§2. Ignition Study on the Compact FFHR Helical Reactor

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FFHR reactor has been designed for the range of the large major radius of 14~16 m. This is about four times larger than the present LHD system (R=3.6 m). It might be difficult to proceed to such larger size by one step from the engineering point of view. In order to avoid engineering risks, we are considering the medium size machine with the major radius of 8~9 m (FFHR-C) which is 2~2.5 times larger than LHD, and studying its ignition characteristics. Although we have studied two operation regimes such as thermally stable and unstable regimes, we only described on the thermally unstable operation in this report.

In Fig. 1 is shown the temporal evolution of high-density operation in FFHR-C with the R=9m, a_{eff}=1.5m (3.6m/0.6mx2.5), B_o=6 T, the fusion power of P_f=0.85 GW, the confinement factor over ISS95 scaling of γ_{ISS}=1.60 (γ_{LHD}=1.0), τ_p*/τ_E=3, $\tau_\alpha*/\tau_E$=4, and alpha heating efficiency of η_α=98 %. The density profile is assumed to be peaked with α_n=3 and the temperature profile parabolic. The heating power of 50 MW was initially applied, and then reduced to zero by preprogramming, leading to ignition. This is the minimum fusion power with ignition for γ_{ISS}=1.60. While a larger fusion power is possible in this reactor, the heating power should be applied to maintain the smaller fusion power than this value. Therefore it is difficult to maintain the sub-ignited operation in the high- density regime using the 1MeV NBI injection. The neutron wall loading is 1.1 MW/m^2 and the density is 6.8 x10^{20} m^{-3}, $T_i(0)$=9.0 keV, f_α=3.4 %, <β>=2.6 %(at 60s), τ_E=1.9s and the divertor heat flux for 10 cm width at the right angle to the magnetic field line is 10.1 MW/m^2 in the steady state.

In Fig.2 is shown the operating path on POPCON corresponding to Fig. 1. It can be clearly seen that the operating point proceeds to the low temperature and high-density thermally unstable operating regime. As the fusion power is small as 0.85 GW, the operating point exists near the lower ignition boundary. Therefore, for the smaller fusion power the ignition does not exit.

A smaller device such as R=8 m is also possible, but the ignition parameter regimes is narrow. Therefore, slightly larger machine with 9m reactor has been actively investigated. The magnetic energy is as small as 28 GJ (=160 GJ (9/16)^3). As this value is slightly smaller than that in ITER, construction might be feasible. If the magnetic field were increased to 7 T, operation regime would be expanded. Even when the confinement factor is reduced to 1.3~1.4, ignition is possible.

However, as the blanket space is not enough for breeding tritium especially in the inboard side of the torus in this machine, only neutron and gamma ray shield is placed. The blanket is placed in the outboard side for testing various types of blankets.

This machine is defined as an experimental reactor aiming at ignition physics and fusion engineering with the partial blanket system, which may reduce the fusion reactor developing risk before construction of a large commercial reactor.

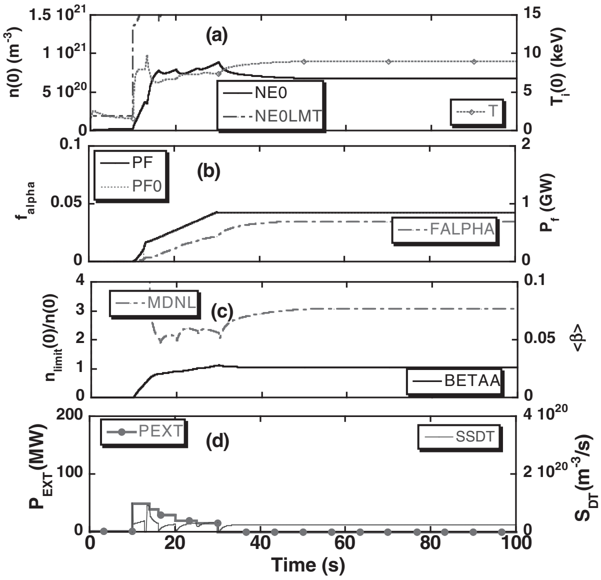

Fig. 1. Temporal evolution of the plasma parameters in FFHR with 9 m. (a) Peak temperature, peak density, density limit, (b) alpha ash fraction, fusion power and its set value, (c) density limit margin, beta value, and (d) D-T fueling rate and the heating power.

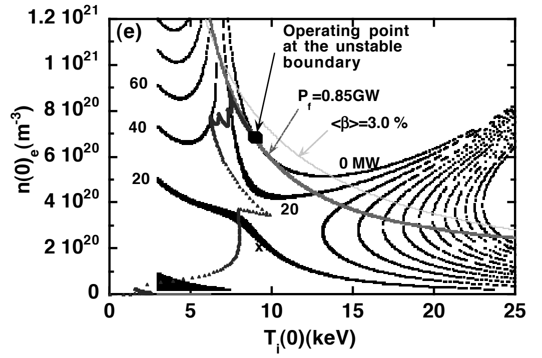

Fig. 2. The operation path to the unstable ignition point on POPCON corresponding to Fig. 1-(a).

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(1) O. Mitarai A. Sagara, N. Ohyabu, R. Sakamoto, A. Komori, and O. Motojima, et al., Plasma and Fusion Research, Rapid Communication, Vol.2 (2007) 021-1-3, and Fusion Science and Technology **56** (2009) 1495.