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Divertor pumping for steady state operation in LHD experiments

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Attempts using various particle control knobs have been made at Large Helical Device (LHD) to achieve steady-state plasmas in long pulse discharges. Divertor pumping is an important tool to control plasma density in fusion plasmas. In the divertor region, neutral particles shall be compressed and efficiently pumped out. In the LHD, the development of divertor pumping has been strongly enhanced. With the pumped helical divertor, we have achieved the low recycling state in the LHD [1]. In the conference, we will present the results of divertor pumping experiments for long pulse discharges.

Divertor pumping was applied to 40-second long pulse Electron Cyclotron Heating (ECH) discharges to assess the improvement in particle control provided by divertor pumping [2]. The results show that without divertor pumping, the electron density was not controlled only by gas puffing using the feedback signal of line-averaged electron density. Then, the plasma confinement deteriorated, finally leading to radiation collapse. On the other hand, with divertor pumping, the density was well-controlled by gas puffing using the feedback signal.

A heat transport analysis shows that divertor pumping did not affect edge electron heat conductivity, but it led to low electron heat conductivity in the core region with the formation of the electron-internal-transport-barrier. The results suggest emergence of the core-edge coupling caused by the divertor pumping.

In this study, we will also present the technical development in divertor pumps which is essential for the steady state operation.

An organic adhesive-free bonding technique, which enables outgassing-free, was developed for divertor cryo-sorption pump in LHD. The technique, which avoids the contamination of vacuum vessel by outgassing, is acceptable in future fusion devices. Also, the pumping performance is maintained during the neutron environment in deuterium experiments.

Sintering method of activated charcoal, in which pore size is optimized for the cryo-sorption pump by SPS (Spark Plasma Sintering), was developed. R&D shows that the pumping capacity with optimized activated charcoal is higher than that in commercially available activated charcoal. The technique contributes to the high performance of the vacuum pumps.

[1] G. Motojima et al., Nuclear Fusion 59 (2019), 086022.
[2] G. Motojima et al., Physica Scripta 97 (2022), 035601.

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