Effect of Nonaxisymmetric Perturbation on Profile Formation

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1. Introduction

It is well known that the stochastization develops with the increase in the central beta value. In the stochastic region, it is expected to have different heat and particle transport properties from those in the region with perfectly nested flux surfaces. For the heat transport it was demonstrated that the effective electron heat conductivity χ_e in the stochastic region increases with the stochasticity of the magnetic field lines [1]. On the other hand, for the particle transport, it is observed that relatively flat profiles spread over the edge region across the boundary of the electron temperature profile. In order to study the effect of stochasticity on heat and particle transport, it is convenient to see the edge plasma behaviour in various edge magnetic topologies.

In this workshop results from edge modification experiments with external resonant magnetic perturbation (RMP) are presented, together with the numerical results with the HINT2 code [2].

2. Experimental conditions and numerical expectations

Experiments were carried out with the superdense core (SDC) plasma with central electron density of ~ 4×10^{20} m^{-3} [3]. The SDC plasma is sustained with the internal diffusion barrier (IDB) established in the core region at ρ ~ 0.6, where ρ is a normalized minor radius. During the IDB-SDC discharge, a large Shafranov shift due to the high central plasma pressure takes place, which strongly modifies the magnetic field structure and stochastize the edge region. In such a high density plasma, RMP was externally applied with 10 pairs of small loop coils installed in upside and downside of the torus. The magnitude of RMPs were in the range between 0.02 – 0.12 % of toroidal magnetic field B_t. Because of some restrictions, RMPs with only m/n = 1/1 and 2/1 are available so far in LHD, where m and n are poloidal and toroidal mode numbers, respectively. In outward shifted configurations, the resonance for RMP of m/n = 1/1 is in the stochastic region, on the other hand, RMP with m/n = 2/1 is in the closed surface region.

The magnetic topology in SDC discharge with RMP was calculated with the HINT2 code. The HINT2 is a three-dimensional equilibrium calculation code which can deal with the stochastic region even if the field lines there are not closed. Figure 1 shows the Poincare plots of the poloidal cross section in finite beta equilibrium. The central beta is increased up to 4.09 % which is almost the same as obtained in experiments shown below. The left column is for the case without RMP, on the other hand, the right column is for the case with RMP of which amplitude is 0.02 %. It can be seen in the high beta regime that the edge region is strongly stochastized in both cases. On the other hand, once the RMP is applied to such a high beta plasma as SDC, the magnetic topology changes

