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Core-pedestal constraints on divertor design

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For reactor-scale tokamaks, the core plasma operational scenario imposes a number of boundary conditions on the divertor and SOL plasma. The most critical of these, upstream power density flowing into the divertor, and upstream separatrix electron and impurity density exert high leverage over divertor designs, and may even determine the need for advanced divertor designs to safely exhaust the power and particle flux from the core plasma. This presentation will summarize recent work to develop the physics basis for projecting these upstream boundary conditions to future DEMO scale fusion plasmas. For heat flux density flowing into the divertor for existing devices an empirical scaling of the heat flux width consistent with plasma drifts has proved valuable for predicting heat flux in existing devices. However, turbulence codes such as XGC and BOUT++ suggest that in future devices with larger ratios of size to ion gyro-radius, a/rI, higher levels of turbulent transport would increase the heat flux width and thereby relax the requirement for divertor heat flux dissipation. Edge MHD instabilities may also play a role in the level of heat flux dissipation that future divertors may face. The lower level of central fueling in DEMO-scale devices compared to edge recycling in existing devices could lead to flatter pedestal density profiles with significant consequences for divertor design. A flat pedestal density profile, such as that predicted for ITER, would allow for larger values of upstream separatrix electron density for a given core scenario density and allow for greater divertor heat flux dissipation. A flat pedestal density would also decrease the pedestal inward neoclassical pinch that causes core impurity accumulation in H-mode in existing devices. This would allow for greater low-Z impurity seeding for higher levels of divertor dissipation. Recent experimental efforts to study pedestal density transport include cross-machine scalings and variations of divertor geometry to examine the response of the pedestal density profile to changes in fueling. Complementary to the experimental studies are emerging numerical models capable of simulating plasma turbulence and transport in the steep gradient regions of the pedestal. The radial fluxes predicted by the models for measured pedestal profiles are now being compared to those inferred from experiment. Further issues and ongoing work to describe the pedestal-SOL interface will be discussed.

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