Transport Barrier and Escape Pattern Due To Ergodic Magnetic Limiters in Tokamaks with Reversed Magnetic Shear

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Ergodisation of the magnetic field

Reversed magnetic shear configurations in tokamaks reduce substantially particle transport and improve plasma confinement due to the formation of a transport barrier. Experiments show that this barrier may result from the magnetic field line reconnection and bifurcation caused by resonant magnetic fluctuations. In order to study this effect, we consider the perturbation created by an ergodic magnetic limiter on equilibria with reversed magnetic shear. This limiter generates resonant magnetic fields that interact with the equilibrium field, causing a selective destruction of the magnetic surfaces at the plasma edge. The equilibrium field with reversed magnetic shear is analytically obtained by solving the Grad-Shafranov equation in toroidal poloidal coordinates, and the limiter field is determined by supposing its action as a sequence of delta-function pulses. With this approach, the perturbed field line dynamics is described by a simplectic nontwist mapping. The island reconnection creates the dimerized islands and a field line trapping on their resonant region. This trapping produces an effect similar to that of a transport barrier and is interpreted in terms of an invariant chaotic set around this region. Thus, we analyze the influence of invariant sets, such as stable and unstable manifolds and chaotic saddles, on the formation of the chaotic layer at the plasma edge. Moreover, we study the resonant action on field lines, considering the so-called exit basins, or sets of points in the chaotic region which originate field lines hitting the wall in some specified region. This investigation shows that, for a tokamak with reversed magnetic shear, depending on the perturbed magnetic configuration, the field line escape pattern spreads over the tokamak wall or concentrates on its external equatorial region. Finally, we approximate this symplectic non-twist Poincaré maps by a map with one resonant mode (the main one induced by the ergodic limiter) to describe the dimerized magnetic islands and another map with two resonant modes (the dominant mode and its side mode due to toroidal geometry) to describe the transport barrier in the chaotic layer of field lines. These approximated maps reproduce the main transport characteristics observed in the exact map and are apt to additional analytical studies.