§29. Investigations on the Dynamic Behaviour and Active Control of Density Profiles in Heliotron J

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1. Introduction

Particle control has long been regarded as an issue of controversy in burning plasmas. In particular, core fuelling becomes more difficult at high density as either NB or pellet penetration depth reduces, and intensive puffing degrades confinement. In addition, it has been pointed out that thermal transport is determined in a competitive process of ITG and TEM, where density profile carries a substantial role. Accordingly, it is prerequisite to develop effective core fuelling schemes and understand the relevant particle dynamics.

Compared with the conventional gas puffing, the supersonic molecular beam injection (SMBI) technique[(1)] is efficient in achieving deeper penetration of neutral particles into the core region. A SMBI system has been applied to Heliotron J (HJ) since 2008[(2)], which resulted in the enhancement of plasma performance[(3)]. In order to explore the profile evolution in SMBI plasmas, a Q-band X-mode amplitude modulation (AM) reflectometer was installed[(4)]. It is therefore capable of resolving hollow profiles ubiquitously observed in stellarators[(5)]. In addition, fixed-frequency fluctuation measurement could also be performed over a broad range of HJ discharges.

2. Electron density profile dynamics in SMBI plasmas

As a rudimentary experiment, an effect of a movable shutter placed in front of the SMBI was investigated. In case the shutter is closed, the SMB particles are practically blocked by the shutter, a part of which diffuse into the plasma in a manner similar to gas puffing. As shown in Fig. 1, where density profiles are reconstructed from the measured group delay profiles averaged over 2ms, SMB particles penetrate toward the center more significantly in the open shutter case. Here, SMBI was applied at 209ms. Even after the decay of core density, a relatively large amount of particles remain in the core region. However, it is modest in the closed shutter case, and the density profile seems to grow as a result of the inward convection.

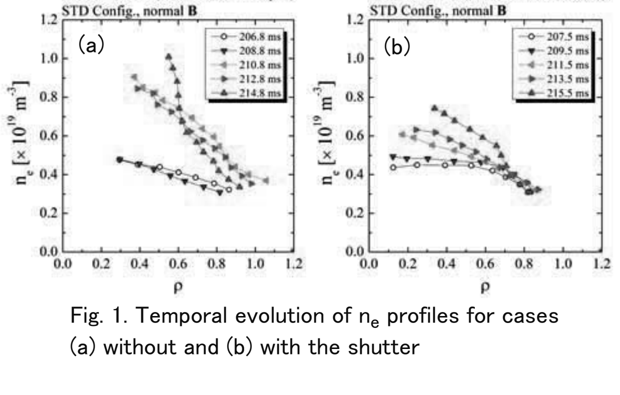

Fig. 1. Temporal evolution of n_e profiles for cases (a) without and (b) with the shutter

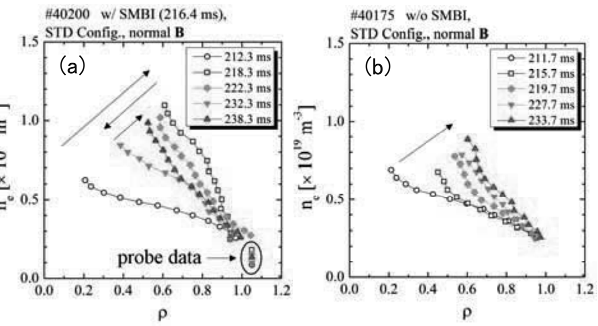

Fig. 2. Evolutions of n_e profiles for (a) SMB and (b) gas puffing plasmas under NBI

3. Comparison between SMBI and gas puffing

The time evolution of density profiles for NB heated plasmas under the two fueling systems is shown in Fig. 2. In the SMBI plasma, immediately after the SMBI pulse at 218.3 ms, the electron density increases in both the core and edge regions. The density at around half the minor radius decreases to the minimum at 232.3 ms. It increases again at 238.3 ms, whilst the averaged density measured by an interferometer continues to increase. The fixed frequency data corroborates the result of the profile measurement, indicating the consistent special shift of the reflection layer. This result imply that density peaking in the core region of plasma considerably increases around 232.3 ms. Here, local dynamics determined as a function of L_n and $L_{Te,i}$ may be present. In contrast, density profile evolution is modest in conventional gas puffing, similar to the case with shutter, described in the previous section. The density profile slowly evolves as a result of the anticipated particle convection, the detail of which is to be analyzed by the multi-channel measurement that is presently under development.

The apparent response of peakedness in density profile to the stored energy seems to be related to the possible interplay of the ITG turbulence. We have recently found in the international tokamak database that the peaked density profile might reduce the growth rate of ITG in NB heated discharges, whilst TEM degrades the confinement in strongly electron heated plasmas, as a result of the peaked density profile formation. However, recent results in LHD that has different magnetic topology indicated that the turbulence structure might be significantly different from tokamaks. Therefore, it is anticipated to perform a comparative experiment to untangle the physics related to the role of density profile in fusion plasmas.

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