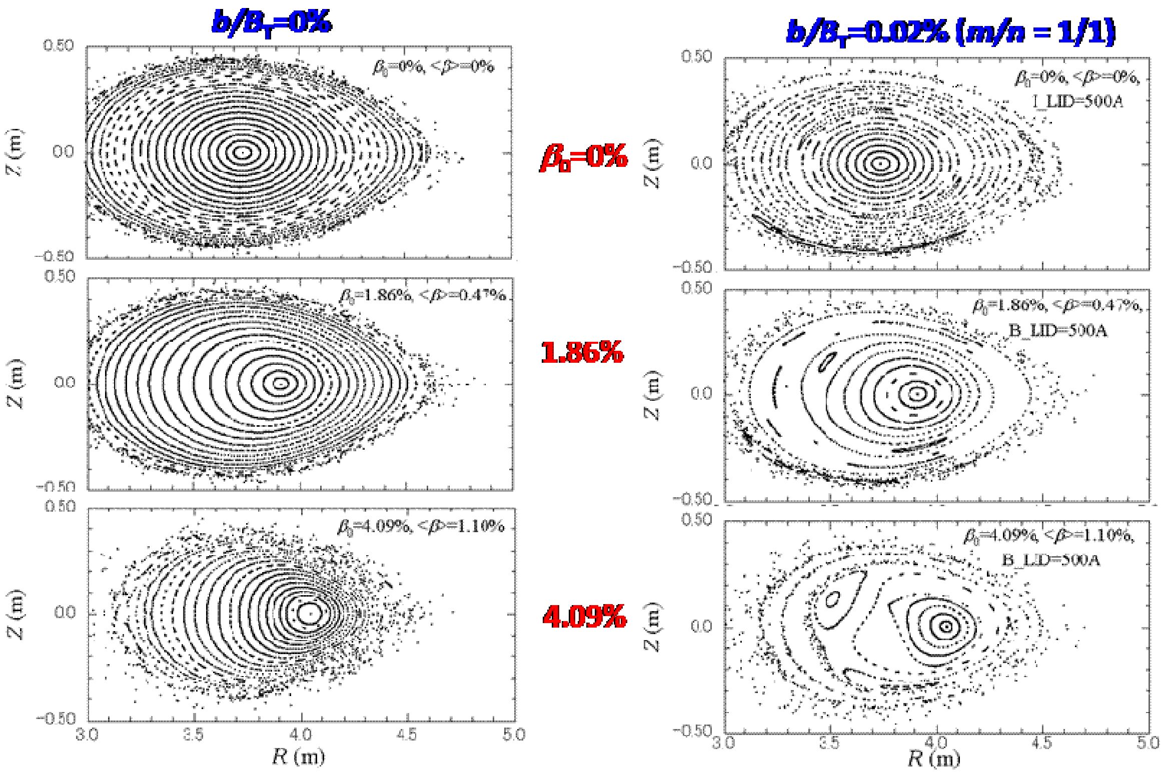

Fig. 1. Poincare plots calculated with HINT2 code. Central beta is increased up to 4.09 % as is obtained in experiments. Results with RMP is right column.

as shown in Fig. 1 (right column), although the RMP amplitude is not so strong (0.02 % of B_t). The m/n = 2/1 island grows drastically in the high beta regime of 4.09 %. The m/n = 1/1 island which was seen in the vacuum or relatively low beta regime is already in the stochastic sea and cannot be identified. It can also be seen in the high beta regime with RMP that the stochastic region increases even in the inner region near the m/n = 2/1 island. Those two configurations in the high beta regime were compared experimentally and the results are shown in the following section.

3. Experimental results

Two SDC discharges with same experimental conditions except for RMP application were examined. Figure 2 presents radial profiles of electron temperature T_e (red) and density n_e (blue) of two discharges with (bottom) and without (top) RMP. In this experiment the magnitude of RMP was relatively high as 4.09 % of B_t. Clear IDBs are identified in both discharges. It is found that the central densities in two discharges are almost the same (~ 4 x 10^{20} m^{-3}) regardless of the RMP application, while n_e outside the IDB in the discharge with RMP is lower than that in the discharge without RMP. The n_e at the foot of the IDB is decreased to about a half with the application of RMP. For this observation it can be understood that the particles outside the IDB were pumped out with the application of RMP. This phenomenon is quite similar to that observed in tokamak RMP experiments [4]. From the 1-dimensional transport analyses, it was found that the particle transport outside the IDB is surely enhanced with the RMP application, while it is less affected at the IDB or core region. According to the HINT2 calculation, it is expected that the application of RMP enhances the edge stochastization, which leads to the particle pump out.

The interesting point is that the central electron temperature T_e with RMP doubled from that without RMP. Due to the increase of central T_e, the central pressure in the discharge with RMP is larger than that without RMP, which results in a larger Shafranov shit, as is seen in Fig. 2. The reason for this increase in T_e is not clear so far. One of the candidates of this is a change of the deposition profile of the heating power. The low n_e is the edge region enables the neutral beam to penetrate deep inside the core region, furthermore, which may lead to the confinement improvement in the core region.

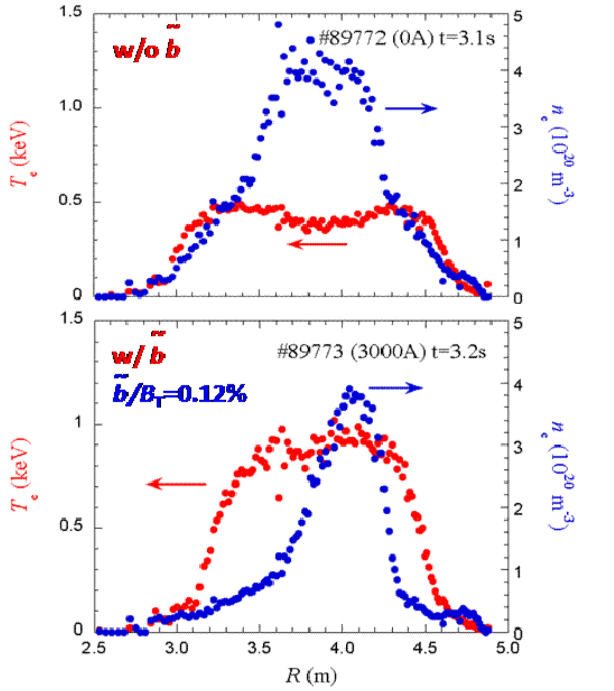

Fig. 2. Radial profiles of electron temperature T_e (red) and density n_e (blue) of the two discharges with (bottom) and without (top) RMP

Terminating the pellet fuelling in the core region, n_e at the center begins to decrease then central pressure decreases accordingly. After the peaked profile disappears, the particle transport in the edge region recovers. This is explained that the edge stochasticity is restored in the low pressure regime with moderate pressure profile.

4. Summary

The particle pump out is observed in the SDC plasma with the application of the resonant magnetic perturbation (RMP). This is the first observation in helical systems or stellarators. The numerical expectation with the HINT2 code suggests the enhanced stochasticity in the edge region of the SDC plasma, which causes the strong particle pump out.

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