7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

MHD numerical analysis of global flow in 3D magnetic configurations

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The global flow can affect the global stability of fusion plasmas. In tokamaks, for example, the effects of the plasma rotation on the edge localized mode and resistive wall mode are studied extensively. Also in stellarators, it has been reported that collapse phenomena were observed in the phase of no plasma rotation in Large Helical Device (LHD) [1,2,3]. However, in the theoretical aspect, the flow has not been studied systematically. One reason is that the evaluation of the global flow is not very easy in three dimensional (3D) magnetic configurations numerically. For this point, we have established a numerical scheme to calculate the 3D profile of the global flow. We already showed the original idea of the scheme and the preliminary results of the application to the flow in the LHD plasma [4]. Also, the effects of the obtained flow on the stability against the interchange instability was examined by utilizing the HINT code [5] and the MIPS [6]. The preliminary result that the global flow has a stabilizing contribution on the instability was obtained in the early nonlinear phase.

Recently, we have improved several points in the flow calculation and in the stability analysis. In the flow calculation, the incompressibility and the surface flow are assumed in the formulation. The accuracy of the numerical achievement of the assumption is improved through the modification of the coordinate transform procedure between Hamada, VMEC, and cylindrical coordinates. As a result, the continuous streamlines of the global flow are obtained. In addition, we have removed a kind of singularity at the magnetic axis position by developing a new root-finding technique.

As the previous work on the evaluation of the 3D global flow, Kumar et al. proposed another formulation [7]. They only treated so-called Pfirsch-Schluter (PS). On the other hand, our formulation covers wider range of the flow including the PS flow. Thus, we have derived the formula corresponding to the PS component and have shown that our formulation is identical to the Kumars's one. We have also revealed that the condition assumed in the Kumar's formulation corresponds to no flow in the surface average.

In the stability analysis we have made improvement significantly. The viscosity has been made work only on the perturbed component of the flow to keep the amplitude of the global background flow in the entire time evolution. The linear growth rate of each toroidal component of the instability can be evaluated from the kinetic energy component now, which was masked by the big contribution of the global flow.

In the conference, we will discuss the numerical results obtained by utilizing the updated numerical tools shown above. In particular, we will focus on the dependence of the linear stability and the nonlinear saturation level of the instabilities on both the beta value and the flow amplitude.

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