§4. Magnetic Fluctuation in High Density Plasma with Flow in the HYPER-I Device

Tsushima, A. (Yokohama Nat. Univ.)
Yoshimura, S., Tanaka, M.Y.

In high density operations of the HYPER-I devices, we have observed narrow current channels in a flowing plasma. These current channels accompaneied by magnetic fluctuations in the annular region at r ~ 30 mm in a plasma with the radius of 150 mm. The typical plasma density for the existence of curent channels is $n \sim 5 \times 10^{18}\ m^{-3}$ under the argon gas pressure p ~ 0.1 Pa. The plasma is produced and sustained by electron cyclotron resonance heating with an electron cyclotron wave (ECW) of frequency 2.45GHz [1]. A klystron amplifier with 80 kW output (CW) is used for the high-density, high-power experiments. The axial size of HYPER-I plasma is 200 cm.

Figure 1 shows the perpendicular component of the magnetic fluctuation measured by a 100-turn picup coil with 3 mm diameter. In each magnetic pulse, there are several wave crests, and the excitaion of this magnetic pulse occurs intermittently. The typycal duration of magnetic pulse is about ~100 μs, and the main Fourier component has a frequency of 100 kHz.

Since the narrow current channel observed in this experiment accompanies magnetic pulsation, it may be worthwhile to consider the relation between the current channel and instability of magnetohydrodynamic wave. With some simplifications, we can derive the following dispersion relation for MHD waves[2]:

$$(\omega - k_{\parallel} v_0)^2 = k_{\parallel} (2 k_{\parallel} - D) v_A^2 \quad \text{for} \quad m > 0 \qquad (1)$$

$$(\omega - k_{\parallel} v_0)^2 = k_{\parallel} (2 k_{\parallel} + D) v_A^2 \quad \text{for} \quad m < 0 \qquad (2)$$

In this calculation, the perturbed field quantity is assumed to be

$$\exp[\, i (k_z z + m \theta - \omega_r t) + \omega_i t \,] \qquad (3)$$

with $\omega = \omega_r + i\,\omega_i$ is the angular frequency of the fluctuation ($\omega_i > 0$ for instability), k_z is the axial component of wavenumber, m is the azimuthal mode number, v_0 is the flow velocity of plasma parallel to the magnetic field. The quantity D is defined by $D = \mu_0 J_0 / B_0$ (J_0: current density, B_0: magnetic field strength) and $k_{\parallel} = k_z + m\, D/2$. The maximum growth rate is achieved at $k_{\parallel}^{(max)} = D/4$ for $m > 0$ and $k_{\parallel}^{(max)} = -D/4$ for $m < 0$. The real frequency and the flow velocity is related to

$$\omega_0 = k_{\parallel} v_0$$

for both the signs of azimuthal mode number m .

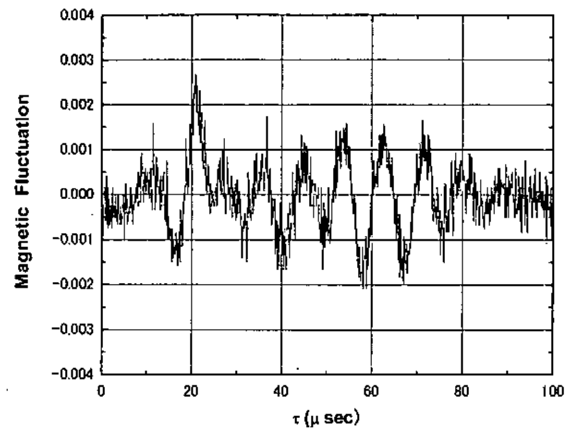

Fig.1 Azimuthal component of magnetic fluctuation measured at r=30 mm.

Then we can estimate the current density $J_0 \sim 2 \times 10^5$ A/m^2 and the flow velocity $v_0 \sim 2 \times 10^5$ m/s, which corresponds to Alfven Mach number $M_A \sim 0.5$, by assuming $k_{\parallel}^{(max)} \sim 3\ m^{-1}$. To determine the wavenumber, it is needed to measure the phase difference of magnetic pulsations between two points. The multipoint measurements of excited fluctuations and the identification of excited mode are left for future studies.

It is worth pointing out that MHD activities are rarely observed in cylindrical laboratory plasmas, since they usually have low densities and low temperatures. The characteristic features of HYPER-I plasma are low field intensity (1kG) and high density $1 \times 10^{19} cm^{-3}$. Then the β-value is 0.4%, showing an exceptionally high value. This may be the reason why MHD activities are frequently observed in the HYPER-I plasma.

Reference

1) Tanaka M, *et al*, Journal of the Physical Society of Japan **60**, 1600 (1991).
2) Tsushima A., Kobayashi M., Hishida T., Amagishi Y., Journal of the Physical Society of Japan **72**, (2003) 2229