§8. Kinetic Ballooning Modes and Their Correspondence to Ideal MHD Modes in an LHD Plasma

Yamagishi, O., Nakamura, Y. (Kyoto Univ.), Sugama, H., Watanabe, T.-H., Nakajima, N.

The ballooning-like shear-Alfven modes can destroy the confined plasma so that it is important to investigate their stability properties. The most applications have been based on the MHD formulation. However, there exist important effects not to be included in the MHD. For example, the MHD modes become more and more unstable as the wave number (toroidal number) becomes high, while the ion FLR effect can stabilize the modes with the high mode number. Thus we investigate the ballooning-like modes based on the linear gyrokinetic formalism [I] in this report.

Here an LHD equilibrium with $R=3.75\text{m}$ is considered as a model. The temperature and the density are assumed as $T/T(0)=1-0.7s$ and $n/n(0)=1-18$ where $s$ is normalized toroidal flux. Then the pressure $p/p(0)=2nT/[n(0)T(0)]$ is used as an input for VMEC code. The net current free is also assumed. The 8.0% of beta value at the axis is assumed. It is noted that the finite value of $T$ at the edge of nested surface is assumed above, which seems to be possible in the LHD plasmas with chaotic field line region around the nested surfaces [2].

In Fig.1, we show the $k_e\rho_{th}$ dependence of KBM frequencies at a surface ($\rho=0.85$). It can be seen that the ion FLR effects reduce the KBM growth rate at higher $k_e\rho_{th}$. The growth rate level of KBMs is smaller than that of ideal MHD modes. In this figure, two cases with or without the perpendicular vector potential $A_L$ are shown and its difference is found to be small at this beta. The radial dependence of the KBM frequencies is shown in Fig.2. Here $k_e\rho_{th}=0.4$ is fixed which gives a nearly peak of growth rate in Fig.1, and only $A_L$ is considered. A strong correlation between the ideal MHD and KBM modes can be seen so that the MHD can capture the shear-Alfven instabilities well, although the KBM growth rate is smaller than the ideal one due to the kinetic effects.

From above, we can expect that if the ideal MHD modes are marginal, the KBMs will be also marginal. Thus we try to find the critical pressure profile for which the MHD modes are stabilized. The procedures to do are as follows: (i) the pressure gradient is changed artificially in order to stabilize the ideal MHD modes, (ii) since the artificial change of $p'$ throw out the MHD force balance, the MHD equilibrium is re-calculated with the new pressure profile obtained by integrating above stabilizing $p'$, and (iii) some iterations give a pressure profile for almost marginal stability. The results are shown in Fig.3. Initially the strong pressure gradient destabilizes the MHD modes, and after iterations, the finite pressure at the edge reduce $p'$ and we can find the marginally stable MHD modes.

It is noted that this stabilization was possible only when both $T$ and $n$ are assumed finite at the edge, which seems possible in the LHD experiments [2]. It is also pointed out that the above procedure would yield a stiff pressure profile that is determined by the critical $p'$ for the linear MHD instabilities. In the tokamak cases, this type of consideration can be utilized only for the drift waves, because the MHD-like KBMs are considered to destroy the plasmas. In the helical cases in contrast, the plasmas seem to be maintained when the beta exceeds its critical value, by virtue of the external magnetic field by the helical coils.

Reference