§13. Core Localized TAE Observed in CHS

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Toroidal Alfven eigenmodes (TAEs) of low toroidal mode number, n=1 and 2, are observed in neutral-beam-heated plasmas in the Compact Helical System heliotron/torsatron. CHS is a helical system with moderate or high magnetic shear, comparable to that in a tokamak but with negative sign (where q is the safety factor and the radial derivative q'<0). In CHS plasmas, the TAE frequency, estimated from the formula $f_{TAE}=V_A/(4\pi Rq)$ where V_A is the Alfven velocity, increases rapidly towards the plasma edge because q decreases towards the edge—just the opposite to the tokamak configuration. As a result, the frequency of a TAE in the plasma core usually intersects the Alfven continua in the plasma edge region where the magnetic shear is high, which can cause the corresponding TAE to be stabilized due to strong continuum damping. However, if the magnetic shear in the plasma core is appreciably reduced by net plasma current I_p or finite plasma pressure, TAEs localized in the plasma core may be more unstable.

In CHS, a hydrogen beam was tangentially injected into a hydrogen plasma in the direction that the current induced by NBI increases the central rotational transform, i.e. co-injection. The injection energy of the hydrogen beam E_b was varied from 28 keV to 40 keV. We have investigated TAE activity by varying I_p. Figure 1 shows dependence of the net plasma current on the toroidal magnetic field when the TAEs are detected. The required lower bound of I_p increases as B_t increases. The required I_p in an inward shifted plasma (R_{ax}=0.92m) is larger than that in the so-called standard configuration (R_{ax}=0.95m). This tendency is interpreted as that the rotational transform in the plasma center region of the inner shifted plasma (R_{ax}=0.92m) is smaller than that of the plasma at standard position (R_{ax}=0.95m). The upper bound of I_p is determined by elimination of the relevant TAE gap. These results suggest that low magnetic shear created in the core plasma in this way facilitates the excitation of TAEs in CHS.

The internal structure of TAEs was measured with the SX array. However, the soft X-ray fluctuation level for TAEs is too low to obtain the radial profile of the fluctuation intensity because of the relatively low electron temperature ($T_{e0} \leq 0.3$ keV). For this reason, the coherence γ between the soft X-ray signal of each channel and the magnetic probe signal was calculated in the TAE frequency range. Figure 2 (a) shows the radial profiles of γ for the n=1 and n=2 TAEs observed in the plasma with R_{ax} = 0.95 m. This figure suggests that the high γ region is localized within $\rho \approx 0.6$, where $\gamma \approx 0.3$ for noise. Note that the high γ observed around the plasma center is caused by the integral effect of soft X-ray emission along the line of sight. Therefore, the TAEs are estimated to be localized around $\rho \approx 0.2$-0.6. TAEs with n = 1 are observed also in inward shifted plasmas with R_{ax} = 0.92 m, where heavy ion beam probe (HIBP) data are available. Figure 2 (b) shows the radial profile of the plasma potential fluctuations and of γ, where the potential fluctuations are normalized to the TAE magnetic fluctuations b_θ in respective shots because HIBP data are obtained shot by shot. This figure clearly shows mode localization at $\rho \approx 0.2$–0.6. These results are consistent with the calculated TAE gap structure. The observed TAEs exhibit ballooning nature, as can be seen in Fig.2.

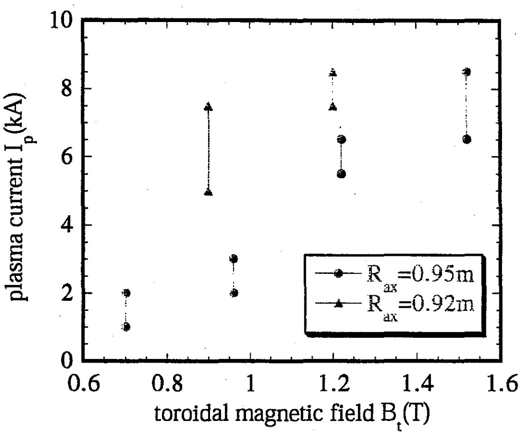

Fig. 1 Dependence of the net plasma current on the toroidal magnetic field when the TAEs are detected .

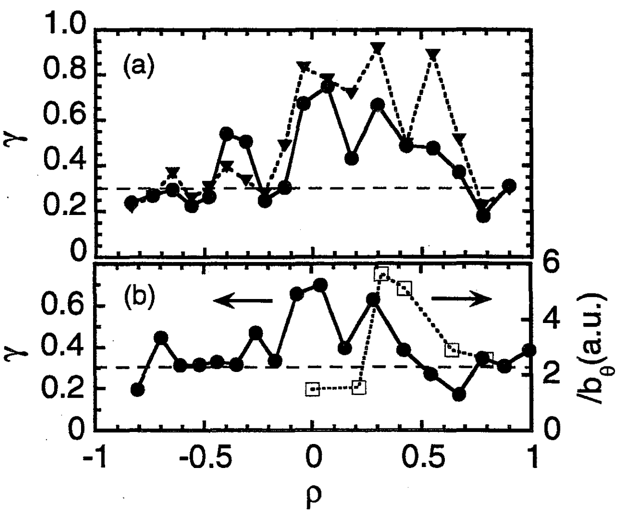

Fig. 2. (a) Radial profiles for the coherence γ between the soft X-ray signal of each channel and the magnetic probe signal, for the modes with n=1 (solid circles) and n=2 (solid triangles). (b) Radial profiles of γ (solid circles) and the potential fluctuations measured by HIBP (open squares) in the plasma with R_{ax} = 0.92 m.