Anisotropic heat diffusion on stochastic magnetic fields

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The magnetic topology is a key issue in fusion plasma researches. An example is the Resonant Magnetic Perturbation (RMP) to control the transport and MHD activities. However, the physics how the RMP affects the transport and MHD is not clear. One reason is the change of the magnetic topology by the plasma response. Since the vacuum approximation cannot interpret experimental observations in many cases, the magnetic topology might be changed by the plasma response. In addition, the change of the magnetic topology is predicted by numerical simulations. However, the identification of the magnetic topology in the experiment is very difficult.

Recently, ideas to identify the magnetic topology experimentally are proposed in many experiment devices. Those are the heat pulse propagation by modulated ECH and measurements of the radial electric field. However, those techniques give only one dimensional profiles. In the peripheral region of the perturbed tokamak and stellarator, the magnetic field structure is very sophisticated because island chains are overlapped by strong magnetic shear. Thus, the heat pulse propagation and radial electric field might be distributed by two- or three-dimensionally. That means the experimental study of the magnetic topology is still very difficult.

In this study, we study numerically the anisotropic heat diffusion on the stochastic magnetic field. The anisotropic heat diffusion is given by a following equation,

$$\frac{\partial T}{\partial t} = \nabla \cdot (\kappa_{\parallel}\nabla_{\parallel}T + \kappa_{\parallel}\nabla_{\perp}T) + Q.$$

Numerically solving this equation, we can simulate the heat transport on the stochastic magnetic field. A difficulty is the time scale of the parallel and perpendicular to the magnetic field. In the realistic case, the parallel heat transport is much faster than the perpendicular transport. So, the numerical integration of the anisotropic heat diffusion equation is very difficult, because the time step of the numerical integration is defined by the parallel transport. If a ratio of $\kappa_{\parallel}$ and $\kappa_{\perp}$ is huge, the time step must be small and that is very time consuming. To resolve that problem, we are developing an implicit scheme of the time integration in fully three-dimensional geometry.

In this study, we discuss initial results from a new code to solve the anisotropic heat diffusion based on the implicit scheme. We applied the new code to a perturbed tokamak and a stellarator. The distribution of the electron temperature on the stochastic magnetic field is obtained. Hudson et al pointed out the KAM surface is a barrier to keep the finite temperature. We simulate those results in realistic magnetic field of the perturbed tokamak and stellarator.