§1. Conceptual Design of the Closed Helical Divertor in LHD

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Particle control for the improvement of plasma confinement and the sustainment of long pulse discharges with high performance plasmas using the intrinsic helical divertor (HD) is a main experimental goal in LHD. To achieve the effective particle control, the edge and divertor plasmas study has been conducted under the 'open' HD configuration both experimentally and theoretically, and the mechanisms of the heat and particle distributions formation on the divertor have been understood [1-5]. For the non-uniformity of the heat and particle deposition profiles on the divertor, and of the plasma parameters in the divertor plasma, the neutral pressure in the HD in LHD (up to several 10^{-2} Pa) is one to two orders of magnitude lower than that in the divertor region in tokamaks [5]. To investigate the effect of the divertor pumping on the plasma confinement, the Local Island Divertor (LID) configuration experiment has been conducted, and the super-dense-core (SDC) plasma operation regime with internal diffusion barrier (IDB) was discovered in the configuration [6-8]. However in the LID configuration, the heat and particle loads on the divertor plates are much larger than that in the HD configuration. Therefore the plates are largely eroded, and the released impurities contaminate the core plasma. In the subsequent experiments, the SDC operation was found to appear in the HD configuration also. In the case of the HD configuration, there is no divertor pump, and the increase of the neutral pressure in the divertor region is attributed to inhibition of the SDC operation. From these backgrounds, we have studied the development of the particle control function in the HD configuration to achieve the above-mentioned major experimental goal in the LHD.

To improve the particle controllability in the HD configuration, the divertor pumping system is necessary, and the neutral pressure should be raised by one to two orders of magnitude to make the divertor pumping effective. Therefore the installation of the appropriate baffle structure is necessary. The neutral particle flux evacuated by the divertor pump should be equal to the fueling particle flux for the steady state operation, and is expected to be comparable to the fueling pellet injection, that is about 5×10^{22} H/s (~100 $Pa\cdot m^3/s$). We make the target parameters as below; the pumping speed > 100 m^3/s (for 1 toroidal section), the neutral pressure in the divertor region > 0.1 Pa.

From the point of the view of the steady state operation, the divertor system should consist of non-accumulation pumps, such as turbo-molecular pumps, and they should be outside the vacuum vessel. However, it is difficult to obtain the conductance which is large enough to achieve the targeted pumping speed in the LHD. Therefore in-vessel pumps, such as cryo-pump or getter pump are the candidates for the LHD.

Two types of the new HD structure equipping baffle structures are proposed for the LHD. One type uses the intrinsic helical divertor structure (Type-I). One the other hand, the closed divertor modules are installed on the inboard periphery of the ergodic layer in each toroidal section in the other type (type-II). Figures 1 (a) and (b) show the schematic view of these two HD structures, respectively. By utilize the three-dimensional plasma and neutral transport code, EMC3-EIRENE [9], the profiles of the heat and particle depositions on the divertor plates and the neutral pressure in the divertor region in these two types of HD structures have been investigated. The best arrangements of the baffle structure, divertor plates and the closed divertor module have been explored. The simulation results show that the neutral pressure of the order of 0.1 Pa in relatively high-density discharge condition can be obtained in both HD structures.

To develop the heat removal function of the divertor plate, the high heat load test device, ACT, has been utilized [10]. The development of the plasma facing components, such as the divertor plates and the baffle structure should be continued using ACT.

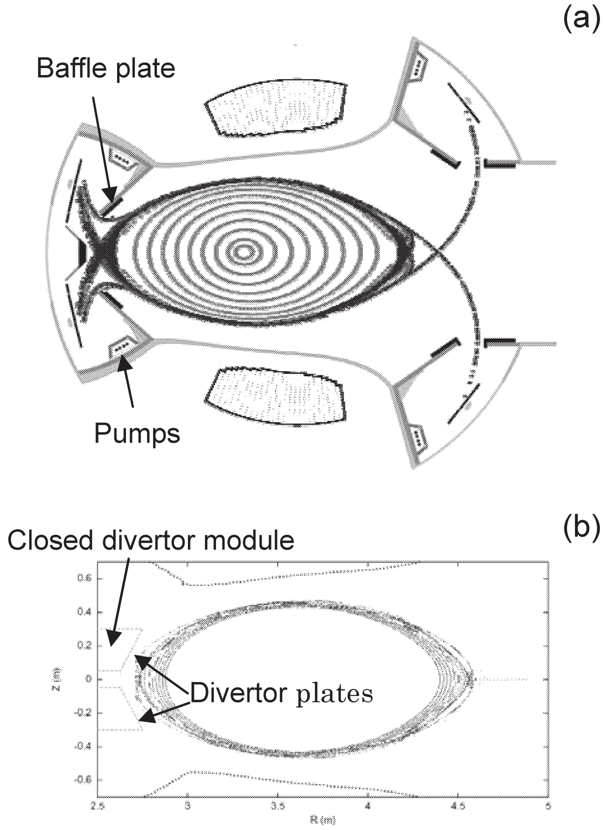

Fig.1 Schematic views of the closed helical divertor structure. (a) Type-I. An design using the intrinsic helical divertor structure. (b) Type-II. The closed divertor module is installed on the inboard periphery of the ergodic layer.

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