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NBI加熱および燃焼炉心プラズマにおける高速イオン平行粘性効果
Parallel Viscosity Effects of Fast Ions in NBI-heated and/or Burning Plasmas

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We previously investigated the configuration dependence of the parallel momentum input by the tangentially injected neutral beams in non-symmetric toroidal plasmas[1]. This dependence is caused by a fast ion trapping effect in which the increase of the trapped particles' fraction in the phase space (**x**,**v**) results in the decrease of the momentum transfer to the target plasma species due to the friction collisions. The total momentum input from the beam injectors is not transferred to the target plasmas, and a part of it is balanced with the parallel viscosity force $\left\langle \mathbf{B}\cdot\nabla\cdot\boldsymbol{\pi}_{\mathrm{f}}\right\rangle = -\left\langle (p_{\|\mathrm{f}}-p_{\perp\mathrm{f}})\mathbf{B}\cdot\nabla\ln B\right\rangle$ of fast ions themselves. For typical magnetic field strength modulation in stellarator/heliotron configurations, it will be a few tens percent of the total momentum input. The poloidal and toroidal variations of the pressure anisotropy $p_{\|\mathrm{f}}-p_{\perp\mathrm{f}}$ generated by this mechanism will cause also a non-ambipolar radial particle transport flux $\left\langle \boldsymbol{\Gamma}_{\mathrm{f}}^{\mathrm{bn}}\cdot\nabla s\right\rangle = -(c/e_{\mathrm{f}})\left\langle (p_{\|\mathrm{f}}-p_{\perp\mathrm{f}})\left(\nabla s\times\mathbf{B}/B^2+\widetilde{U}\mathbf{b}\right)\cdot\nabla\ln B\right\rangle$ that should be taken into account in determination of the ambipolar electrostatic potential. It is analogous to the non-diagonal coupling of the parallel forces and the radial transport that is known as the Ware pinch in the neoclassical transport of thermalized particles. Though we have already shown a calculation method for thermalized particles' radial transport caused by the momentum input by the tangential NBIs in Ref.[2], the radial transport of the NBI fast ions themselves was not yet investigated. This is one theme of this presentation.

Another parallel viscosity effect on fast ions themselves is that caused by the radial gradient of the velocity distribution function of the fusion-born fast ions (He or T) in burning plasmas. It will cause the spontaneous net parallel particle flux by the balance of the viscosity and the friction. This mechanism is analogous to the well-known bootstrap current of thermalized particles. Although a theory on this spontaneous flow had already been proposed for axisymmetric tokamaks in Refs.[3-4], the effect of non-symmetric magnetic field strength such as that in the stellarator/heliotrons or the tokamaks with the broken symmetry is not yet investigated. The extension or generalization of the theory to non-symmetric toroidal configurations is second theme of this presentation.

For both purposes (i.e., the NBI-heated and the burning plasmas), we shall apply the eigenfunction method that was generalized to general toroidal configurations in Ref.[1], and the Fourier expansion method that was previously used for the banana regime parallel viscosity of thermalized particles in Refs.[5-7].

References

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