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プラズマ回転を含むMHD安定性解析に基づいた高性能トカマク統合モデリング
Integrated Modeling of Advanced Tokamaks Based on MHD Stability Analysis Including Plasma Rotation

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Rotation is one of the most important physical quantities in fusion plasma dynamics; it brings about stabilization of RWMs (Resistive Wall Modes) and suppression of turbulence through radial electric field change. Hence it is important to include the rotation effects self-consistently in integrated simulations that predict tokamak plasma behavior by solving a coupled problem of 2D MHD equilibrium and 1D transport equations. In consideration of the importance of rotation, an integrated modeling code, TOPICS [1], has been extended to include a momentum transport solver to predict the profiles of rotation and radial electric field [2]. From the viewpoint of MHD theory, the rotation affects the plasma dynamics by changing the equilibrium profiles via centrifugal force and imposing non-self-adjointness on the linear dynamics. Additionally, it has been recently clarified that the equilibrium modification due to the rotation can stabilize the RWMs [3]. This fact encourages us to try to include the rotation effects self-consistently in the MHD physics parts of the integrated modeling. However, the existing integrated codes have employed the static plasma for the MHD analysis. In this research, we incorporate the plasma rotation effects self-consistently in the MHD parts of TOPICS.

Plasma rotation (for simplicity, the toroidal rotation is assumed) generalizes the Grad-Shafranov equation through the centrifugal force. The pressure, which is a flux function in the static case as $p = p(\psi)$, is affected by the centrifugal force and it depends on R explicitly as $p = p(\psi, R)$. Hence firstly, we extend the Buneman solver in TOPICS to solve the generalized Grad-Shafranov equation. In the transport simulation, the MHD equilibrium needs to be solved under the FCT (Flux Conserving Tokamak) process [4]. Hence secondly, we generalized the FCT formalism by taking the flux average of the generalized Grad-Shafranov equation, and show that the ordinary differential equation needed for FCT computation is modified. Thirdly we modified the interface between equilibrium and transport solvers. Fourthly, we replace the linear MHD code in TOPICS from static one to MINERVA/RWMaC[3], which can solve the linear MHD dynamics with plasma rotation including the equilibrium change due to the plasma toroidal rotation. By this extended TOPICS, we can conduct the integrated simulation self-consistently including the rotation physics in the MHD parts for the first time. The application to the RWM analysis with rotation in advanced JT-60 discharges will be reported.

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[4] R.A. Dory and Y.-K.M. Peng, Nucl. Fusion **17**, 21 (1977).