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Baffle-structured Divertor Experiments in LHD
LHDにおけるバッフル構造ダイバータ実験

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The baffle-structured helical divertor has been constructed in two helical sections in LHD to control edge plasma via neutral particles. The divertor consists of vertically installed divertor plates and domes, which spontaneously form the baffle-structure. Before installing the pumping system, effect of the baffle-structure on neutral gas compression was investigated. In the experiment, it was demonstrated that the neutral pressure in the baffle-structured divertor was more than 10 times higher than that in the open region.

1. Introduction

The neutral particle control with a divertor is a crucial issue for fusion research. Especially in reactors, hydrogen isotopes, helium ash and impurities have to be pumped out to sustain the burning plasma in steady-state. In tokamaks, particle control experiments with closed divertors have been performed. On the other hand, in helical devices, closed divertor experiments have also been conducted using magnetic islands, i.e. island divertor. In LHD the super dense core plasma with the formation of the internal diffusion barrier was obtained by the highly pumped local island divertor (LID) [1]. However, due to the small wetted area of LID, it cannot be utilized for the long pulse or steady-state operation. Hence helical divertor (HD) which is intrinsically equipped with the heliotron configuration shall be utilized for the future devices. Recently the high density operation with HD has been performed to investigate the prospect of HD. According to the experimental results, however, the neutral pressure in HD was ~ 0.01 Pa at the highest, in spite of the high line averaged density more than 10^{20} m^{-3}, although ten times higher neutral pressure is necessary for the effective pumping. Therefore the closed configuration with baffles is urgently required to increase the neutral pressure in HD.

2. Baffle-structured divertor

After the numerical study for the optimization of the configuration, baffles combined with target plates and domes have been installed in LHD, which are made of graphite to withstand the high heat load more than 1.5 MW/m^2 (steady-state). In 2010, baffles for two helical sections (20 %) were installed, although the pumping system has not been installed yet. Fig. 1 shows the baffles-structured helical divertor installed on the inboard side of the torus for one helical section in the LHD vacuum vessel. The schematic view of its cross section is also presented in Fig. 2. It is found that divertor plates combined with baffles face the private region to concentrate neutrals in the closed region. In the private region the “dome” structure is installed. To measure the neutral pressure in the baffle-structured HD, three ASDEX-type fast ion gauges are installed under the dome. Another fast ion gauge is also installed in HD without baffle-structure, to compare the neutral pressure each other.

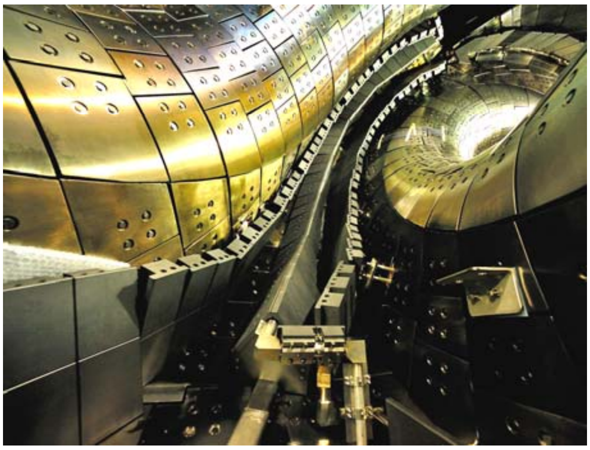

Fig. 1. Baffle-structured divertor installed in LHD.

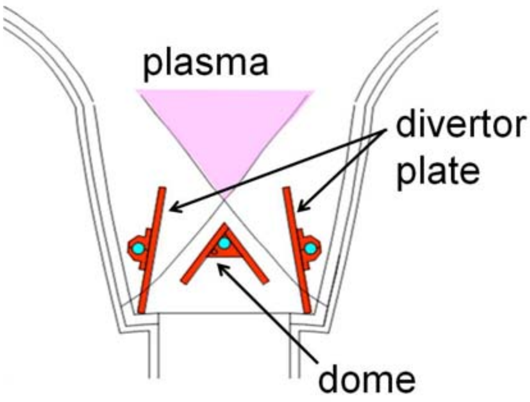

Fig. 2. Schematic of its cross section.

