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Investigation of Finite Larmor Radius Effects in Ripple Resonance Diffusion of Alpha Particles

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1. Introduction

The toroidal field in an actual tokamak is neither axisymmetric nor uniform due to the finite number of toroidal field coils, creating a magnetic field ripple in between. It had been shown that the ripple will cause a loss of α-particles, whereas a confinement of fusion-produced α-particles is important to maintain the plasma. However, the loss processes remain unclear.

α-particles will mostly be produced in the core of plasma, so we can avoid the ergodic loss. Its pitch angle scattering in a one-bounce motion is also small enough to maintain banana orbits. Thus, evaluation of collisionless orbits are important for the diffusion process and will be investigated on this research. The purpose of the investigation is to open a possibility of understanding the processes of α-particles loss caused by magnetic field ripple for further research.

2. Research Method and Results

The basic thought of this research comes from the following Larmor radius equation,

$$\rho_\Omega = \frac{mv_\perp}{|q|B} \tag{1}$$

where the parameter of magnetic field B, parallel velocity $v_\parallel$, and perpendicular velocity $v_\perp$ are simultaneously affecting the guiding center and Larmor radius itself. The particle velocity (as a variable of energy function) and Larmor radius will later affect the particle diffusivity, showed by diffusion coefficient.

Fusion-produced α-particle is used as a tested particle of the calculation with energy of 3.5 MeV and pitch angle scattering of 75°. ITER-based configuration is used as the reactor parameter. Toroidal magnetic field strength B_T = 5 T and plasma current I_p = 5 MA are set initially. The collisionless banana orbit is evaluated using both guiding center and full gyro-orbit equation.

The numerical calculation has been done using Orbit-Following Monte Carlo (OFMC) simulation code. The results are shown in the figure below.

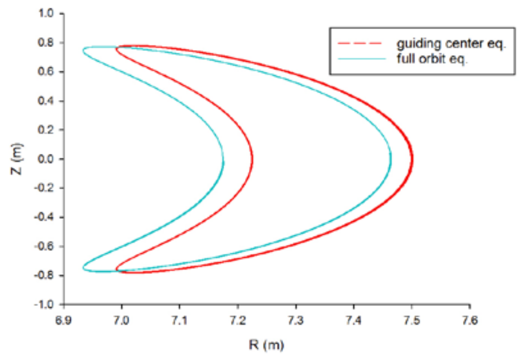

Figure 1. Banana orbit trajectory of α-particle

Figure 1 shows the existence of banana regime, where the Larmor radius and banana orbit width are affected by toroidal magnetic field and poloidal field strength respectively. The difference of both equations gives a change of the diffusion coefficient.

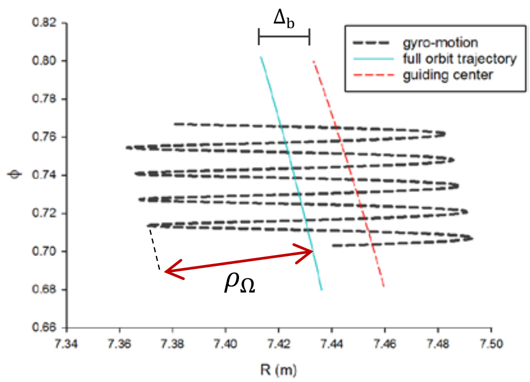

Figure 2. Extended view of α-particle trajectory

From figure 2, Larmor radius is obtained. The result is showing a sign that the Larmor radius is affecting the diffusion coefficient of the particle, which can be used to explain numerically about its effect to the ripple resonance diffusion of α-particles.