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Measurement and modelling of magnetic configurations to mimic overload scenarios in the W7-X stellarator

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Experiments were performed in short pulse operation (OP1.2) on the Wendelstein 7-X (W7-X) stellarator using a set of five magnetic configurations that were designed to mimic the topology and resultant divertor fluxes of a high-power long-pulse scenario that is predicted to cause component overload. These experiments demonstrated the capability of edge transport simulations to accurately predict the location and relative magnitude of wetted areas on divertor and baffle components, as well as the ability to mimic the effects of otherwise inaccessible operational conditions (toroidal current, significant beta) using the magnetic coil set. The overload scenario is predicted to occur in the actively cooled divertor operational phase (OP2) of W7-X, in configurations where the toroidal current is evolution (over ~100 s) causes the edges of the primary divertor components along the pumping gap to receive a load in excess the of the 5 MW/m2 rating. The pulse length and energy input limitations of the non-actively-cooled operational phases of W7-X prohibit direct access to the overload scenario. To validate the predictions of the heat flux patterns and magnitude, and to establish baseline measurements for comparison before two scraper element components are installed, a set of five configurations were designed to mimic the effects of finite plasma beta and toroidal current on the magnetic topology and flux patterns. The mimic configurations correspond to five values of the OP2 net toroidal current as it evolves from 0 to 43 kA, including the peak overload case of 22 kA. Measurements of the divertor heat fluxes, H-alpha emission, and neutral pressure were obtained in each configuration with 2 MW of input power and hydrogen and helium as working gasses. In the steady-state and peak overload mimic configurations, density and power scans were performed. The heat flux patterns are well described by predictions from both field-line diffusion and higher fidelity EMC3-EIRENE simulations, indicating that the approach of mimicking inaccessible OP2 configurations is successful and that rapid diffusion-type calculations are valid for approximating fluxes. These results improve confidence in the predictions for advanced operation of W7-X, and more broadly, in the ability to predict the heat flux patterns in stellarator divertors.

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