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Analytical estimation of drift-orbit island-width for passing ions in static magnetic perturbation

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The fast ion transport plays a key role in the simulation for developing operational scenarios. But the transport of fast ions in the perturbed field, such as a resonant magnetic perturbation or MHD, is complex compared with that of thermal ions. The transport depends on energy and pitch angle as well as a spatial coordinate. The Monte-Carlo approach can handle the transport in the straight forward way, however the approach is computationally expensive and is not suitable for integrated codes used for the operational scenario development. Thus, we need reduced transport models. In the model, the island structure in the phase space can be a characteristic scale of the transport and can be an important factor. Thus, a simple method to determine the width of the island structure are useful. In the previous work[1], we proposed a method to map a magnetic-field island-width onto a drift-orbit island-width for passing particles in the presence of static magnetic perturbations. We assumed the orbit perturbation is dominated by the magnetic perturbation with the same toroidal and poloidal mode number. But the method has deficits. One deficit is the assumption on the perturbation. Another deficit is a cost to calculate a Poincaré map for the magnetic perturbation though it is much smaller calculation than the Monte-Carlo approach. A smaller calculation is better for reduced models. In this paper, we present a better method to estimate the drift-orbit island-width from the velocity perturbation on a resonant canonical angular momentum surface. We have derived an expression for the drift-orbit island-width in the similar way how we estimate the magnetic island width from the magnetic perturbation on a resonant magnetic poloidal flux surface. The derived expression is an analytic form using velocity perturbation. Thus, we can avoid the issue on the difference between the magnetic perturbation and velocity perturbation. We can also eliminate the cost for the Poincaré-map calculation of the magnetic perturbation. The estimated drift orbit island widths were compared with those from Poincaré maps obtained from a drift-orbit-following calculation. The estimated island widths well correlate with those from Poincaré maps. The island overlaps are also explained by the estimated island position and its width. The estimation method can provide an indicator to evaluate an overlapping threshold for chaotic orbits in the same way with the magnetic perturbation.
[1] K. Shinohara et al., Nucl. Fusion 58 (2018) 082026

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