§14. Comparison of Observed TAE Frequency with the TAE Gap Structure in CHS

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Toroidal Alfven eigenmodes (TAEs) are observed in neutral-beam-heated plasmas in the Compact Helical System heliotron/torsatron. Calculation of the TAE gap structure in the three-dimensional configuration such as CHS is fairly complicated and at present is not available for our experiments.

A simple calculation of the shear Alfven continua in a cylindrical configuration is here employed to predict the frequency range and radial location of the TAE gap. The TAE gap structure is calculated by a simple dispersion relation for a large-aspect-ratio tokamak equilibrium. Here, the expression for the TAE (full) gap width includes the effect of helical field ripple as $2\Delta f \approx 2(\varepsilon_t + \varepsilon_h + \Delta')f_{TAE}$, where ε_h is the helical ripple, ε_t is the toroidal ripple ($\approx \langle r\rangle/R$), and Δ' is the radial derivative of the Shafranov shift. Note that in the region of $\rho \leq 0.7$ (ρ: the normalized minor radius to the plasma radius), the width $2\Delta f$ is dominantly determined by the term of ($\varepsilon_t + \Delta'$). The q-profile is derived from the sum of the rotational transform (1/q) due to I_p and the external rotational transform in a three-dimensional current-free equilibrium with an average total beta of 0.2%, where the current density profile is assumed to be the shape $j_\varphi = j_0(1-\rho^2)^\lambda$. The peaking parameter λ was chosen in the plausible range $1 \leq \lambda \leq 2$. Figure 1(a) shows a typical example of the uncoupled shear Alfven spectra(dotted curve) and TAE gaps calculated by the above-mentioned simple equation (thick curve) for the n=1 mode, where the measured n_e profile (broken curve) and the calculated 1/q-profile (solid curve) shown in Fig.1(c) were employed and λ=1.5 was assumed. The Alfven continua are labeled by the respective m. Moreover, the plasma mass density was enhanced by a factor of 1.4 in order to simulate the presence of impurity ions. As shown in Fig.1(a), the observed frequency (horizontal broken line) of n=1 mode lie near the lower bound of the innermost TAE gap. The similar feature was also found for the n=2 mode, as shown in Fig.1(b).

Three-dimensional configuration has another important effect, namely, toroidal mode coupling . In this case the n-mode family which consists of many harmonics with the different toroidal mode number n'=±(n-Nk) takes the place of mode coupling and generates densely packed TAE gaps, where the toroidal field period number N=8 in CHS and k=0, ±1, ±2, ... This leads to formation of the envelope of the TAE gaps calculated in the axisymmetric configuration (Fig.2). Although thus modified Alfven spectrum might bring about appreciable continuum damping, the TAE gap structure shown in Fig.1 is still useful to predict the possible frequency and radial extent of TAEs. Detailed numerical calculation in the three-dimensional configuration is required to estimate enhancement of continuum damping due to the spectrum modification and is left for a future study.

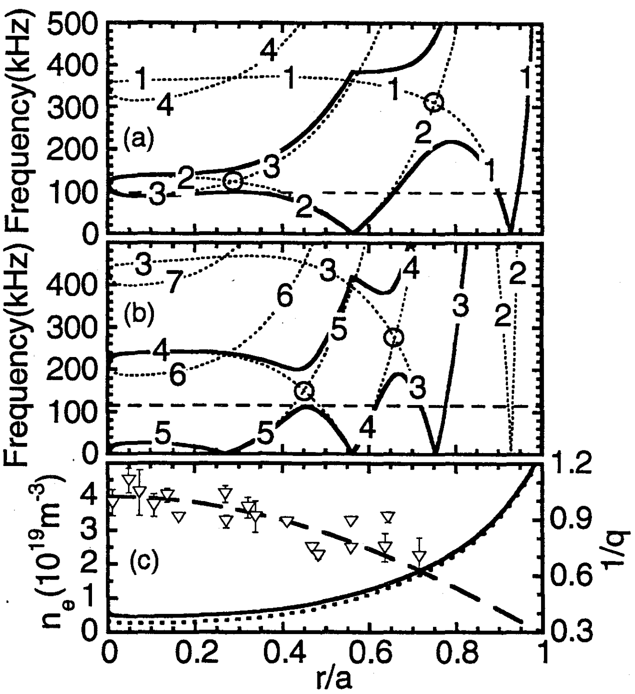

Fig. 1. (a) TAE gap structure for the n=1. (b) For the n=2 mode. (c) The radial profiles for the measured electron density and the calculated rotational transform 1/q (solid curve). The horizontal broken lines in Fig.1(a) and(b) indicate the observed TAE frequency.

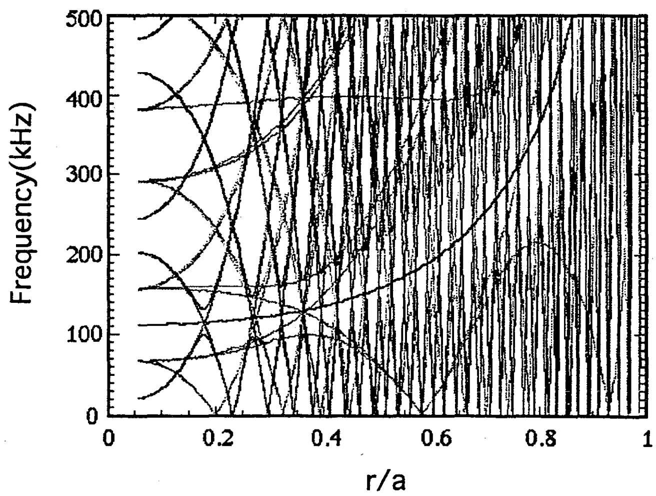

Fig. 2 The n=1 TAE gap structure calculated by including n=9 and n=17 modes, which is introduced to show the effect of toroidal mode coupling.