§ 28. The Effect of the Radial Electric Fields on the Geometric Factors for the Bootstrap Currents in Non-symmetric Magnetic Configurations

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Including self-consistent bootstrap currents in the studies of MHD equilibrium and stability becomes important also in recent design activities for advanced stellarators. These MHD calculations require the iteration of 3D equilibrium codes with analytical calculations of the currents. For this kind of MHD calculations and the comparison of the experimentally measured parallel plasma flows with the theoretical calculations, the derivation of reliable analytical formulas and the benchmark tests to clarify their validity in various magnetic configurations are required. A recently developed neoclassical transport calculation method[1] is applied to study the geometric factor for the bootstrap currents in the banana collisionality regime in non-symmetric toroidal configurations. In past studies related to the bootstrap currents using the neoclassical transport codes based on the direct calculation of the linearized drift kinetic equations or the Monte Carlo method, quantitative discussions have not yet been done since these codes used the pitch-angle-scattering (or Lorentz) collision operator [2-5]. Due to breaking the collisional momentum conservation by employing this simplified collision model, the obtained "bootstrap current coefficient" \(D_{13}\) does not give the exact current value and it has been used only for some qualitative discussions. In analytical derivations of the bootstrap currents in non-symmetric configurations based on so-called moment method in which the collisional momentum conservation is already taken into account, the magnetic configurations are characterized by two kinds of coefficients expressing the parallel viscosity effect, the parallel viscosity coefficients \(\mu_{ij}\) and the geometric factor \(G^{(BS)}\), in contrast to axisymmetric tori where only the parallel viscosity coefficients are required to the neoclassical transport calculations. Although several analytical formulas for the geometric factor have been proposed and applied to the studies of MHD equilibrium and stability [2,6-7], the benchmark tests of these formulas by using the numerical calculation codes also have not yet been done by the same reason mentioned above. Especially, the calculation of the geometric factor for the banana regime is complicated, and thus to investigate the geometric factor in the banana regime using the new method which also follows the line of the moment method[1] is an important task.

Figure 1 shows the numerically obtained mono-energetic geometric factor \(G^{(BS)}\) for case with \(\alpha_0=0.05\) in Ref.[1] as the function of the collisionality \(\nu/v\) and the radial electric field \(E_r/B_1\). The banana regime \((\nu/v<10^{-5} m^{-1})\) value for \(E_r/B_1=3 \times 10^3 T\) corresponds to the analytical formula in Ref.[2].

Fig.1 The numerically obtained mono-energetic geometric factor \(G^{(BS)}\) for case with \(\alpha_0=0.05\) in Ref.[1] as the function of the collisionality \(\nu/v\) and the radial electric field \(E_r/B_1\). The banana regime \((\nu/v<10^{-5} m^{-1})\) value for \(E_r/B_1=3 \times 10^3 T\) corresponds to the analytical formula in Ref.[2].

References