§21. Study of Fuel Particle Balance in a Fusion DEMO Reactor: Preliminary Results

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Tritium balance and tritium production are key issues for the feasibility of a fusion power plant. Thus, we estimated the tritium particle balance using the helical type fusion reactor FFHR2m2 design parameter. According to the FFHR2m2 design parameter for the fusion power of 3GW, the total number of particles in the main plasma, N, was 1.48×10^{23} particles, the sink rate due to fusion reaction in the main plasma, S_L, was 1.25×10^{21} particles/s, and the particle confinement times for the main plasma, τ_c, was 2.6s. The particle confinement time for the edge plasma τ_e is assumed to be 2.6ms.

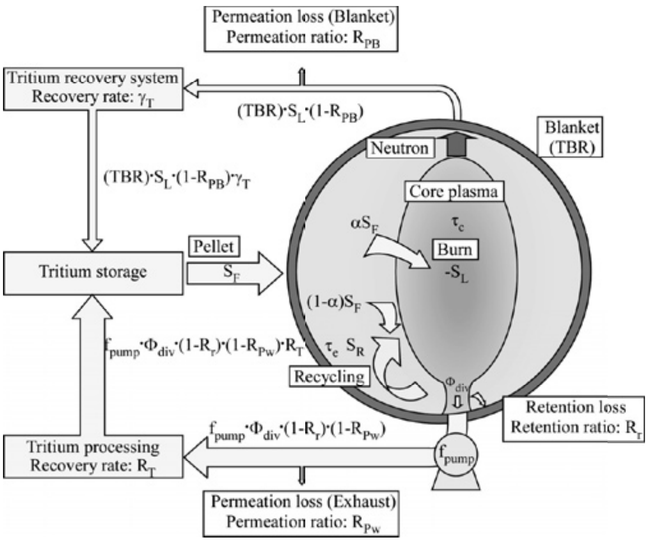

Fig. 1. Steady-state analytical model for calculating tritium balance in an example of a fusion reactor.

Figure 1 depicts the schematic analytical model of tritium balance by way of an example. In this model, to discuss the effects of fuel efficiency and the tritium loss due to permeation and retention, it is assumed that tritium is fueled by only pellet injection in the main plasma. Then, we introduce a new parameter of the fuel efficiency "α" of pellet injection. The detailed analysis in burning plasma due to the effect of pellet injection is in progress by the FFHR group. Additionally, new parameters of tritium loss ratio by permeation "R_p" from the wall and retention in the vacuum vessel "R_r" are also introduced in the model.

In the steady-state tritium balance, the total numbers of tritium in the main plasma and the balance of fueling and pumping are expressed as

$$N = \tau_c(\alpha S_F - S_L) + \tau_e[S_R + (1-\alpha)S_F] \quad , \qquad (1)$$

$$f_{pump}\Phi_{div}(1-R_r) = S_F - S_L - \Phi_{div}R_r \, , \qquad (2)$$

$$\Phi_{div} = S_F - S_L + S_R \, , \qquad (3)$$

where S_F is the fueling rate in the main plasma, and S_R is the recycling rate, f_{pump} is the divertor pumping fraction, Φ_{div} is the particle fluxes to the divertor plates. In this report, since particle balance in a steady-state operation with the fixed number of particles is discussed, the divertor pumping fraction is fixed at 5% in this model.

We introduce the tritium balance considering the tritium processing systems for the exhaust gas and the blanket expressed as

$$S_F = f_{pump}\Phi_{div}(1-R_r)(1-R_{P_w})R_T + (TBR)S_L(1-R_{P_B})\gamma_T \, , \qquad (4)$$

where R_T and γ_T are the recovery ratio for tritium processing system and the blanket tritium recovery system, and R_{Pw} and R_{PB} are the permeation ratios from the wall and assumed to be almost equal (R_P~R_{Pw}~R_{PB}). For the analysis of tritium balance in a steady-state condition, S_F and S_R are derived from Eqs. (1) through (3). The relation between α and R_T is then estimated from Eq. (4).

Figure 2 plots the analytical results of the dependence of the tritium recovery ratio in the tritium processing system as a function of the fuel efficiency of pellet injection. These parameters are shown in the figure. A high tritium recovery ratio for the tritium processing system is required with a decrease in the fuel efficiency of the pellet injection. For TBR = 1.08, a fuel efficiency of more than 0.68 is required to maintain the tritium balance under these assumptions. The tritium recovery rate in the tritium processing system and the fuel efficiency of pellet injection must be as high as possible in order to achieve tritium balance in a fusion reactor within acceptable loss rate. In other words, analysis indicates that the design parameters in the core plasma and blanket are key factors in the tritium fuel cycle.

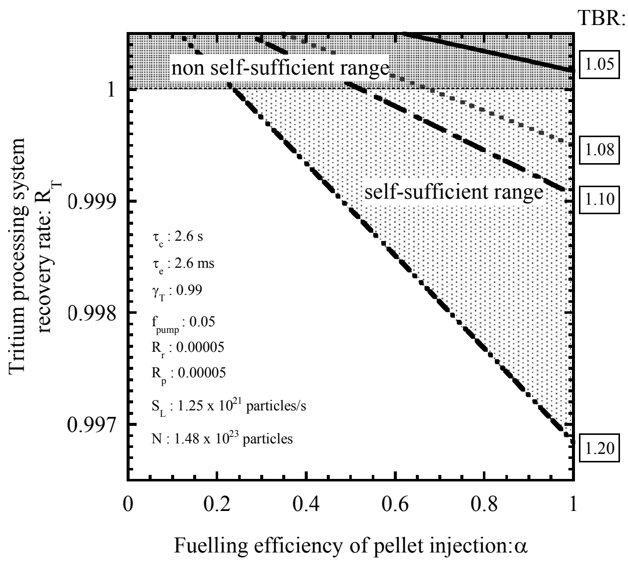

Fig. 2. An example of dependence of tritium recovery rate in the tritium processing system as a function of the fuel efficiency of pellet injection for FFHR2m2.