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トカマク周辺プラズマにおける不純物の新古典輸送のモデリング
Numerical Modeling of Impurity Neoclassical Transport in Tokamak Edge Plasmas

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1. Introduction

Understanding and control of tungsten impurity transport is one of the most important issues. Recently, we have developed a numerical scheme of impurity classical/neoclassical transport[1,2,3,4]. The numerical scheme makes it possible to reproduce not only the classical transport but also the neoclassical self-diffusion (NC SD), the neoclassical inward pinch (NC IWP), and the neoclassical temperature screening effect (NC TSE) for impurity ions. However, impurity transport has been modeled only in the case where plasmas are in the Pfirsch-Schluter (PS) regime.

The final goal is to extend our model to wider range of collisionality regimes, i.e., not only the PS regime, but also the plateau and banana regimes. In this study, we focus on the NC SD and the NC IWP. Some test calculations have been done and compared with neoclassical theory.

2. Impurity Neoclassical Transport[5]

Now consider two types of ion denoted by subscript 1 and 2. Subscript 1 and 2 correspond to the impurity ions and the background fuel ions, respectively. In the case where background ions have a radial density gradient, the collisional radial flux of impurity ions $\boldsymbol{\Gamma}_{r1}$ is given by

$$\boldsymbol{\Gamma}_{r1} = -D_1 \nabla_r N_1 + N_1 \boldsymbol{V}_{\mathrm{pinch}}, \qquad (1)$$

$$\boldsymbol{V}_{\mathrm{pinch}} \approx D_1 \frac{Z_1}{Z_2} \frac{\nabla_r N_2}{N_2}, \qquad (2)$$

where D, N, $\boldsymbol{V}_{\mathrm{pinch}}$, and Z are the diffusion coefficient, density, the IWP velocity, and charge state, respectively. The first term in Eq. (1) denotes the SD effect relaxing the density gradient of impurity ions. The second denotes the IWP effect, which is in the direction parallel to the density gradient of the background fuel ions. In neoclassical transport theory, the diffusion coefficient D depends on the collisionality parameter and has different characteristics in each collisionality regime.

3. Numerical Scheme

In this study, the trajectory of each impurity ion in the magnetic field is followed by Boris-Buneman algorithm[6]. Furthermore, to calculate the effects of Coulomb collisions, the Binary Collision Monte-Carlo Model (BCM)[7] has been used. In the BCM, after sampling the velocity and density of background ions from the given distribution function, the velocity change of test impurity ions is calculated by using random numbers.

In addition to these, so as to simulate the neoclassical transport with the BCM, velocity distribution of background ions has been modeled as a deformed Maxwellian distribution which includes the density gradient.

4. Results

By using this scheme, some test calculations with a simple torus magnetic configuration have been done. Some parameter dependence of NC SD and NC IWP have been checked. Figure 1 shows the dependence of NC IWP velocity on safety factor q in the case where impurity ions and background ions are in the plateau regime. Other simulation results will been shown in the presentation.

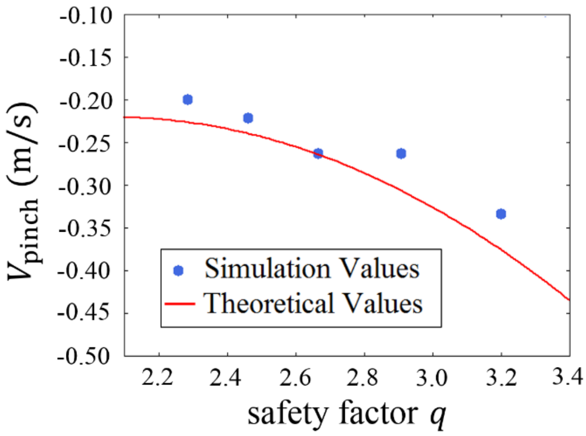

Fig. 1 Dependence of NC IWP on safety factor (in the plateau regime).

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