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Assessing Alternative Divertors for DEMO –strategy and first results

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The uncertainties surrounding the physics of plasma exhaust and its centrality in reactor design require a thorough evaluation of promising exhaust configurations, so EUROfusion established a project to assess alternative divertors for reactor relevant devices and DEMO in particular. An alternative here is any divertor solution that cannot be qualified by ITER and it includes, but is not limited to, Double Null, Snowflake, Super-X and X divertors.
From 2019 the project has a revised strategy and it is delivering new systematic results, presented here for the first time. It focuses on a clear and quantitative evaluation of the potential benefits that alternatives might have with respect to conventional solutions as far as exhaust performances and core compatibility are concerned. These will be weighed against their unavoidable additional engineering complexity, which might rule out some solutions. Additionally, it will drive new ideas in the form of optimized, hybrid or novel solutions, noting the deadline to complete the assessments.
The approach is to deliver integrated results through a "main loop"where physics and engineering concepts are synergistically iterated and optimized. In parallel more refined techniques and new concepts are developed that will become part of the "main loop"when (or if) they reach maturity.
The results of the first iteration of the "main loop"show that all alternatives investigated (Double Null, Super-X, X-divertor and Snowflake divertor) could be generated with only external coils while respecting engineering force constraints on the poloidal field coils and central solenoid. New detailed structural calculations of stresses in the toroidal field coils show that some configurations are subject to much larger stresses. These are mostly caused by out of plane forces, possibly needing more rigid supports, so unconventional toroidal field coil designs may still be acceptable, although not all are equally efficient. Full 3D builds, including intercoil structures and port access for remote maintenance have been produced and their technical complexities will be discussed. For each configuration, vertical stability was also taken into account. On the physics side, multi-fluid scans of core and wall fueling and seeded argon concentration were performed to assess the detachment quality at an unprecedented level by comparing each design for an identical and large range of fueling and argon fluxes. The analysis is now performed with state of the art tools (SOLPS) to enable good understanding of complex effects and prepare for full kinetic simulations. Also, the resilience of the operating point to variations is systematically examined, leading to a full map of the plasma response to changes in fueling and seeding. Hence, detachment onset, depth, stability are obtained, rather than just the operating point. Also, pumping efficiency was assessed. As preliminary conclusions, snowflake configurations appear to be challenging from a structural and remote handling point of view. The other configurations do not present showstoppers, although more complex than the baseline single null design. The Super-X configuration seems to provide more heat flux mitigation benefits, but it might complicate the power handling at the inner target, still under investigation.

Affiliation

Country or International Organization

United Kingdom

Author: Prof. MILITELLO, Fulvio (Culham Centre for Fusion Energy)

Co-authors: Dr AHO-MANTILA, Leena (VTT); Dr AMBROSINO, Roberto (Consorzio CREATE); Mr BODY, Thomas (IPP); BUFFERAND, Hugo (CEA); Prof. CALABRO, Giuseppe (University of Tuscia); CIRAOLO, GUIDO

(CEA); Dr COSTER, David (MPG-IPP); Dr DI GIRONIMO, Giuseppe (CREATE); Prof. FANELLI, Pierluigi (Universita' della Tuscia); Dr FEDORCZAK, Nicolas (CEA); HERRMANN, Albrecht (Max-Planck_Institut für Plasmaphysik, Garching, Germany); Dr INNOCENTE, Paolo (Consorzio RFX); KEMBLETON, Richard (EUROfusion, CCFE); Dr LUNT, Tilmann (MPG-IPP); Dr MARZULLO, Domenico (CREATE); Mr MERRIMAN, Sam (UKAEA); Dr MOULTON, David (CCFE); NIELSEN, Anders Henry (Technical University of Denmark, Physics Department); Dr OMOTANI, John (UKAEA); Dr RAMOGIDA, Giuseppe (ENEA); REIMERDES, Holger (Ecole Polytechnique Fédérale de Lausanne (EPFL), Centre de Recherches en Physique des Plasmas); Dr REINHART, Michael (EUROfusion); RICCI, Paolo (CRPP-EPFL); Dr RIVA, Fabio (UKAEA); STEGMEIR, Andreas (Max-Planck-Institute for Plasma Physics); Dr SUBBA, Fabio (Politecnico di Torino); SUTTROP, Wolfgang (Max-Planck-Institut für Plasmaphysik); TAMAIN, Patrick (CEA); Dr TESCHKE, Markus (MPG-IPP); Mr THRYSOE, Alexander (DTU); Dr TREUTTER, Wolfgang (MPG-IPP); VAROUTIS, Stylianos (Karlsruhe Institute of Technology (KIT)); Dr WENSING, Mirko (EPFL); Dr WISCHMEIER, Marco (MPG-IPP); Dr XIANG, Lingyan (CCFE)

Presenter: Prof. MILITELLO, Fulvio (Culham Centre for Fusion Energy)

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