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Assessing Alternative Divertor Configurations for Power Exhaust in EU-DEMO

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The realization of EU-DEMO will pose unprecedented challenges to the power exhaust system. Its plasma-facing components will have to cope with a steady-state load of about 450 MW (fusion + additional heating). It is expected that creating and controlling a proper radiating edge region will isotropically dissipate ˜ 300 MW, with the remaining 150 MW flowing in the Scrape-off Layer towards the targets. The increase in machine size with respect to ITER (RDEMO ˜ 9m, RITER ˜ 6 m) compensates only partially for the larger power to exhaust, resulting in an environment more severe than the one expected for ITER. On the top of that, requirements to keep a sufficient Tritium Breeding Ration (˜1.2) pose severe constraints on the First Wall design.
There are suggestions that operating a divertor extrapolated from the ITER design could be possible, at least in steady state. However, such predictions are not conclusive. They are sensitive to the Scrape-off Layer power decay length, which is itself a largely uncertain quantity (ranging between <1 and >10 mm, according to current models). As a backup option, EUROfusion is exploring several Alternative Divertor Configurations (ADC) including X Divertor, Super-X, Double Null and Snow-Flake configurations. On the one hand, preliminary studies showed that many ADCs have a larger acceptable operating space than the standard SN, potentially allowing for a more robust and easily controlled reactor. On the other hand, such configurations often present challenging engineering constraints, and may become worth pursuing only if sufficient advantages over standard SN can be reliably demonstrated. Such task requires considerable modeling effort.
Here we present the status of computational studies on ADCs in Europe. Much work was performed using the fluid neutral option available in the SOLPS-ITER code. This allows capturing most of the magnetic equilibrium-dependent effects (e.g., flux flaring, connection length and grazing angle). First results suggest that detachment can indeed be obtained more easily. Comparison with simple analytical models (e.g., by Lengyel) shows that radial transport plays a significant role in reducing the impurity concentration needed to obtain a sufficient radiation level, by increasing the available radiating volume. This contributes to favor configurations with large connection length. Recently, studies with kinetic modeling of neutrals were also started. Although more computationally demanding, they allow increasing the accuracy of the physical description, by (i) including a proper treatment for hydrogenic molecules, (ii) allowing for a more detailed description of the chamber wall and reflection processes, and (iii) de-coupling the ion and neutral temperatures. We also discuss the status of such modeling and highlight planned studies. Finally, recent developments in the available computational tools, including advanced fluid neutral models and extension of the fluid mesh up to the vessel wall, show potential for strong increase in the accuracy of edge plasma studies. We also discuss the development level and first applications of such advances, focusing on consequences for ADC studies.

Speaker's Affiliation

NEMO-Group, Politecnico di Torino. C.so Duca degli Abruzzi 24, 10129 Torino (ITALY)

Member State or IGO

Italy

Primary authors: JÄRVINEN, Aaro (VTT); SUBBA, Fabio (Politecnico di Torino); RUBINO, Giulio (University of Tuscia); CALABRO, Giuseppe (University of Tuscia); REIMERDES, Holger (Ecole Polytechnique Fédérale de Lausanne (EPFL), Centre de Recherches en Physique des Plasmas); AHO-MANTILA, Leena (VTT Technical Research Centre of Finland); Dr PAN, Ou (Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany); Dr CHMIELEWSKI, Piotr (Institute of Plasma Physics and Laser Microfusion ·Division of Theoretical Analysis, Poland); BREZINSEK, Sebastijan (Forschungszentrum Jülich); Dr CARLI, Stefano (KU Leuven, Department of Mechanical Engineering, Celestijnenlaan 300, 3001 Leuven, Belgium); DEKEYSER, Wouter (KU Leuven, Department of Mechanical Engineering)

Presenter: SUBBA, Fabio (Politecnico di Torino)

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