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Numerical investigation of 3-D plasma edge transport and heat fluxes including impurity effects in Wendelstein 7-X start-up plasmas with EMC3-Eirene

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Heat flux mitigation and power dissipation is a crucial and challenging topic in the 3-D environment of stellarator devices foreseen for steady state operation. We show that the limiter startup configuration of the first quasi-isodynamic optimized stellarator Wendelstein 7-X features a complex helical scrape-off layer topology of helical scrape-off layer flux bundles of three different magnetic target-to-target-connection length scales L_C. This enables to study the link between the scrape-off layer flux tube geometry and the eventual heat and particle deposition on target surfaces which is important for advanced stellarators as well as next generation tokamaks like ITER.

The plasma transport and the resulting limiter heat and particle loads are modeled with the fully 3-D coupled plasma fluid and kinetic neutral edge transport Monte-Carlo-Code EMC3-Eirene.

The helical 3-D topology causes plasma pressure modulated with L_C and counter streaming flows. This leads in particular at low density and high heating power scenarios (n_LCFS ˜1e18m-3, P_in=4MW) to a heterogeneous heat and particle load distribution on the limiter surfaces correlated to L_C.

Heat flux mitigation can be achieved by increasing the perpendicular transport. E.g. increasing the density at a fixed input power of Pin=4MW by an order of magnitude leads to a drop of the maximum peak heat loads P_peak=12MWm-2 by ˜24%, while the heat flux channel width, defined by the e-folding length lambda_q|| of the parallel heat flux deposited on the limiters, is increased by a factor of ˜2.

The impact of intrinsic and actively injected impurities on the limiter heat loads and radiative edge cooling performance is investigated as it is tested during the limiter operation phase as preparation for the later island divertor scenarios. It is shown that for sputtered Carbon based on a yield of 2% of the recycling flux no significant power dissipation has to be expected. Fluxes are found that lead to a power dissipation of ˜40% of the input power significantly reducing the maximum heat peak loads. Additionally seeded impurities tend to localize within the helical flux tubes. Radiative losses by Nitrogen have the advantage to contribute as a Carbon like species mainly to edge cooling while Neon is a more effective radiator, but dissipates a significant power fraction within the confinement region.

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