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Lモード境界負三角度トカマク炉における高磁場と高閉じ込めの影響

Impact of High Field and High Confinement on Negative Triangularity Tokamak Reactor with L-mode Edge

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Negative triangularity tokamak (NTT) is a unique reactor concept based on the "power handling first" philosophy [1,2]. Long-leg divertors are located at large-major-radius outboard side to maximize heat exhaust surfaces. The conceptual design of the NTT reactor with L-mode edge has been developed by our informal international collaboration. We report here the present status of the NTT reactor design.

Current standard concept for tokamak reactor is D-shaped plasma with H-mode under the "plasma confinement first" priority. However in the H-mode operation, huge transient heat load due to ELMs is a crucial issue for the reactor divertor in addition to the large stationary heat load. In contrast, the NTT plasma can be operated with the L-mode edge. Even when the H-mode happens, the pedestal pressure stays several times lower than that of standard D-shaped plasma [3]. The improved core confinement under the L-mode edge has been studied actively in TCV NTT plasmas [4]. Recently, DIII-D made a ground-breaking experiment in the NTT configuration demonstrating $H_H = 1.2$ and $\beta_N = 2.6$ simultaneously with L-mode-like edge [5].

Previously it was widely suspected that the MHD stability limit of NTT is low due to its magnetic hill nature. Contrary to this suspicion, we found that the NTT plasma becomes rather high $\beta_N > 3$ by optimizing the pressure profile without large pedestal [6]. Afterwards we proposed a DEMO reactor of single-null NTT, which was based on the conservative guidelines for physics and engineering [7]: $R = 9$ m, $a = 3$ m, $I_p = 21$ MA, $B_t = 5.9$ T ($B_{max} = 13.6$ T), $\kappa = 1.8$, $\delta_u = -0.4$, $\delta_l = -0.9$, and $n/n_{GW} = 0.85$. With a moderate confinement improvement of $H_H = 1.1$, a fusion power of $P_F = 3$ GW ($q_N \sim 1.4$ MW/m^2) is deliverable at $\beta_N = 2.1$ which is much smaller than no-wall limit $\beta_N = 3.1$.

In order to reduce the reactor size, we studied the impact of high field and high confinement [8]. If B_{max} can be increased up to 16 T, R is reduced to 7 m by keeping $H_H \sim 1.1$ and $I_p \sim 20$ MA. β_N is kept ~ 2, but P_F is increased up to ~ 3.5 GW. Especially the neutron wall load becomes quite high $q_N \sim 2.6$ MW/m^2. On the other hand, by improving H_H up to ~ 1.5, R and I_p can be reduced to 7 m and 15.4 MA, respectively, without increasing B_{max} (Fig. 1). β_N is increased to ~ 2.8, but P_F is decreased to ~ 2 GW ($q_N \sim 1.5$ MW/m^2). For further capability of the power handling, the flux-tube-expansion divertor [9] is introduced to the NTT reactor design.

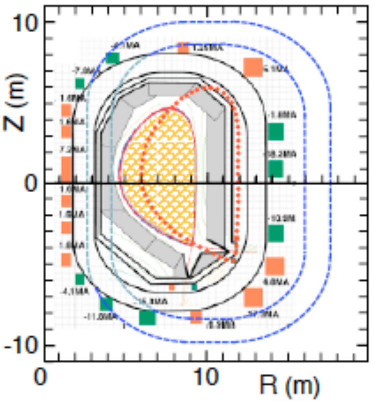

Fig. 1 Compact NTT reactor of $R = 7$ m compared with conservative one for $R = 9$ m [8].

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