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§46. Beam Pressure Effect on MHD Equilibrium and Stability in LHD

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In LHD experiments, the high beta plasma with the low density has been produced in the low magnetic field ($B_{\rm ax} \simeq 0.5$ T).[1] It is pointed out that the proportion of the beam pressure to the total plasma pressure is large in such plasmas. The precise identification of the beam pressure is one of the most important subjects on the equilibrium and stability studies in the high beta helical plasmas. The method to identify the beam pressure with accuracy, however, has been unestablished. Consequently, the purposes of the present study are to establish the high accuracy identification method of the beam pressure and to investigate the effects which the beam pressure has on the equilibrium and stability. For those purpose, we have investigated i) the high energy particle orbit in the high beta LHD plasmas and ii) the linear and non-linear resistive MHD instability modes.

The behavior of the high energy particles in the high beta LHD plasma are numerically analyzed with the use of the real coordinate system. Especially, the re-entering particles,[2] which repeatedly go out of and get into the core plasma region, are focused and the effects of these particles to the high beta plasma confinement are investigated. Particles are traced in the 3 magnetic field configurations (case 1: $B_{\rm ax} = 3$ T, $\langle\beta\rangle = 0.0$ %, case 2: $B_{\rm ax} = 3$ T, $\langle\beta\rangle = 3.2$ % and case 3: $B_{\rm ax} = 0.5$ T, $\langle\beta\rangle = 3.2$ %). The 100 keV protons are traced for a period of 30 ms by numerically solving the guiding-center equation. The particle loss boundary is set at the vacuum vessel wall. The starting points of particles are located at R axis on the horizontally elongated poloidal plane. The initial pitch angels are varied from 0 to π with a step size of $\pi/20$. According to the results, it is found that the particle orbit characteristics are largely-unaltered even if the plasma beta rises. It is also found that the large number of the prompt loss particles exist in the $B_{\rm ax} = 0.5$ T, $\langle\beta\rangle = 3.2$ % case and that such prompt loss particles are promptly lost due to the drift arising from the grad B in the poloidal direction. In addition, it is shown that the number of the re-entering particles increases with increasing the plasma beta. These results are summerized in the paper[3].

With the use of the FAR3D code,[4] we analyze the linear resistive MHD instability modes in LHD. Especially the low n resistive instability modes for the typical LHD high beta plasmas are analyzed with the effect of the toriodal and helical couplings included. It is found that the primary unstable modes are $m/n = 1/1$, $3/2$, $4/3$. The rational surfaces of these modes exist in the plasma periphery ($\rho > 0.6$). It is confirmed that both γ and W obey the theoretical formula of the gravitational interchange mode($\propto S^{-1/3}$) independent of n. Their dependencies on S become small when $\langle\beta\rangle$ and/or S are high. The range of S, in which γ and/or W are proportional to $S^{-1/3}$, becomes narrow as n decreasing. When $\langle\beta\rangle = $ const., γ is proportional to W. The slope becomes steep with $\langle\beta\rangle$ increasing. These results are summerized in the paper[5]. We also have analyzed the non-linear evolution of a single-helicity mode (cylinder). As shown in Fig. 1, the non-linear evolution for the cylinder case leads to saturation with bursting activity. The pressure profile flattening around the sungular surface is obtained.

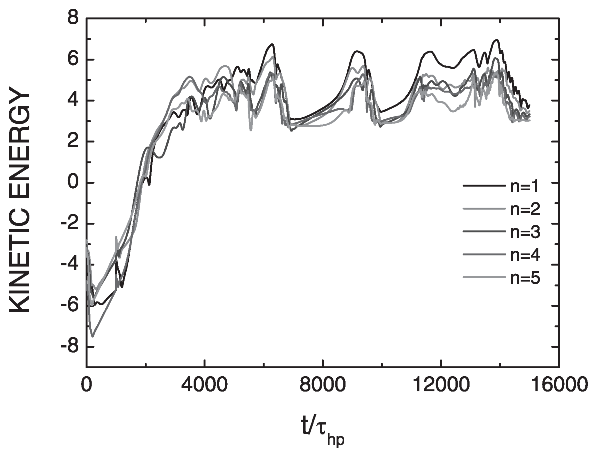

Figure 1: Non-linear evolution of the kinetic energy for the single-helicity mode(cylinder).

We will calculate the beam pressure using the Monte-Carlo simulation based on the particle orbit analysis. Additionally, the linear and non-linear instability modes for the LHD plasmas will have been computated.

1) Watanabe, K., *et al.*, 2004 EX3-3 20th Fusion Energy (Vilamoura, 2004).

2) Hanatani, K. and Penningsfeld, F., Nucl. Fusion **32**, 1769 (1992).

3) Seki, R., *et al.*, J. Plasma Fusion Res. **3**, 016 (2008).

4) Garcia, L., *Proc. 25th EPS Conf. on Controlled Fusion and Plasma Physics* (Prague, 1998), VOL. 22A, PartII, p. 1757.

5) Matsumoto, Y., *et al.*, *Proc. ITC/ISHW2007* (Toki, 2007).