3. Experimental results

Experiments were carried out in density ramp-up discharges where the magnetic axis was at R = 3.6 m [2]. Fig. 3 shows the time evolution of line averaged electron density n_e at the midplane and the neutral pressure P_0 in HD with and without baffles. Hydrogen gas puffing was performed during the discharge as shown in Fig. 3 (b), thus the line averaged density increased up to 7×10^{19} m^{-3}. The neutral pressures in both configurations increased with the line averaged density. It is favorable that the neutral pressure in the baffle-structured HD was more than 10 times higher than that in HD without baffles, which is called “neutral particle compression”. No negative effect on the core plasma was observed during the discharge. Furthermore, in the detailed inspection after vent, no serious damage on tiles was found.

In the long pulse operation of the SDC discharge in the open HD, it was usual that the edge electron density n_e increases gradually during the discharge. The increased edge n_e enhances the edge radiation, and finally brings about the radiation collapse when it exceeds the density limit [3]. In this experimental campaign, however, with the baffle-structured divertor of only two sections, the enhanced recycling is not observed, i.e., edge n_e is kept low during the discharge for ~ 6 sec. The low recycling regime is achieved even though the active pumping in the baffle-structured divertor has not been installed. The reason for this phenomenon is not clear up to now.

Summarizing the initial experimental results, it can be concluded that the baffle-structured HD works well and is expected the efficient neutral particle control when the pumping system is installed in the dome.

Refrences

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[2] S. Masuzaki, et.al., Plasma Fusion Res. 6, 1202007 (2011).
[3] S. Sudo, et al., Nucl. Fusion **30** (1990) 11.

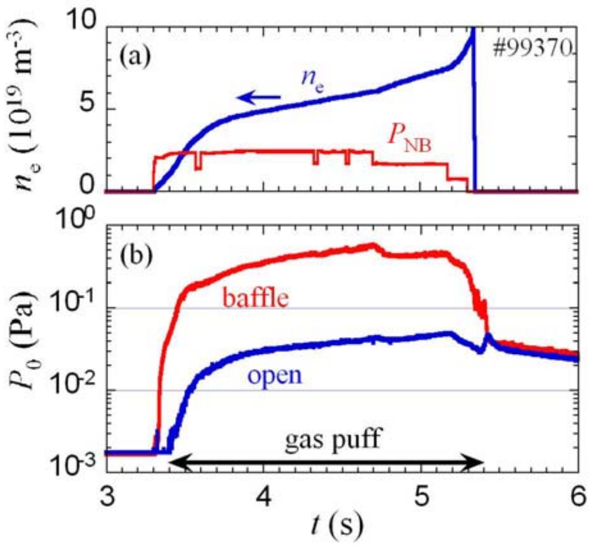

Fig. 3. Time evolution of (a) line averaged density, NB injection scheme, and (b) neutral pressure, together with gas puff injection scheme.

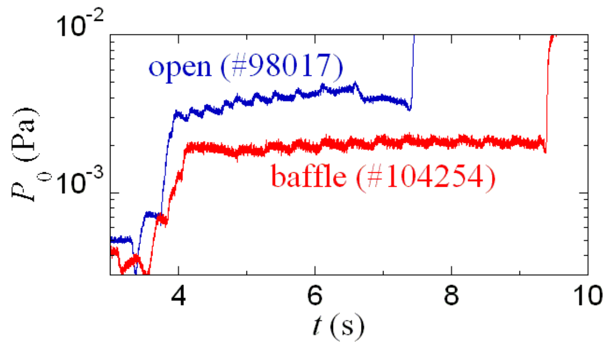

Fig. 4. Temporal evolutions of neutral pressure in open divertor configuration (blue) and baffle-structured divertor configuration (red).