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Optimization of the Vacuum Pumping System for the Closed Helical Divertor in the Large Helical Device III

LHDにおける閉ダイバータ用真空排気装置の最適化検討Ⅲ

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A vacuum pumping system for a Closed Helical diverotr (CHD) in the Large Helical Device (LHD) has been designed for active control of the periperal plasma denstiy. The distance between the puming sytem and divertor plates is short (~0.1m) in the CHD configuration. One of the major concerns for designing the pumping system is reduction of the heat load by the heated divertor plates with good puming efficiency. The heat load and the pumping efficiency are investigated using a neutral particle transport simulation code, which proposes an improved design of the pumping system for the CHD configuration.

1. Introduction

Physical issues required for a vacuum pumping system installed in the divertor region in future fusion reactors are helium ash removal, impurity reduction in the core plasma, neutral particle pumping in the peripheral plasma.

Two test modules of a closed helical divertor (CHD) have been installed in the inboard side of the torus in the Large Helical Device (LHD) from the last experiment campaign (2010y) [1]. The CHD consists of three instrumental components: slanted divertor plates, a roof shaped dome and target plates. It successfully enhanced the neutral particle density behind the dome by more than one-order of magnitude compared to that in the open divertor [2].

In the near future, a vacuum pumping system behind the dome will be installed for active control of the peripheral plasma density. Because of the short distance (~0.1m) between the divertor plates and the pumping system, heat loads by radiation from the heated divertor plates and by thermal conduction due to neutral particles released from the plates should be carefully considered for designing the pumping system. Using a neutral particle transport simulation code, an improved design of the pumping system optimized to the CHD configuration is proposed.

2. Vacuum Pumping System for the Closed Helical Divertor

The vacuum pumping system consists of the three components: water cooled (WC) blinds, liquid nitrogen (LN_2) cooled chevrons and gas/liquid helium (LHe) cooled panel. Figure 1 shows a three-dimensional model of the pumping system installed behind the dome (a half part). There are two heat transfer mechanisms to the LHe cooled panel: radiation from heated divertor plates, thermal conduction due to neutral particles. The LN_2 cooled chevrons are covered with the WC blinds for protecting from the heat load. The LHe cooled panel is enclosed with the LN_2 cooled chevrons for minimizing the heat load to the panel.

A previous analysis using a finite element method based software for multi-physics analysis (ANSYS) and a neutral particle transport simulation code (EIRENE) proposed the above configuration for reducing the heat load with good pumping efficiency. It showed that the heat load on the LHe cooled panel by thermal conduction due to neutral particles is dominant over that by radiation. It also proved that the installation of buffer plates, on which many deep grooves are scratched, is very effective to minimize the heat load [3].

3. Improvement of the Configuration of the Pumping System

The configuration of the WC component is modified in order to improve the pumping efficiency. It is defined as the current of neutral particles reaching to the LHe cooled panel to the total plasma current flowing to the divertor plates. The neutral current is counted by tracking test particles (representatives of neutral hydrogen atoms/molecules) in the neutral particle transport simulation code. Examples of the track of the test particles released from the divertor plates are

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illustrated as gray thin lines in Fig. 1.

The pumping efficiency and the heat loads are calculated in the case of four different WC components which cross-sections (a half part) are illustrated in Fig. 2. Type I is the original configuration which is previously proposed [3]. Type II is a configuration with expanded inlets of the WC blinds with a small sized dome to efficiently take in neutral particles. Type III is that with a slit at the bottom of the WC component in order to introduce neutral particles beneath the pumping system. Type IV is that with a buffer plate on the vacuum vessel in the inboard side for reducing the energy of neutral particles impacting the LN_2 cooled chevrons through the bottom slits. In the all configurations, the buffer plates are installed on the WC components and the LN_2 cooled chevrons. A 50% transparent mesh is mounted between the WC and LN_2 cooled components for microwave protection.

The calculations of the pumping efficiency and the heat load on the three components for the four different WC components are shown in Fig. 3. The current flowing to the divertor plate (I_{Div}) is fixed to be 1A. The pumping efficiency is improved by modifying the configuration of the WC components: the expanded inlet of the WC blind, the bottom slit. The heat load on the LN_2 chevrons increases by these two modifications. The calculations show that the buffer plate in the inboard side of the torus is effective for reducing heat load on the LN_2 cooled chevrons.

