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Parametric scaling of power exhaust in EU-DEMO SOLPS-ITER simulations

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Investigations of scaling of power exhaust processes in the SOLPS-ITER database for single-null, Super-X, and X-divertor configurations of the EU-DEMO are conducted and compared to predictions based on the Lengyel model [1 - 6]. A robust solution to power exhaust is one of the main challenges faced by reactor-scale fusion devices. To address the risk that a conventional divertor, as pursued in ITER, may not necessarily extrapolate to a DEMO reactor, the EUROfusion consortium has been systematically investigating alternative divertor configurations (ADCs) [1 −5, 7, 8]. This effort has produced a large database of SOLPS-ITER simulations for the EU-DEMO with various divertor configurations [3 −5, 9]. If accurate, the simple Lengyel model would provide an attractive approach to assess scrape-off layer (SOL) power exhaust and dissipation in scaling studies [10, 11]. However, many of the physical processes that are not included in the Lengyel model, such as cross-field transport, cooling due to interaction with the neutral population in the divertor, convective energy transport, or changes of flux expansion within the divertor leg, are the key features that separate ADCs from conventional configurations. Therefore, the Lengyel model is not expected to appropriately capture the key benefits of ADCs. In this study, it is observed that due to these missing physical processes, the Lengyel model overpredicts the threshold SOL impurity concentration for the onset of detachment in EU-DEMO by a factor of 5 −10 relative to SOLPS-ITER simulations. Due to the dissipation of the peak heat flux by other processes than impurity radiation, such as cross-field transport to lower heat flux regions in the divertor, the total amount of power that must be dissipated by the impurity radiation is reduced by a factor of 2 −4. Furthermore, one of the key assumptions of the Lengyel model is that heat is transported solely through electron heat conduction. Due to the strong temperature dependencies of the heat conduction and impurity cooling rates, the Lengyel model tends to predict a spatially very narrow radiative volume, limiting the total radiated power for a given impurity concentration. The SOLPS-ITER simulations indicate that the assumption of conduction dominated heat transport can be highly inaccurate in the region of divertor impurity radiation, such that the radiative volume and total dissipation for a given impurity concentration is enhanced compared to the pessimistic values predicted by the Lengyel model.

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