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L-mode-Edge Negative Triangularity Tokamak (NTT) Reactor

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Present paper gives reactor concept using L-mode edge based on negative triangularity tokamak (NTT) configuration providing merits of no (or very weak) ELM, larger particle flux and large major radius for power handling. It is shown that a reasonably compact (R_p from *9m* to *7m*) NTT reactor is possible by utilizing reasonably higher magnetic field and higher confinement improvement.

1. Importance of L-mode edge operation

"NTT" [1-3] is a unique reactor concept based on "power-handling-first" philosophy by locating long-leg (~2.7m) divertor at outboard side with negative triangularity $\delta<0$ and making flux tube expansion to maximize heat exhaust surfaces (grazing angle $\sim 2^o$). Negative triangularity makes this configuration a magnetic hill but both the Mercier stability and low-n ideal MHD stability analyses showed that plasma with $\beta_N>3$ can be stable for both double null [2] and single null [3] divertor configurations while local edge beta limit is low so that ELM energy loss is small even if H-mode occurs. Experiments on TCV and DIII-D show that NTT can operate at reactor relevant improved confinement with L-mode edge. Especially DIII-D[4] demonstrated $H_H=1.2$ at $\beta_N=2.6$ with L-mode edge which meets the design requirement of NTT reactor. Demonstration of NTT improved confinement in different size will make it possible to extrapolate to the reactor. This improved confinement is thought to be due to stabilization of collisionless TEM by negative triangularity as well as high β_p operation. Configuration design of NTT has been made and the racetrack shaped TF coil is found to be effective to allow flexible NTT shape control with reasonable PF AT $\Sigma I_{PF}[A*t]/I_p[A]=6.8$[3]. Growth rate of vertical instability is similar to ITER value $\sim 14s^{-1}$ by locating 6cm thick steel wall at $a_w/a=1.3$. We show impact of high B_t and H_H on size reduction of NTT reactor.

All past reactor designs are based on the H-mode operation. Question has been cast on the feasibility of H-mode for reactor operation mode considering difficulty in controlling transient and inter-ELM heat fluxes [1]. L-mode is a robust operation mode and free from the dangerous edge bootstrap current in H-mode. It also provides much larger particle flux than H-mode necessary to form cold & dense divertor (i.e. neoclassical particle flux in H-mode is too small [1]). It is known that SOL density is necessarily high in cold & dense or detached divertors. In this regime, degradation of H-mode confinement has been observed due to reduced temperature gradient. NTT L-mode edge operation is robust since necessary confinement improvement does not rely on edge pedestal.

2. Impact of High Field Magnet and High Confinement to NTT reactor

Our previous design ($I_p=21MA$, $A=3$, $R_p=9m$, $H_H=1.12$, $B_t=5.86T$) [3] uses standard magnet design based on the wedge support and maximum field is limited to *13.6T* due to stress limit *800MPa* and large reactor size (Fig.1 a)). It allows adoption of currently available Nb_3Sn superconductor at *4.5K* as well as B_i2122/P_b high T_c superconductor at *20K*. Parameter studies on impact of high B_t and H_H for $A=3$, 3.5 are done while $H_HI_pA=69.3MA$, $n/n_{GW}=0.85$ and $q_{cy}=3.5$ are fixed [5] which provides more compact reactor design is possible as shown in Fig. 1 b).

References

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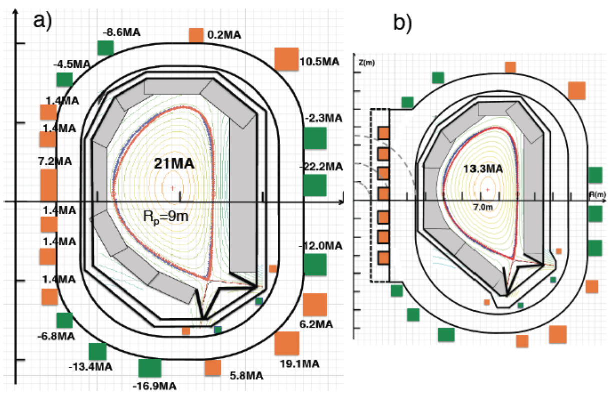

Figure 1 Cross sections of NTT reactors, a) moderate field (13.6T) and b) high field (15.5T). Parameters of b) are $I_p=13.3MA$, $B_t=7.53T$, $n=0.9$ x 10^{20} m^{-3}, $P_F=1.9GW$, $B_{max}=15.5T$, $P_{CD}=115MW$ ($\eta_{CD}=0.5$ x 10^{20} A/m^2W is assumed).