2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Remarks on DD start-up of a fusion reactor

K. Miyamae[1], H. Yamada[1,2], R. Kasada[3]
[1] Graduate school of Frontier Sciences, The University of Tokyo,
[2] National Institute for Fusion Science, National Institutes of Natural Sciences,
[3]Institute for Materials Research, Tohoku University
e-mail: miyamae.kento18@ae.k.u-tokyo.ac.jp

Initial loading of tritium in a fusion reactor is a serious issue because of availability of tritium. The natural abundance of tritium is almost zero, and resource produced by HWR (Heavy Water Reactor) is limited to several tens kilogram worldwide. Thus, the start-up only from deuterium has been attracting interests. While the previous research of this DD start-up scenario [1] showed the technical feasibility of this scenario, the model of energy confinement was so simple that temperature is assumed constant during the start-up. It should be noted that temperature changes during the start-up phase due to the dependence of energy confinement on the fusion power heating as well as the isotope effect by the build-up tritium concentration. In the present model, evolution of temperature consistent with power balance including radiation losses and an empirical scaling of an energy confinement time has been integrated.

Operational parameters are based upon the recent tokamak fusion DEMO design by the Joint Special Design Team [2]. Plasma temperature is assumed uniform through plasma for now, and is calculated from the relation

$$T = W_p / (3\mathrm{k} V_p \langle n \rangle)$$

where V_p is the plasma volume (m^3), $\langle n \rangle$ is the volume averaged density, and W_p is the plasma thermal energy (MJ).

W_p and accumulation of tritium are calculated using the idea of stock and flow of a system dynamics model. In the model, inflows to the W_p are the alpha heating and NBI heating of 61.9MW; outflows are bremsstrahlung radiation, cyclotron radiation, and the loss due to energy confinement. For energy confinement time, the ITER-98P(y,2) scaling has been used [3],

$$\tau_E = 0.0562 I_p^{0.93} B^{0.15} P^{-0.69} n^{0.41} M^{0.19} R^{1.97} \varepsilon^{0.58} \kappa_a^{0.78}$$

, where I_p, B, P, n, M, R, ε and κ_a are plasma current in MA, magnetic field in T, density in $10^{19}\mathrm{m}^{-3}$, mass number of fuel ions (AMU), major radius in m, inverse aspect ratio and elongation, respectively. The mass number is traced by $(2n_D+3n_T)/n_e$, where n_e is fixed at $5.27\times10^{19}\mathrm{m}^{-3}$. Fusion cross sections are calculated by polynomial approximation based upon the well-used model [4].

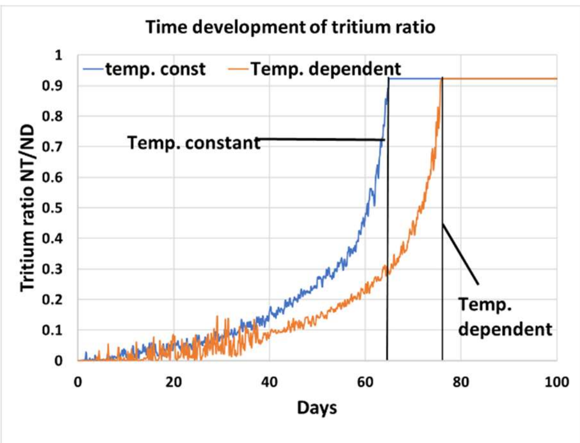

Figure 1. Time development of tritium ratio n_T/n_D

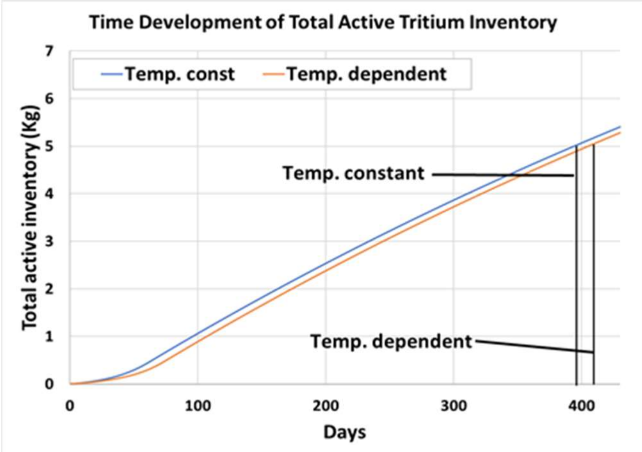

Figure 2. Time development of total active tritium

Temporal development of tritium ratio in a plasma is compared between the temperature dependent model and the temperature constant model in Fig.1. In the case of the temperature dependent model, the tritium concentration reaches to the equilibrium state in 76 days, which is 10 days later than the temperature constant model. Figure 2 shows the development of tritium inventory in a plant. Consequently, it takes 405 days to secure 5 kg, which takes also 10 days more time than the case of constant temperature.

The temperature and the density profiles are assumed to be uniform in the present model. Also, isotope effect on energy confinement and transport could be more pronounced than in the scaling expression. The impact of effects of profile and isotope effect will be discussed.

This work is supported by the JSPS KAKENHI Grant Numbers JP17H01368 and the National Institute for Fusion Science grant administrative budgets (NIFS18KLPP051).

References

[1] R.Kasada, S.Kwon, S.Konishi, Y.Sakamoto, T.Yamanishi, K.Tobita, Fusion Eng. Design **98-99** (2015) 1804.
[2] Y.Sakamoto, M.Nakamura, K.Tobita, H.Utoh, Y.Someya et al., Fusion Eng. Design **89** (2014) 2440.
[3] ITER Physics Basis, Nucl. Fusion **39** (1999) 2137.
[4] H.-S.Bosch, G.M.Hale, Nucl.Fusion **32** (1992) 611.