§15. Core Density Collapse and High-n Ballooning Modes

Ohdachi, S.

Core density collapse (CDC) is a large-scale relaxation event observed in internal diffusion barrier (IDB) plasmas. The increase of the central beta is limited by the CDC; the central beta is decreased up to 50%. In order to extend operational regime, understanding of the CDC is required. Steep pressure gradient with peaked profile of IDB plasma is a candidate for the events. However, the greater part of the plasma including the steep gradient region is within the magnetic well due to the large Shafranov-shift. CDC thus cannot be explained by the interchange mode by the pressure gradient. From the stability analysis, low–n MHD mode is stable in the center[1]. Another pressure–driven mode, high–n ballooning mode [2, 3] is an instability destabilized in the magnetic hill region. It is a candidate to explain CDC phenomena since it is unstable in the edge region in the LHD. It is consistent with the experimental observation that the collapse starts form the edge region[4].

The growth rate of ideal high–n ballooning mode is calculated using Hn-bal code. The pressure profile is assumed to be $p = p_0(1 - \rho^2)^2$ where p and ρ is the pressure and normalized minor radius, respectively. In order to fill the parameter space of the experiments shown by Fig. 1 (A), the preset–magnetic axis R_{ax0} and the central pressure p_0 is scanned. The growth rates in the edge region ($\rho \sim 0.8$) are shown in Fig. 1(B) with the same range of x axis and y axis of Fig. 1(A). The growth rate drastically increases at the experimental boundary for the appearance of the CDC (shown by the dotted line in Fig. 1(B)). It is thus likely the origin of the initial edge activity is high–n ballooning modes.

The scale of the collapse is reduced with the decrease of the magnetic field. When the B_t is lower than 1.0 T, no CDC is observed. Large amplitude m = 1 modes localized in the core region are observed instead. The beta profile during the m = 1 modes are almost identical to the beta profile just before the CDC in high B_t cases. When $1T < B_t < 1.5T$, we sometimes observe m = 1 oscillation evolves and shift to a small CDC–like collapse. Therefore, those pre–cursor oscillations are considered to be direct cause of that CDC. Two-step scenario for CDC is being considered from the results. At the first the step, the edge density profile is flatten from the enhancement of the transport due to the edge instabilities (possibly, high–n ballooning mode). That makes the pressure gradient in the central region steeper. An m = 1 mode is destabilized in the core then and the magnetic axis is moved radially. In the collisional plasmas ($B_t > 1.5$ T), the movement causes a magnetic reconnection, i.e. CDC. In less collisional condition ($B_t < 1.5$ T), continuous m = 1 mode are activated.

There remain several points to be cleared for the confirmation of this scenario. One is the determination of the unstable region of the high–n ballooning modes. Calculation of the spatial structure of the high–n ballooning modes with realistic pressure profile is in progress using CAS3D code. The location where the initial small crash takes place will be compared with the eigen function of the high–n ballooning modes in detail. Identification of the m = 1 kink–type oscillation is also required for understanding of the whole CDC process.

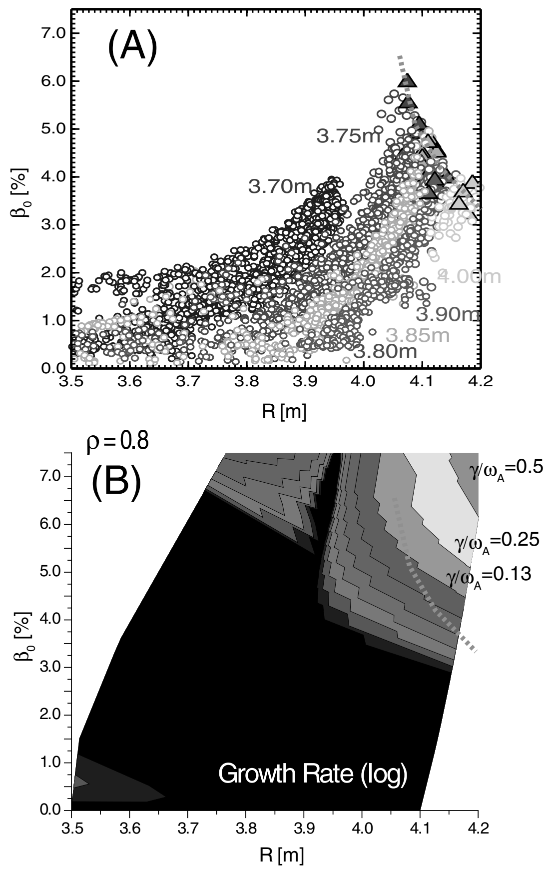

Fig. 1: *Operational space of the IDB type discharges is shown in (A). Each color corresponds to the vacuum magnetic axis position. CDCs are observed with the plasma parameters shown as the closed triangles. Fig. (B) shows the growth rate of the ballooning modes of bad curvature magnetic field line on ρ = 0.8. Yellow dotted line is a rough marking where CDCs are activated with those plasma parameters.*

1) Y. Narushima, et.al., J. Plasma Fusion Res. SERIES, **8**, 1070 (2009).

2) N. Nakajima, Physics of Plasmas **3**(12), 4545 (1996).

3) N. Nakajima, Physics of Plasmas **3**(12), 4556 (1996).

4) S. Ohdachi, et. al, "Density Collapse events observed in the Large Helical Device:", Contrib. Plasma Phys. accepted