§51. Effect of Resistivity on Mode Structure of Interchange Instability in Heliotron Plasma

Ueda, R., Matsumoto, Y. (Hokkaido Univ.),
Watanabe, K.Y., Sato, M.

In the LHD experiments, the reactor relevant high β value is achieved. Since the heliotron type devices do not intrinsically require the toroidal current drive, such devices are suitable for steady operation. However, the pressure driven instabilities, such as the interchange mode, are observed in experiments. Thus, it is one of the important issues to investigate the effect of the interchange instabilities on the plasma confinement property. Moreover, the effect of a magnetic island is a meaningful issue. 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$^{1)}$. One of the causes generating such fluctuations is considered to be the magnetic island due to the interchange mode. The purpose of this study is to clarify the relationships between the magnetic islands and the mode structures of instability.

The mode structures of the radial displacement inside the plasma are observed by use of soft X-ray and ECE measurement$^{2,\ 3)}$. In such measurements, the two types of radial mode structures are observed. One type seems to be an even structure$^{2)}$ and an other seems to be the odd structure$^{3)}$ with respect to the rational surface. Based on the assumption that the pressure profile is flattened in the magnetic island, in the case of the even structures, it is considered that the large magnetic islands are not formed. On the other hand, in the case of the odd structures, it is considered that the large magnetic islands are easy to be formed. However, in the previous numerical linear researches, it is not well known whether the interchange mode have an odd mode structure.

In this study, as a first step, we analyze the mode structure of instability by use of the reduced MHD equations. By use of the linearization and expansion to Fourier series, the reduced MHD equations are solved as an eigenvalue problem. In many previous linear researches, the first eigenmode with the largest growth rate is mainly studied. However, we analyze also the second eigenmode which has the second largest growth rate. As a result, we found that the second eigenmode structure is different to that of the first eigenmode. Figure 1 shows the first (left) and second (right) eigenmode structure. In this calculation, the β is 2% and the magnetic Reynolds number is $S = 10^4$. The LHD-like magnetic hill and rotational transform are given. Then, the Suydam limit are $\beta = 2.3\%$. The dashed lines indicate the mode structure of the stream function, which correspond to the mode structure of the radial displacement topologically. The first eigenmode have the even structure with respect to the rational surface. On the other hand, the second eigenmode is the odd structure. These results suggest the possibility that has the clear magnetic island structure in the interchange mode even in the linear growing phase. It is noted that though the growth rate of the second eigenmode is smaller than that of the first eigenmode, we found the difference of these growth rate is not significant for the resistive modes. Figure 2 shows the growth rate γ as a function of the S. It can be seen that the both eigenmode are close to the resistive g mode theory$^{4)}$ $\gamma \propto S^{-1/3}$ in low β. In the next stage of this study, the relationships between the magnetic island structure and the mode structure will be investigated.

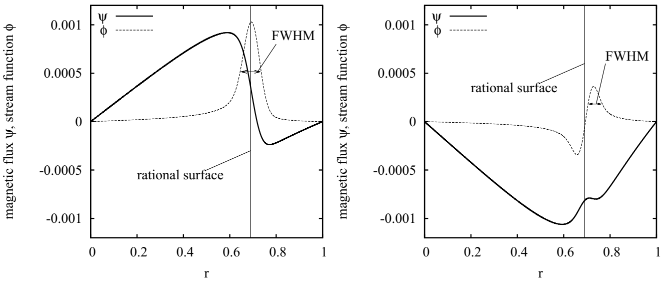

Fig. 1: Mode structure of the first (left) and second eigenmode (right). Solid and dashed lines indicate the mode structure of the magnetic flux and the stream function, respectively.

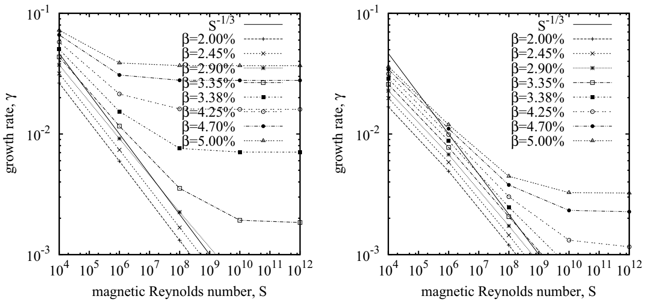

Fig. 2: Growth rate of the first (left) and second (right) eigenmode. Solid lines indicate $\gamma \propto S^{-1/3}$

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).

4) Coppi, B., Green, J. M., Johnson, J. L., Nuclear Fusion, **6**, 101 (1966).