

BURNING CRITERIA FOR D-³He ST REACTOR

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Fusion reactors using D-³He fuels are attractive because of significantly reduced neutron and the elimination of tritium fuel. In early works for D-³He tokamak reactors, peaked the temperature and the density profiles have been considered. The plasma current with the bootstrap current fraction of 100 % is preferable for the steady state tokamak operation. So, it can be considered that the steady state tokamak reactor has internal transport barrier. This paper will present the criteria for D-³He tokamak reactors using the energy and the particle balance equations. Considering recent improvements of tokamak research, new assumption of this paper are as follows: (1) the temperature and density profiles are ITB type; (2) the bootstrap current fraction is 100 %; (3) the confinement time (τ_E) is γ_{HH} times of IPB98(y,2) scaling; (4) the particle confinement time (τ_p) is $\tau_p \sim 2 \tau_E$. Equations are solved numerically starting from the initial condition as $n_{e0} \sim 2 \times 10^{20} \text{ m}^{-3}$ and $T_{e0} \sim 80 \text{ keV}$ with give fueling rate of D and ³He. When the system is stable, the density and the temperature settle down to steady state.

When the ³He density is 25% of whole ion density the lowest T_i/T_e that is about unity can be obtained. In most cases the hot ion mode ($T_i/T_e > 1$) and the high central beta are required for the steady burning D-³He reactor. As the impurity density increases the required T_i/T_e increases. The T_i/T_e should be larger than 1.6 if the fraction of carbon density is 3 %. In order to operate D-D reactor or low-neutron D-³He reactor, it is required $T_i/T_e > 2$ even if no impurity other than ash remains. The required T_i/T_e ratio is almost constant in the wide range of major radius (R). In a D-³He reactor, the radiation loss (Bremsstrahlung and the synchrotron radiation) is the major energy loss mechanism. The alpha heating power increases as the T_i increases and the radiation loss power decreases as the T_e decreases. Therefore the hot ion mode is necessary to obtain the steady burning D-³He reactor.

Traditionally, the beta value has been considered as the most important parameter for the D-³He reactor. In order to increase the alpha heating power, the beta or the toroidal field (B_t) should be increased. In this calculation, as the B_t increases, the required central beta (β_0) reduces. As the radius of the ITB foot-point reduces with $\beta_0=1$, the averaged beta decreases, and the required γ_{HH} increases to obtain burning plasma. However, no lower limit of the foot point radius. Therefore the averaged beta is not important, but high β_0 ($\beta_0 \sim 1$) is required to burn D-³He plasma. As the γ_{HH} increases, the required B_t and R are reduced. From the view point of reactor engineering, the coil field (B_{coil}) is more important than the B_t . The D-³He reactor requires two times higher coil field and γ_{HH} than the D-T reactor, but the output power is half.

In order to obtain ST D-³He reactor, some improvements are required in the coil field, the confinement improvement factor and the central beta. The most critical condition is the hot ion mode ($T_i/T_e > 1$).