§23. Feasibility of Reduced Tritium Circulation in the Heliotron Reactor by Enhancing Fusion Reactivity Using ICRF

Yanagi, N., Sagara, A.,
Shyshkin, O.A. (Kharkiv "V.N. Karazin" National Univ.)

Handling of tritium is one of the most important technological issues for realizing fusion power plants. Since the burning ratio of the presently designed deuterium-tritium (D-T) fusion reactors remains in a couple of percentage level, a large amount of tritium should be recovered from the vacuum vessel and constantly circulated in the reactor system. A big concern is the permeation and retention of tritium within the vacuum vessel and circulation plumbing. Moreover, unless the recovery rate is close to 1, it would be very difficult to obtain the sufficient tritium breeding ratio (TBR). In this respect, it would be useful if the D-T reactivity is enhanced by applying high-power Ion Cyclotron Range of Frequency (ICRF) waves for producing high-energy tails accelerated by wave-particle energy transfers.[1]

We examine an enhancement of fusion reactivity in the power balance equation by including high-energy components of tritons. For this purpose, we crudely assume that the high-energy component can be expressed by a Maxwellian distribution function having an effective temperature.[2] As shown in Fig. 1, if the high-energy temperature is 10 times the temperature of bulk deuterons, the fusion reactivity is found to be ~10 times the value without having a high-energy component, in the energy range of deuterons lower than ~10 keV.

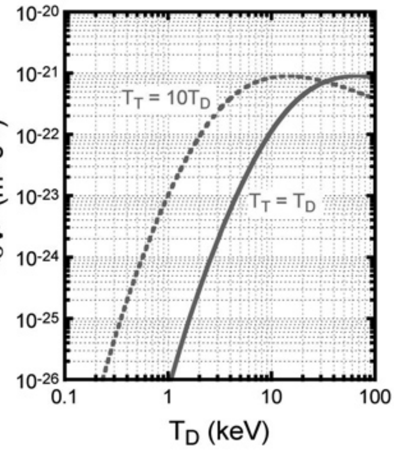

Fig. 1 Enhancement of fusion reactivity by having high-energy tritons with 10 times the temperature of bulk deuterons. The horizontal axis is taken as the bulk deuteron temperature.

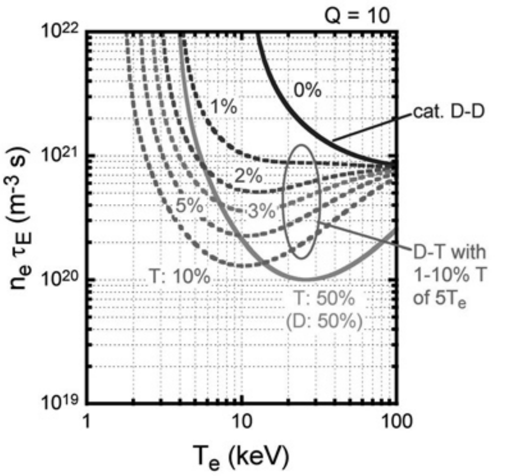

Fig. 2 Ignition condition with high-energy component of tritons having 5 times the temperature of bulk deuterons and electrons. The *Q*-value is assumed to be 10.

Using the enhanced fusion reactivity in Fig. 1, we then solve the power balance for the D-T fusion reaction, and the result is shown in Fig. 2 for the tritium fractions of 1, 2, 3, 5 and 10%.[2] Here the *Q*-value is assumed to be 10. We observe that there is a significant reduction for the required density, energy confinement time and bulk temperature compared to the standard case for the 50%-50% D-T ratio with $Q = \infty$ (self-ignition).

In order to examine the feasibility of having the generation high-energy tritons using minority ICRF heating, we examine the ξ-parameter derived by T.H. Stix. We found that it reaches up to ~9 under the condition of electron density: 0.8×10^{20} m^{-3}, tritium ratio 5%, energy confinement time: 2.4 s, electron temperature: 6 keV, and the volume averaged ICRF power: 0.2 MW/m^3. This value of the ξ-parameter gives the effective temperature of tritium ~10 times the bulk deuteron temperature. However, we also found that the *Q*-value reaches only 5 in this case. In another condition, we find that *Q* reaches up to 10 but this is still not sufficient. These results suggest that we need to consider some more improvement to make this scenario attractive and practical. In our further analysis, we also need to incorporate more precise analysis, such as the test particle calculation.[3] On the other hand, we consider that the application of ICRF heating could be used for producing tritium in D-D operations in order to start up a D-T reactor without an external supply of tritium loading.

1) E.A. Chaniotakis, D.J. Sigmar, Nuclear Fusion 33 (1993) 849.
2) Yanagi, N. et al., to be published in Plasma and Fusion Research.
3) Shyshkin, O.A. et al., to be published in Plasma and Fusion Research.