§19. Comparative Study of MHD Instabilities in LHD and JT-60U – Instability at $\iota \sim 0.5$ during Counter-NB –


i) Introduction
It is generally recognized that in helical systems Mercier stability increases with increasing plasma current in counter direction. However, an instability localized at $\iota/2\pi \sim 0.5$ has been observed in LHD experiments with standard configuration ($B=2.75 \, T$, $R=3.60 \, m$, $\gamma=1.25$, $B_0=100\%$). This research aims to clarify the characteristics of this instability and to compare with similar instabilities in tokamaks.

ii) Experiments
In the previous campaign, characteristics of the instability was investigated at $B=2.75 \, T$ alone, where it was not clear whether the onset of the instability depends on $I_p$ or $I_p/B(-t)$. In this campaign, experiments were performed at $B=1.32 \, T$ to discriminate between the $I_p$ dependence and the $I_p/B$ dependence. In the experiment, the instability was measured with magnetic probes and electron cyclotron emission (ECE) diagnostics. In addition, Mercier stability of an experimental result has been investigated using a computational code.

iii) Results
In this campaign, the following results has been obtained:
- When the direction of NB was switched from counter-direction (counter-NB) to co-direction (co-NB), no instability was observed even with large negative $I_p/B$ value. On the other hand, in the case of counter-NB after co-NB, the instability was observed shortly after the switch of the NB direction.
- Spatial structure and temporal evolution of the instability at $B=1.32 \, T$ have been successfully measured with the ECE heterodyne radiometer. It was found that the instability is localized at $\iota/2\pi \sim 0.5$, and its frequency is 1 to 2 kHz, as shown in Fig. 1. These are the same characteristics as those at $B=2.75 \, T$.
- The instability can be classified into the following three types: (a) sinusoidal oscillations, (b) sawtooth oscillations, (c) mixture of the sinusoidal and the sawtooth oscillations. The sinusoidal oscillations were observed at higher density ($n_e > 0.8 \times 10^{19} \, m^{-3}$) region, while the mixture oscillations were observed in low density ($n_e < 0.6 \times 10^{19} \, m^{-3}$) region.
- Stability analysis using experimentally obtained pressure profile and equilibrium shows that plasma becomes more stable when plasma current is increased in counter direction, as considered generally.

iv) Discussion and summary
It is found that temporal evolution and spatial structure of the instability for $B=1.32 \, T$ shows the same characteristics as that at $B=2.75 \, T$. As for the onset condition, however, no clear tendency was found, while the dependence of $I_p$ was clearly observed for $B=2.75 \, T$. This result suggests that some parameters other than $I_p/B$ contribute to the mode onset.

Results from the NB switch-over experiments suggest that NB injection pattern and resulting change in current and pressure profiles destabilize the instability.

![Fig. 1: (a) Plasma current, (b) spectrum of electron temperature perturbation at $\rho=0.506$, (c) contour plot of the electron temperature perturbation, (d) rotational transform profile.](image)

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