4. Summary

The neutral particle transport simulation shows that the improved configuration of the pumping system with the expanded inlet of the WC blinds and with the bottom slit can enhance the pumping efficiency by about 60% compared to that in the original configuration. It also indicates that the heat load by conduction due to neutral particles on the LN_2 cooled chevrons rises by about factor 20 for the improved configuration compared to that in the original configuration. Suppression of the heat load by about factor 3 is expected by installing the buffer plate in the inboard side of the torus with keeping the enhanced pumping efficiency.

References

[1] A. Komori, H. Yamada, S. Imagawa et al.: Fusion Sci. Technol. **58** (2010) 1.

[2] S. Masuzaki, M. Kobayashi, M. Shoji et al.: Plasma Fusion Res. **6** (2011) 1202007.

[3] M. Shoji, S. Masuzaki, T. Morisaki et al.: Plasma Fusion Res. **6** (2011) 2401035.

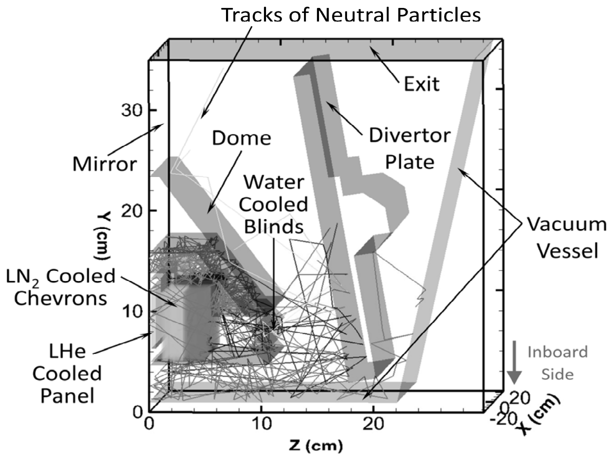

Fig.1. A three-dimensional model of the pumping system for the closed helical divertor

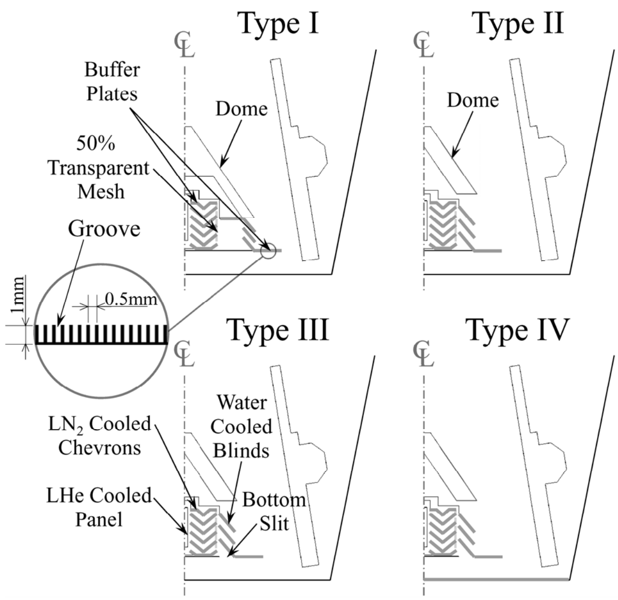

Fig.2. Cross sections (a half part) of the four different configurations of the WC components in the pumping system

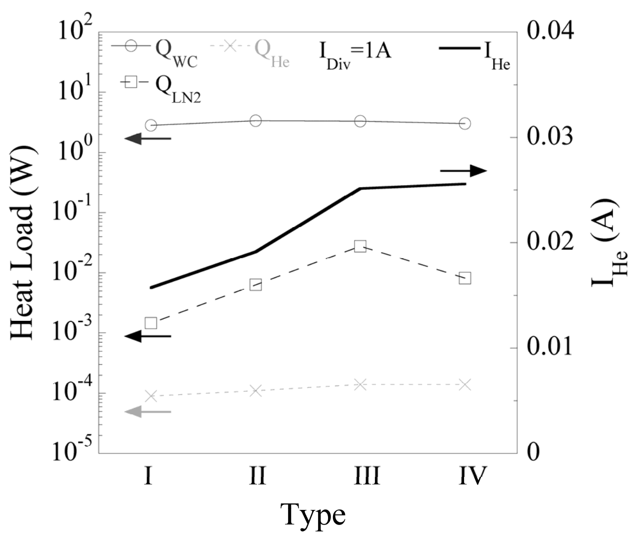

Fig.3. Heat load and pumping efficiency in the four different configurations of the WC components

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