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TH/P4-18: Theory and Simulations of ELM Control with a Snowflake Divertor

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This paper is concerned with the use of a snowflake (SF) divertor for the control and mitigation of edge localized modes (ELMs). Our research is focused on the following three issues: 1) Effect of the SF geometry on neoclassical ion orbits near the separatrix, including prompt ion losses and the related control mechanism for the electric field and plasma flow in the pedestal; 2) Influence of the thereby modified flow and of high poloidal plasma beta in the divertor region on plasma turbulence and transport in the snowflake-plus geometry; 3) Reaction of the SF divertor to type-1 ELM events. Neoclassical ion orbits in the vicinity of the SF separatrix are changed due to a much weaker poloidal field near the null and much longer particle dwell-time in this area. This leads to an increase of the prompt ion loss, which then affects the radial electric field profile near the separatrix. The resulting ExB flow shear in the pedestal region affects the onset of ELMs. The electric field and velocity shear are then used as a background for two-fluid simulations of the edge plasma turbulence in a realistic geometry with the 3D BOUT code. A SF-plus geometry is chosen, so that the separatrix topology remains the same as for the standard X-point divertor, whereas the magnetic shear both inside and outside the separatrix increases dramatically. It is found that mesoscale instabilities are suppressed when the geometry is close to a perfect SF. In situations where complete suppression of ELMs is impossible, the SF divertor offers a path to reducing heat loads during ELM events to an acceptable level. Two effects, both related to the weakness of the poloidal field near the SF null, act synergistically in the same favorable direction. The first is the onset of strong, curvature-driven convection in the divertor, triggered by the increase of the poloidal pressure during the ELM and leading to the splitting of the heat flux between all four (as is the case in a SF geometry) divertor legs. The second effect is a temporal dilation of the heat pulse caused by a large connection length between the midplane and divertor plates. The net result is a more than 10-fold decrease of the divertor-surface temperature rise initiated by an ELM event. Work performed for U.S. DoE by LLNL under Contract DE-AC52-07NA27344 and LDRD project 11-ERD-058, and by PPPL under Contract DE-AC02-09CH11466.

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