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3D Effects of Edge Magnetic Field Configuration on Divertor/SOL Transport and Optimization Possibilities for a Future Reactor

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This paper overviews recent progress on the experimental identification and physics interpretation of 3D effects of magnetic field geometry/topology on divertor transport in helical devices and tokamaks with RMP. The 3D effects are elucidated as a consequence of competition between transports parallel (\parallel) and perpendicular to magnetic field, in open field lines cut by divertor plates or in magnetic islands. The competition process has strong impacts on divertor functions, density regime, impurity screening, and detachment stability. Based on experiments and numerical simulations, key parameters (indicated with [] below) governing the transport process are discussed suggesting demanding issues to be addressed for divertor optimization in future reactors.

The divertor density regime, which is known for strong up- and down-stream coupling, high-recycling regime in 2D axi-symmetric configurations, is affected by the 3D configuration. In W7-AS, LHD, TEXTOR-DED and HSX, the dependency is weakened. This is due to enhanced loss of \parallel -momentum or of \parallel -conduction energy. The dependency is functions of magnetic geometry parameters, [field line connection length], [poloidal wave length of RMP] and [Br/Bt].

Impurity screening is observed in Tore Supra, LHD, TEXTOR-DED with edge stochastization, and in W7-AS/X, TJ-II with island divertor. The enhanced outward particle flux due to [Br] provides the screening via friction force exerted on impurity. It is also found that suppression of ion thermal force, in the case of small [Br/Bt] $\sim 1.e-4$, is responsible for the screening. The systematic study in TEXTOR-DED and LHD has shown that [a thicker stochastic region] provides better screening effects.

In W7-AS and LHD, the larger [edge island width] leads to detachment stabilization. This is due to capturing of radiation with the islands and to the decoupling of edge and core plasmas in terms of core fueling of plasma/impurity. In TEXTOR-DED, [rotating RMP] fields result in density limit extension, avoiding MARFE onset. This is caused by spreading of recycling region, preventing edge cooling localization by recycling neutral/impurity.

Systematic understandings of the 3D effects of edge magnetic field based on the key parameters shown above will offer new perspectives on divertor optimization for future reactors, which are not available in 2D axi-symmetric configuration.

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