§9. Study on the Characteristics of Ignition Shutdown in FFHR

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i) Introduction

Although the feedback control method of the heating power during ignition access to the thermally unstable operation point has been discovered for FFHR[1], the fueling is continuous and then it does not show the actual behavior of a reactor operation. Discrete fueling such as pellet injection may provide the similar behavior to the actual situation [2]. As the thermally unstable operation depends on the pellet injection system, the fusion power should be shut down immediately if it has a failure. Therefore shutdown studies are very important in the thermally unstable operation. In this annual report, we study the shutdown behavior of the normal steady state discharge prior to the abnormal shutdown studies.

ii) Calculated results on shutdown phase

In Fig.1 is shown the temporal evolution of the various plasma parameters in FFHR2m2 with R=15.7 m, a_{eff}=2.5 m, B_o=4.5 T, P_f=3 GW, γ_{ISS95}=1.43, $\tau_p{}^*/\tau_E$=3, and $\tau_p{}^*/\tau_E$=4 for the discrete fueling. The density profile is α_n=3 and the temperature profile is α_T=1. After 75 sec, the temperature limit is set to T_c=5.5 keV from 7.5 keV for applying the heating power to cope with the sudden confinement change and impurity influx. When shutdown of of the fusion power is started from 110 s to 115 s, the temperature ratio $T(0)/T(0)_{lim}$ is increased, and then the heating power is automatically applied as shown in Fig.1. Although the H-L transition is not expected in a helical reactor as like in a tokamak, it is not necessary to apply the heating power to keep it. Therefore, we study the effect of the heating power on the shutdown characteristics.

In Fig.2 is shown the detailed behaviors of the fusion power shutdown phase when this control algorithm is used. Many discrete fueling pulses were applied to keep the fusion power to the set value. Therefore the fusion power is linearly decreased (Fig.2 left).

When the heating power is artificially switched off during the shutdown phase, the discrete fueling was stopped due to the smaller fusion power than the set value as shown in Fig.2 (right). (This comes from the unstable control algorithm). However, nothing happens, and the fusion power decreases faster than the set value. It is thus found that the heating power can be switched off during the fusion power shutdown phase. When the shutdown time is shorter than 2 sec, the bremsstrahlung loss power increases due to discrete fueling. Thus the shutdown time should be around 5 sec.

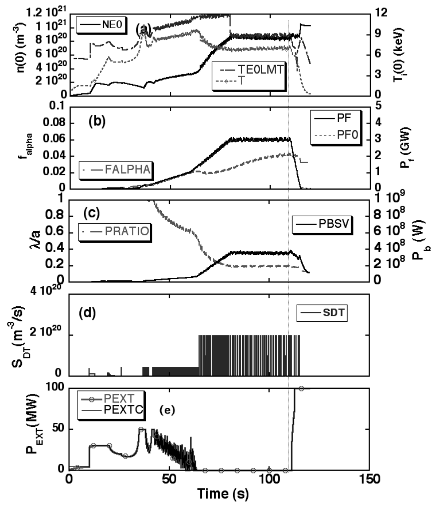

Fig.1 Temporal evolution of plasma parameters in FFHR including the shutdown phase. (a) Density, temperature and temperature limit, (c) Fusion power and alpha ash fraction (c) Bremsstrahlung loss and NBI penetration ratio, (d) discrete fueling waveform, and (e) the NBI heating power.

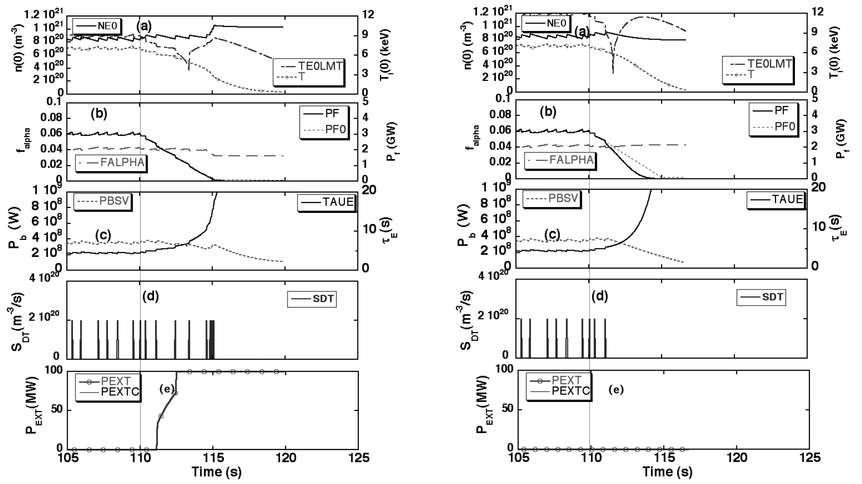

Fig.2. Detailed behaviors of fusion power shutdown phase in FFHR with discrete fueling case. Left: with the heating power (the same as Fig.1). Right: without the heating power. Notations in (a)-(e) are the same as in Fig. 1.

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1) O. Mitarai, et al., Fusion Engineering and Design **88** (2013) 1046–1049

2) O. Mitarai, et al., in Fusion Energy and Power: Applications, Technologies and Challenges, (2015) Nova Science Pub.