§10. MHD Instabilities in a Current Carrying Finite Beta Heliotron Plasma with a Hollow Profile

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It is assumed that heliotron/torsatron devices can confine toroidal plasmas with zero net current for studying MHD equilibrium and stability. According to the neoclassical transport theory the bootstrap current flows even in heliotron/torsatron plasmas[1]. It is estimated that the bootstrap current becomes on the order of $100KA$ for $\beta(0) \simeq (2-3)\%$ in LHD[2]. The profile of bootstrap current has a tendency to be hollow for standard pressure profiles. Thus we study MHD instabilities in a current carrying finite beta plasma with a hollow current profile given by $J = J_0(1-\Phi)^2\Phi^2$, where Φ is a toroidal flux function. Here the pressure profile is assumed $P = P_0(1-\Phi)^2$.

When there is no net current in heliotron/torsatron plasmas, Mercier criterion describes stability behavior of interchange mode. Usually low n unstable interchange modes are obtained by numerical stability codes, when $D_I = 0.1$ line or $D_I = 0.2$ line appears for the Mercier criterion contours on $(\beta(0)-\Phi^{1/2})$ plane, where n is a toroidal mode number. Here the Mercier criterion is written as that the shear stabilization term is $-1/4$.

When the net plasma current is $50KA$ with $J = J_0(1-\Phi)^2\Phi^2$ in LHD, a new trend appears for the stability against low n MHD modes as shown in Fig. 1. For $\beta(0) \gtrsim 3\%$, $n = 2$ and $n = 3$ modes become unstable, although there is no $D_I = 0.2$ line. The unstable mode with $n = 3$ appears on the Mercier stability boundary. There results are different from the general tendency obtained for currentless plasmas. Figure 2 shows growth rates of $n = 2, 3$ and 4 modes as a function of $\beta(0)$. The Mercier criterion predicts that there appears the second stability region for $\beta(0) \gtrsim 10\%$ as shown Fig. 1. However, Fig. 2 shows strong unstable modes exist for $\beta(0) \gtrsim 10\%$ in the case of current carrying plasma with the hollow profile.

In summary, although the hollow current improves the beta limit for the interchange modes compared to the currentless case, more unstable modes exist for $\beta(0) > 3\%$ than the currentless case.

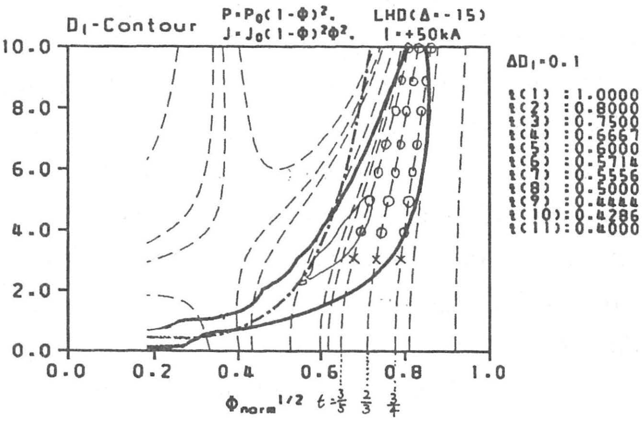

Fig. 1 Unstable MHD modes with $n = 2$ and $n = 3$ on the $(\beta(0)-\Phi^{1/2})$ plane, where n is a toroidal mode number. Mercier unstable region is also shown here.

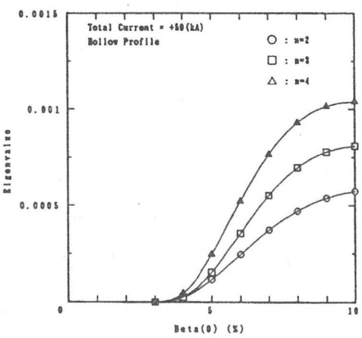

Fig. 2 Growth rate of unstable MHD modes with $n = 2, 3, 4$ for a finite beta plasma with a hollow current profile.

References

1) Shaing, K. C., and Callen, J. D., Phys. Fluids 26 (1983) 3315.

2) Watanabe, K. et al., Nucl. Fusion 35 (1995) 335.