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Transport modeling of LHD peripheral plasma based on multiple measurements with regard to intrinsic/seeded impurities

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Numerical modeling of peripheral plasmas such as ergodic region and divertor regions of Large Helical Device (LHD) has been conducted to understand transport physics of plasma and neutral, and to reveal key physical processes necessary for re-production of experimental results. The three-dimensional fluid transport codes EMC3 for plasmas and the kinetic transport code EIRENE for neutrals are coupled self-consistently, and employed to obtain steady state distribution of plasma and neutrals in the entire peripheral regions with realistic magnetic field and wall configurations of LHD [1]. Radiation power from the plasma and line radiation from specific impurities are routinely measured, and some impurity gases like neon, argon, and nitrogen are employed for impurity seeded experiments.

Recently, we developed a data processing tool for synthetic diagnostics to realize a direct comparison between EMC3-EIRENE results and optical measurements like bolometer and spectroscopy. Many modeling efforts on impurity transport have been made with the aid of the synthetic diagnostics. As for the intrinsic carbon impurity coming from the plasma-facing walls, influence of the transport coefficient and the source locations on the radiation profiles from carbon is evaluated, and it was found that those parameters are essential to reproduce the radiation distribution obtained by the spectroscopy measurement [2]. The flow direction of carbon ions reproduced the spectroscopy flow measurement, and the parallel flow of the plasma along the magnetic field is identified as an essential factor for the impurity transport in the ergodic region [3].

As for the seeded impurity, different transport characteristics of neon and nitrogen are modeled to understand the toroidal symmetry/asymmetry, respectively, observed in experiments. Different recycling coefficient at the divertor plates were assumed: 100% for neon and 0% for nitrogen to model the low and the high chemical activities of neon and nitrogen, respectively. The recycling due to the surface recombination confines neon atoms in the device and the long confinement time cuts the connection between the seeded location of the gas and the spatial distribution of atoms and ions in the plasma, and hence the toroidally distribution becomes symmetric independent of the toroidal sections. On the other hand, the nitrogen distribution is strongly asymmetric due to the localized distribution caused by the seeded location and the immediate loss at the divertor plates. That symmetric/asymmetric characteristics are validated by the comparison with the particle flux reduction measured by the Langmuir probe installed on a divertor tile of multiple toroidal sections [4]. A two-dimensional imaging bolometer installed at a port is modeled as a pin-hole camera, and synthetic images were generated from the EMC3-EIRENE results. The image for neon seeded discharge has a good qualitative agreement with the measurement, however, the image for the nitrogen seeded discharge has a different pattern from the measurement [5]. Further investigations on impurity transport are needed in the case with the significant toroidal locality.

In addition to the various validation works mentioned above, applications of EMC3-EIRENE and the synthetic diagnostics have been performed. In the numerical modeling, source amount of impurities is an essential factor, but is usually difficult to determine because the sputtering yield of carbon significantly depends on the surface condition and exact values of the gas flow rate and the duration time are not available. Also the reflection coefficient of gas atoms on the wall is unknown factor. The radiation power measured by the bolometer systems installed in LHD can provide the time-resolved radiation power with the specific viewing fields. The EMC3-EIRENE provides radiation distribution in the three-dimensional space for each atomic species. The total radiation power measured by the synthetic diagnostics can be represented with a linear combination, and the coefficient for each component can be determined by least squared method to have a best fitting to the measurements. The core radiation outside of the calculation region of EMC3-EIRENE can be included as a component in the regression analysis. The radiation powers of carbon and neon were estimated from the regression using multiple bolometer systems. Similar results were obtained with different combinations of bolometer systems, and the robustness of the regression was confirmed. Also other recent applications of the modeling to LHD and other devices will be briefly presented.

References

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