

§20. Dependence of Radial Thermal Diffusivity on Aspect Ratio and Reentering Particles

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We show dependences of the radial thermal diffusivity χ_r on aspect ratio R_{ax}/a and reentering particles under the following conditions, where R_{ax} is the major radius of the magnetic axis and a is the minor radius of the plasma which is fixed as $a = 1$ m. 1) The unperturbed tokamak field without resonant magnetic perturbations (RMPs) is a simple tokamak field \mathbf{B}_0 . The safety factor q is $q^{-1} = 0.9 - 0.5875(r/a)^2$. 2) The RMP field is represented as $\delta\mathbf{B} = \nabla \times \{\alpha\mathbf{B}_0\}$ causing resonance with rational surfaces of $q = k/\ell = 3/2, 10/7, 11/7$, where $\alpha = \sum_{k,\ell} \alpha_{k\ell} = \sum_{k,\ell} a_{k\ell}(r(R, Z)) \cos\{k\theta(R, Z) - \ell\varphi + \varphi_{k\ell}\}$. Here, $a_{k\ell} = c_{k\ell} \exp\{-(r - r_{k\ell})^2/\Delta r^2\}$ having constants $\{c_{k\ell}\}$ that are set to $c_{k\ell} = A_{\text{RMP}} = \text{constant}$ for arbitrary k and ℓ , $r = r_{k\ell}$ is the rational surface of $q = k/\ell$, Δr is a small parameter controlling the width of the perturbation, which is set to $\Delta r/a = 5 \times 10^{-2}$, and $\varphi_{k\ell}$ is a phase and $\varphi_{k\ell} = 0$. 3) The temperature profile is fixed as $T_i = T_e = T(r) = T_{\text{ax}} - (T_{\text{ax}} - T_{\text{edge}})(r/a)$ with $T_{\text{ax}} = 1.137$ keV and $T_{\text{edge}} = 0.8T_{\text{ax}}$. The density is constant: $n = 10^{19} \text{ m}^{-3}$.

The simulation results of the dependence of χ_r on aspect ratio, R_{ax}/a , are shown in figure 1. From the dependence of $N_{\delta B} := \{\chi_r/\chi_r^{(0)}\} - 1$ on R_{ax}/a , which is illustrated with the squares and the regression line in figure 1, the radial thermal diffusivity becomes close to a value of the neoclassical diffusivity as R_{ax}/a increases. Here, $\chi_r^{(0)}$ is the neoclassical diffusivity.

There is a possibility that the particle orbit-loss at the outer edge of the perturbed region influences the radial thermal diffusivity in the perturbed region. Therefore, in order to investigate fundamental properties of the radial heat transport affected by only the RMP field, the perturbed region is assumed to be sufficiently away from the plasma edge $r/a = 1$ in the simulations shown in figure 1. On the other hand, in ordinary tokamaks, the perturbed region is contiguous with the scrape-off-layer (SOL), and thus the possibility that the particles reenter the perturbed region is reduced. Note that the simple tokamak field used in the simulations does not include the SOL.

In order to execute the preliminary to a realistic kinetic simulation treating experimental results, we investigate the effect of particle orbit-loss on the radial thermal diffusivity in the case that the particles moving across the outer edge of the ergodic region (i.e., $r/a \approx 0.75$) are not allowed to reenter the ergodic region, where the particles outside the outer edge are vanished in the simulation. After several collision times, as shown in figure 2, the radial heat transport without the reentering particles is slightly stronger at the center of the

ergodic region ($r/a \approx 0.6$) than one with the reentering particles. The contribution of the untrapped particles is reduced as compared to the results in the case that the reentering particles are allowed. This result suggests that the drift motion of the trapped particles affected by the RMP field mainly carries the energy at the center of the perturbed region, and that the ratio of the untrapped particles to the trapped particles in the distribution of the contributing particles is influenced by the boundary condition.

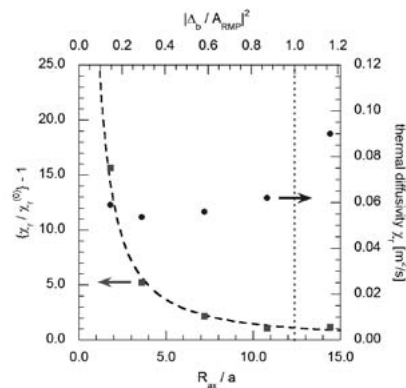


Fig. 1: Dependence of χ_r on R_{ax}/a at the center of the perturbed region, where $A_{\text{RMP}}/a = 6.0 \times 10^{-3}$ and Δ_b is the banana width. The results of $N_{\delta B}$ and χ_r are illustrated with the solid squares and circles, respectively.

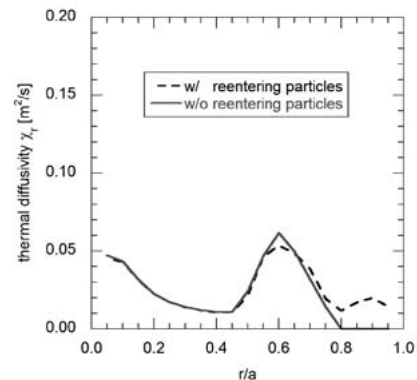


Fig. 2: Radial profile of the ion (proton) thermal diffusivity in the perturbed tokamak field, where the collisionality is $\nu_* \approx 0.04$ and $R_{\text{ax}}/a = 3.6$. In the case that the particles moving across the outer edge of the ergodic region (i.e., $r/a \approx 0.75$) are allowed to reenter the ergodic region, the result is illustrated with the dashed line. In the case that the particles moving across the outer edge of the ergodic region (i.e., $r/a \approx 0.75$) are not allowed to reenter the ergodic region, the result is illustrated with the solid line.