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Study on impurity transport model based on JT-60U experimental data

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Tungsten (W), which is to be used as a divertor target material in ITER and DEMO reactors, is a high-Z element, and there is concern about its high radiation loss when introduced into plasma as an impurity. Elucidating the mechanism of impurity accumulation is one of the challenges to realize thermonuclear fusion reactors.

In the large tokamak device JT-60U, W accumulation has been observed to increase with increasing toroidal rotation (V_t) in the opposite direction to the plasma current in H-mode plasmas [1]. To understand this phenomenon, impurity transport simulations have been studied.

To understand this phenomenon, impurity transport simulation studies have been conducted with the integrated transport code TOTAL. In previous studies, pinch models (PHZ pinch and Er pinch) [2] proposed by Hoshino et al. have been incorporated into TOTAL to examine whether they can reproduce the toroidal rotation dependence of tungsten accumulation [3].

The purpose of this study is to examine the validity of the tungsten transport model by comparing the radial distribution and time evolution of tungsten accumulation, which have not been compared before, in order to further improve the impurity transport calculations.

In order to compare the radial distribution of W accumulation, it is necessary to relate the tungsten density calculated by TOTAL to the experimental data from JT-60U. The soft X-ray intensity reflects the W density. Therefore, the soft X-ray intensity distribution is selected as the experimental data to be compared in this study. The soft X-ray array in JT-60U has 16 poloidal lines of sight and observes radiation in the range of 2.7 keV to 20 keV.

In the TOTAL code, soft X-ray intensities are calculated taking into account bremsstrahlung radiation (P_{brem}) from free electrons and line radiation from tungsten ions (P_{line}). This is written as $P_{SX} = f_b P_{brem} + f_l P_{line}$ where f_b and f_l are correction factor that takes into account the observed energy range (2.7 keV to 20 keV). At present, f_l is assumed to be 1/10 because it is difficult to get the energy spectrum of the line radiation of tungsten ions. Another consideration is that the soft X-ray intensity distribution is given by the line integral in experiment. We assume a cylindrical line of sight and integrate the local soft X-ray intensities along the line of sight.

In this study, two cases are selected for comparison: (a) a case with small V_t and small W accumulation, and (b) a case with large V_t and large W accumulation. In TOTAL's transport calculations, the rate equation with radial transport is solved for W^{q+} $(0 \le q \le 74)$.

$$\frac{\partial n_k}{\partial t} = -\frac{1}{V'}\frac{\partial}{\partial \rho}(V'\Gamma_k) + [\gamma_{k-1}n_{k-1} + \alpha_{k+1}n_{k+1} - (\gamma_k + \alpha_k)n_k]n_e,$$

$$\Gamma_k = -(D_k{}^{\mathrm{NC}} + D_k{}^{\mathrm{AN}})\frac{\partial n_k}{\partial \rho} + (V_k{}^{\mathrm{NC}} + V_k{}^{\mathrm{AN}})n_k,$$

where γ_k is the ionization coefficient and α_k is the recombination coefficient. The subscripts NC and AN represent neoclassical and anomalous transport, and the PHZ pinch and Er pinch models are considered in $V_k{}^{\mathrm{AN}}$. The W atoms are injected through the plasma surface. The background plasma parameters (n_i, T_e $etc.$) are fixed based on the experimentally obtained profiles.

Simulation results are shown in Figure 1. Figure 1(a) reproduces the weak peak of soft X-ray intensity observed in the case of low tungsten accumulation. Here, scales of the vertical axes are adjusted to match the heights of peaks. Figure 1 (b) shows the calculation results for the case with high tungsten accumulation on the same scale as Figure 1 (a), which reproduces a strong peak reflecting W accumulation but overestimates it.

Comparative method of time evolution is under consideration. In order to compare the time evolution, it is necessary to consider the time evolution of the pinch velocity and diffusion coefficient due to changes in the background plasma. Detailed discussion, including details under consideration regarding time development, will be given in the presentation.

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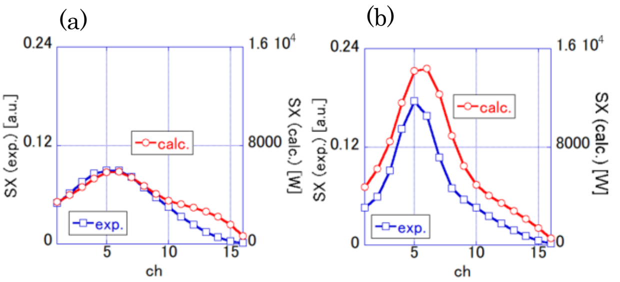

Figure 1 Comparison of soft X-ray intensity distribution (a) in small V_t and small W accumulation and (b) in large V_t and large W accumulation.