§13. Characteristics of the Interchange Instability Focused on the Magnetic Islands in Heliotron Plasma

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The heliotron type devices are suitable for the steady operation, because such devices do not intrinsically require the toroidal current. However, the interchange instabilities are observed in the heliotron type devices. In the LHD, since there are the magnetic hill around the peripheral plasma, the resistive interchange mode can be induced even if the ideal interchange mode is stable. Since the instability degrades the plasma confinement property, it is important issue to investigate the characteristics of the resistive interchange mode.

In the LHD experiments, the magnetic fluctuations are observed in a wide β range as low frequency coherent modes by use of the magnetic probes located outside the plasma[1)]. Using the ECE measurements, the even and odd mode structures of Te with respect to the rational surface are observed [2, 3)]. The characteristics of the resistive interchange mode have been studied by evaluating the S dependence and β dependence of the growth rate and the width of the resistive layer, where S denotes the magnetic Reynolds number. However, the characteristics of the resistive interchange mode with respect to the magnetic fluctuations have not been studied. Additionally, the difference between the even and odd mode structure with respect to the rational surface has not been studied. In this study, we investigate these characteristics by introducing a new index which combines the radial displacement and the magnetic fluctuations.

The analyses are carried out by use of the reduced MHD equations. Solving these equations as the eigenvalue problem, some eigenmodes are obtained. Among them, we define the eigenmode with the largest growth rate as the first eigenmode. Similarly, the eigenmode with the second largest growth rate is defined as the second eigenmode. Figure 1 shows the first and second eigenmode structures of the poloidal flux, ψ and the stream function, ϕ. It can be seen from the mode structure of the stream function that the first eigenmode has the even mode structure with respect to the rational surface, while the second eigenmode has the odd mode structure. On the other hand, it can be seen from the mode structure of the poloidal flux that the first eigenmode has the odd mode structure with respect to the rational surface, while the second eigenmode has the even mode structure. The magnetic island width w is represented by $w = 4\sqrt{\psi_s/\iota_0'}$, where s and prime denote the position of the rational surface and the derivative with respect to the radial direction, respectively. ι_0 is the rotational transform. Since the value of the odd mode structure in the vicinity of the rational surface is close to 0, it is considered that the magnetic island of the first eigenmode is small. On the contrary, the magnetic island of the second eigenmode is larger than that of the first eigenmode because of the even mode structure. And we investigated the S dependences of the magnetic fluctuations in various β values. Since the linear analysis cannot evaluate the strength of the fluctuations quantitatively, the new index w^2/ξ_r which indicates the ratio of the poloidal flux, ψ, and the radial displacement, ξ_r is devised. Figure 2 shows the S dependencies of our new index w^2/ξ_r in the first and second eigenmode. At the low-β the indexes w^2/ξ_r of both eigenmodes are close to the $S^{-1/3}$. The second eigenmode has the larger index than the first eigenmode, which implies that if the radial displacement of the fist and second eigenmode is comparable the second eigenmode has the larger magnetic islands.

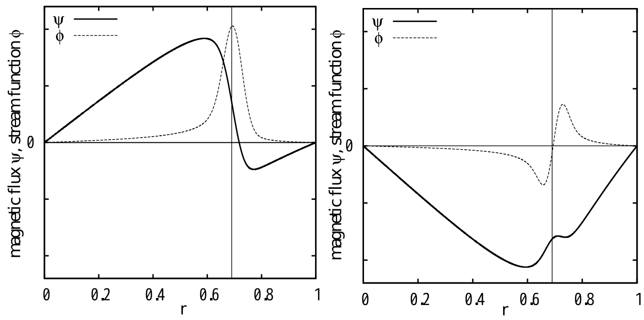

Fig. 1: Mode structures of the first (left) and second eigenmode (right). Solid and dashed lines indicate the mode structure of the magnetic flux and the stream function, respectively. The line of $r = 0.7$ is the position of the rational surface.

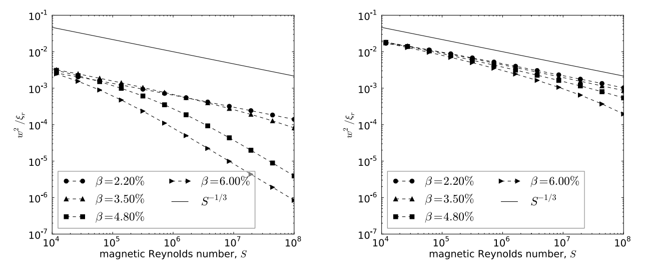

Fig. 2: Characteristic index ψ/ξ_r of the first (left) and second (right) eigenmode. Solid lines indicate $w^2/\xi_r \propto S^{-1/3}$

1) Watanabe, K. Y., Weller, A., Sakakibara, S., et al., Fusion Sci. Technol. **46**, 24 (2004).

2) Isayama, A., Inagaki, S., Watanabe, K. Y., et al., Plasma Phys. Control. Fusion **48**, L45.L55 (2006).

3) Murakami, A., Miyazawa, J., Yasui, K., et al., Plasma and Fusion Res. **6**, 1402135 (2011).