§3. Study of the Fusion Power Rise-Up, Steady State, and Shutdown Scenarios in Helical Reactors

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When the major radius of the present LHD is scaled up to 14 m with the pitch parameter of γ=1.15, it is possible to meet the minimum requirement for the blanket and shield thickness with 1.2 m. In this report, the fusion power rise-up phase, steady state phase, and shutdown phase are studied in this FFHR2m-1 reactor with the major radius 14 m, the minor radius 1.73m, the magnetic field strength 6.0 T, and the fusion power 1.9 GW.

In the temporal evolution of the plasma parameters where the plasma energy is changed, it is important to take the dW/dt effect into account in the heating power term in the confinement time scaling. The following question arises; In an actual experiment, the scaling is made in the steady state or at the small dW/dt value. Can such scaling be used during the transient phase? Recent examination of LHD data has confirmed that such scaling can be used in the transient phase, which is justified by comparing the experimentally determined confinement time and formulated scalings with P_{net}-dW/dt [1]. In this report, we study this effect in the fusion power rise-up phase and shutdown phases by comparing the scalings with P_{net} and P_{net}-dW/dt. We have confirmed that it is better to use the confinement scaling with the plasma conduction loss P_L=P_{net}-dW/dt, and the density limit scaling with the net heating power P_{net} for the 0-dimensional modeling.

In Fig. 1 is shown the temporal evolution of the plasma parameters in the case of the density limit factor γ_{SUDO} =1.5, the confinement factor γ_{ISS}=1.92(γ_{LHD}=1.2), and 10 % alpha prompt loss. Upon consideration of the discharge initiation by NBI alone, the preprogrammed and step like heating power is applied up to 80 MW, and then the heating power is feedback controlled after 30 sec. The heating power is increased to 100 MW due to the artificial large margin of the density limit (MDNL), and then decreased due to ignition at 100 sec. During the fusion power rise-up phase, the dW/dt effect is not so large, then the difference with/without it is not so large. The temperature is slightly larger in the case of P_L=P_{net}-dW/dt.

The peak density at the steady state is 2.67x10^{20} m^{-3}, the density limit is 10% over the operation density, temperature is 15.8 keV, averaged neutron wall loading is 1.5 MW/m^2. Beta is 3 % which is already achieved in LHD.

The heating power should be applied during the shutdown phase to keep the density limit higher than the operating density. After shutdown (> 250 s), discharge behaviors for the confinement scaling for P_{net} and P_{net}-dW/d are quite different. For the case of P_{net}, the temperature is kept high around 8 keV after shutdown. However, for the experimentally verified case of P_{net}-dW/dt in the confinement scaling, the temperature is decreased to a reasonable value as shown in Fig.1-(a) after 250 sec. This is because that dW/dt<0 provides the larger plasma conduction loss P_L and hence the smaller confinement time after shutdown.

The bootstrap current of ~2 MA is expected in the FFHR2m-1, which should be considered separately for the safe fusion power shutdown.

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References:

[1] J. Miyazawa FFHR meeting 2005, July.

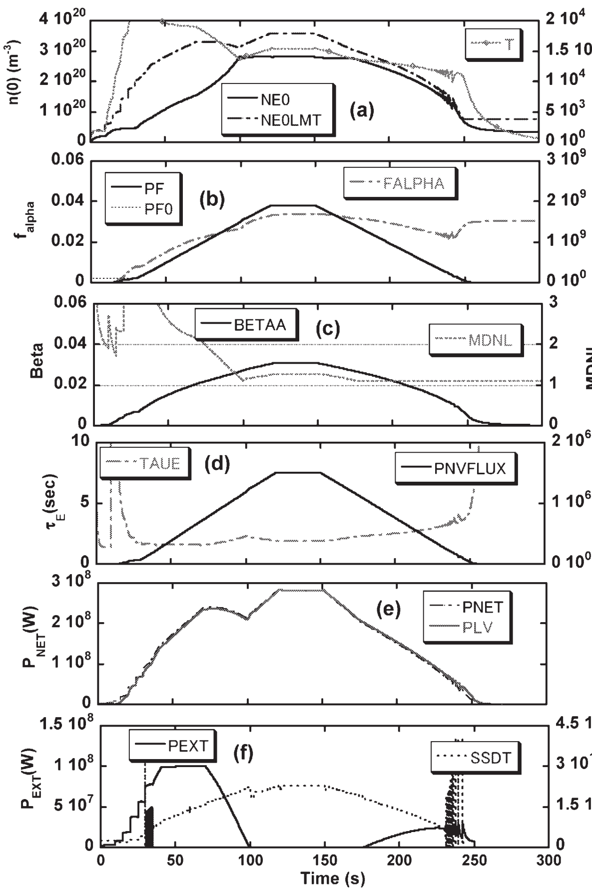

Fig. 1 The temporal evolution of the plasma parameters for the confinement scaling with P_{net}-dW/dt in FFHR2m-1.