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Simulation Modeling of Plasma and Neutral Transport in Closed Divertor Configuration of LHD

ＬＨＤ閉ダイバータにおけるプラズマおよび中性粒子輸送シミュレーションモデリング

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Dynamics of neutral hydrogen in closed divertor is essential issue to analyze and predict hydrogen recycling and pumping of the gas to sustain high-density discharges in LHD. Calculation grid of EMC3-EIRENE code has been developed by using information of magnetic field and geometrical data to simulate plasma and neutrals in edge, leg and vacuum regions in LHD. The grids for leg and vacuum are newly made and connected the previous edge grid. Plasma profiles and neutral-hydrogen distribution were simulated with the new set of grids. Neutral compression by baffle plates in closed divertor were investigated and the compression ratio were obtained in the same level in experimental measurement. Significant increase of hydrogen recycling due to the neutral compression was also obtained.

1. Introduction

The Large Helical Device (LHD) has been upgraded with the installation of closed divertor, which currently covers 20% of the full torus. The first experimental campaign with the closed divertor has been conducted in fiscal year of 2010, and has demonstrated the efficient neutral compression by the dome and the baffle structure, up to 10 times larger than the previous open divertor region [1,2]. The rest of the torus is now under construction for the full closed divertor configuration. The design of the divertor was mainly based on the three-dimensional neutral transport simulation with EIRENE [3]. For understanding the compression mechanism as well as the divertor plasma characteristics in the closed divertor configuration, however, consistent treatment of the plasma-neutral interaction including the plasma-facing component is of great importance.

2. Simulation code

The task is undertaken by utilizing the new version of the 3D edge plasma transport code, EMC3[4], which is extended being capable of including the divertor legs of LHD with strong flux tube deformation due to the magnetic shear, which usually prevents construction of feasible field aligned 3D grid. The calculation grid employed in this work is constructed from the magnetic field to be aligned along them. Since the helical field has large magnetic shear apart from the core region, consistent arrangement of a single set of grid is difficult from the geometrical point of view. The simulation in the previous work [5] approximated the divertor legs on the half way to the divertor plates by shifting the Bohm boundary condition slightly upstream, 1~2 m. This was considered a reasonable assumption for the open divertor configuration, where the most relevant transport physics for the LHD divertor was found in the stochastic region, upstream of the divertor legs.

3. Grid generation

For the closed divertor configuration, however, the inclusion of full divertor legs is prerequisite for understanding the role of the baffle structure and the dome in the new closed divertor configuration. In order to include the full divertor leg in the calculation, four new grid systems are connected to the SOL grid. They were generated separately to cover the divertor legs and share the grid points on the surface of the SOL grid around the X-points. The generation of leg grids was carried out by using a contour of connection length as a guideline (see Figs. 1 and 2). The outline of the leg was approximated by a spline in the plane where toroidal angle ϕ=153. Other legs in different toroidal cross sections were made by tracing the magnetic line of each grid point. Since four legs lie in each toroidal plane, we made 80 legs for 20 planes in the range of 144≤ϕ≤162. The vacuum grid surrounded by edge, leg and vacuum vessel were generated from the geometrical shape of their boundaries (see Fig. 3).

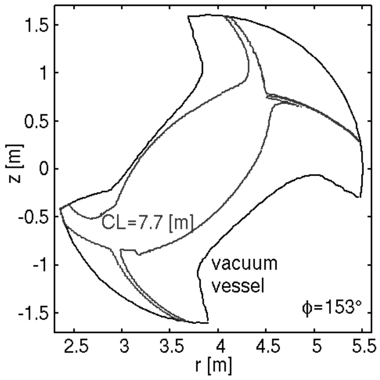

Fig. 1: Contour of connection length for 7.7m where the toroidal angle ϕ is 153 degree.

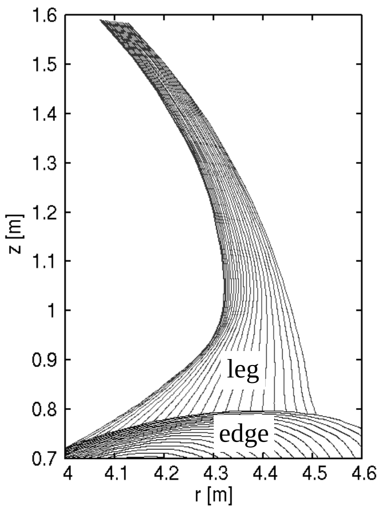

Fig. 2: Generated grid of the top leg in Fig. 1.

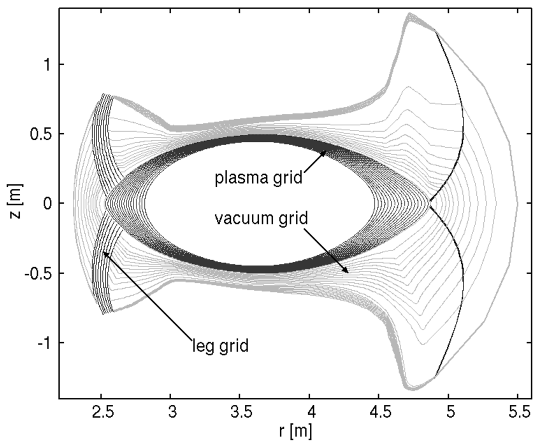

Fig. 3: Generated grid in the plane ϕ=162.

4. Calculations and results

We installed baffle plates to simulate the closed divertor configuration (see Fig. 4). We carried out simulation with the new grid system and obtained a plasma distribution in a hydrogen discharge. Neutral compression ratio derived from open and closed configurations are investigated by changing the geometry. The same level of compression ratio was obtained as experimental measurement [1]. The hydrogen recycling was investigated for both configurations and significant increase of hydrogen recycling was observed because of the neutral compression.

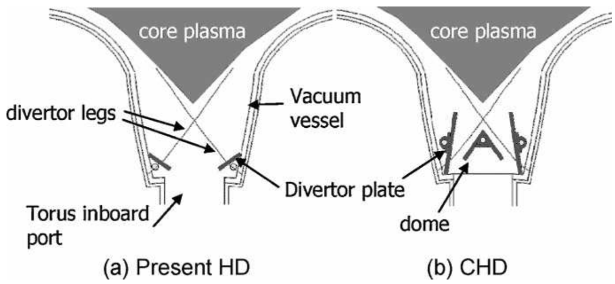

Fig. 4: (a) Open and (b) closed divertor configuration in the cross section.

Acknowledgments

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