER to describe the edge plasma in the far SOL region will be evaluated. Building on this first phase, the EMC3 code will then be used to assess in detail the plasma behavior in the far SOL region and the proximity of sensitive first wall elements with a complex 3D structure, including antennas for radio-frequency heating and current driver, limiters, and diagnostic ports. The capabilities of EMC3 in studying local gas puff will be finally explored in connection with DTT. Local gas puff was proven in several tokamaks to play a significant role in enhancing the performance of radio-frequency antennas. Its effect has been studied with reference to ITER and is now assessed when new radiofrequency systems are designed, like for example in the case of BEST and CFETR. EMC3 is a suitable tool for this kind of analysis, being able to provide guidelines to properly locate the position of gas injection. This project will build upon the experience developed at Politecnico di Torino, where codes SOLPS-ITER and EMC3 are both available and employed. The existing expertise will help the student acquiring the necessary skills to autonomously complete the project, while the proposing group will provide continuous technical support and scientific guidance. The resulting work will produce both a detailed analysis of critical 3D wall components of a fusion experiment and a consolidated modeling framework to be possibly replicated for other machines. This project will be developed in close collaboration with the DTT SCARL organization.

Skills and competencies for the development of the activity	The successful candidate should be strongly motivated to start a scientific career in plasma physics and nuclear fusion reactor engineering. A strong scientific background in physics or engineering is mandatory, preferably including some previous exposures to areas such as plasma physics, nuclear fusion engineering, simulation and modelling techniques. Some knowledge of modeling tools like, e.g., SOLPS-ITER will be, if available, a major bonus.