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Erosion analysis considering interaction with plasma in DEMO fusion reactor

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In a tokamak fusion reactor, the concentration of heat load on the divertor target from the core plasma is significant in terms of device design. Tungsten(W) is expected to be used as a material for divertor targets because of its high durability in Japanese demonstration fusion reactor (JA-DEMO). However, the divertor wall is still eroded by the high heat load and the W impurity is sputtered from the wall. Contamination of the core plasma by the W impurity may decrease the fusion reaction rate and power generation efficiency. Furthermore, erosion by W, so-called self-sputtering, may cause severe damage to the device. Therefore, it is essential to understand the W impurity transport process in fusion reactors.

In the previous research [1], the W impurity simulation using the Monte Carlo particle code for impurity transport IMPGYRO [2] showed that the net erosion of the outer divertor target is almost suppressed in the detached condition. However, the following effects were still unclear: (i)anomalous diffusion, (ii)global transport in the SOL/divertor region, and (iii)interaction with plasma.

Our final goal in the future is to develop a control scenario for divertor erosion. As a first step towards this goal, in this study, we discuss these effects on the W impurity transportation and evaluate the net wall erosion.

The divertor erosion in JA-DEMO is analyzed by using IMPGYRO code with the above effects. As these effects, we developed the random walk model for (i), expanded the simulation region to the whole area in the SOL/divertor region for (ii), and coupled IMPGYRO with the integrated divertor code SONIC [3] for (iii).

A preliminary simulation with (i) and (ii) was carried out [4]. By including the effect of anomalous diffusion, the W impurity distribution was expanded in the radial. In other words, more W impurity can reach to the core plasma or first wall than that in the previous study. The deposition on the divertor target decreased and led to an increase in net target erosion.

Considering the effect of (iii), the plasma may be more cooled by the radiation of sputtered W impurities, and erosion may result in a decrease. To couple the IMPGYRO code with the SONIC code, an interface for data exchange is developed. Figure 1 shows the normalized radiation power in a test calculation by IMPGYRO. In this simulation, the background plasma is still fixed, and the W impurity generated from the outer divertor is traced. In Fig. 1, the W radiation can be seen at the edge of the core and near the outer divertor. Although the strong radiation in the core region is not preferable for the DEMO operation, it may be suppressed by the plasma cooling by the radiation and the resultant decrease in the divertor plasma temperature.

Simulation results with effect (i) – (iii) will be discussed in detail in the presentation.

References

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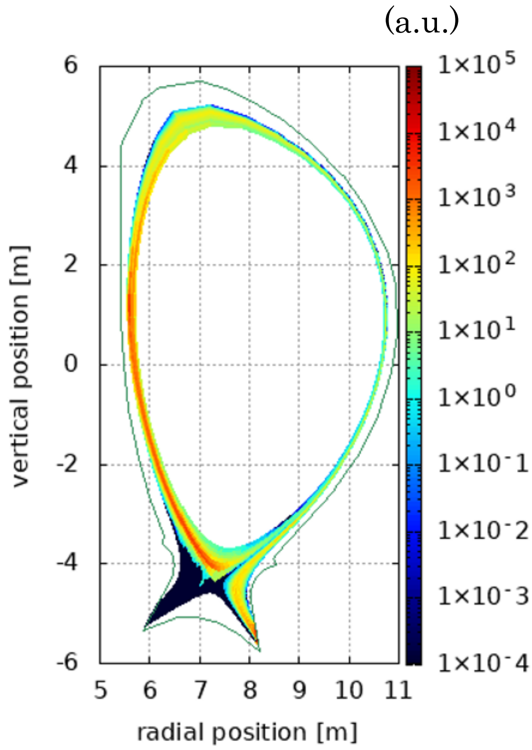

Figure 1. Distribution of the normalized radiation power by W impurity in cross-section of DEMO fusion reactor.