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高ベータ簡約化MHDモデルにおける流れをもつ平衡とその安定性
Equilibria with flow in high-beta reduced MHD model and their stability

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Toroidal equilibria with both toroidal and poloidal flows and their stability are studied based on a high-beta reduced magneto-hydrodynamic (MHD) model. Reduced equilibrium equations for high-beta tokamaks in the presence of toroidal and poloidal flows comparable to the poloidal sound velocity were derived by means of asymptotic expansion with respect to the inverse aspect ratio of a torus [1]. The set of equilibrium equations include the Grad-Shafranov type equations for the first and second order magnetic fluxes, ψ_1 and ψ_2. An analytic solution of the equilibrium equations was found [2]. Its first order is identical to that of the static equilibria [3]. The solution with second order quantities shows that the magnetic structure is modified and the pressure isosurfaces depart from the magnetic flux surfaces due to the strong poloidal flow indicating transition from sub- to super-poloidal-sonic flow. To study the stability of this equilibrium solution, we derive magnetic coordinates and reduced MHD equations with time evolution. The magnetic coordinates are derived from the analytic equilibrium solution by extending those for the first order magnetic flux [4]. The modified flux coodinates (ξ,Θ) by adding second order magnetic flux are obtained numerically (Fig.1). The reduced MHD equations consistent with the equilibrium solution must include terms corresponding to third order of the magnetic energy. We have derived the reduced MHD equations by modifying those obtained in Ref. 5 to allow density variation and dynamics in the order of poloidal sound velocity. We have confirmed that the resulting reduced MHD equations conserve the energy up to third order of the magnetic energy. The reduced MHD equations are linearized based on the magnetic coordinates. In the cylindrical limit, the linearized equations include the shear Alfvén and the slow magnetosonic waves.

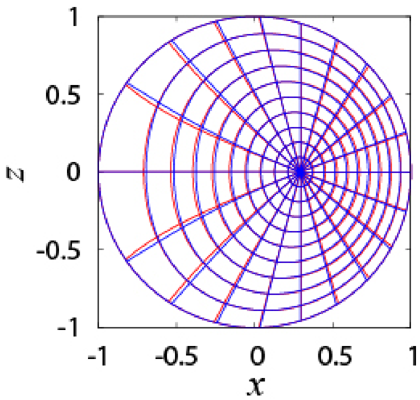

Fig. 1 Magnetic flux coordinates (ξ,Θ) for (red) ψ_1 and $\psi_1+\psi_2$ (blue).

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