§ 1. Optimization of the Burning Plasma in Helical Reactors

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We have surveyed physics plasma parameters including the machine size in order to optimize the ignited plasmas in FFHR reactors. Although "optimization in a helical reactor is a controversial problem, for achieving the large Q value ($Q=P_f/P_{EXT}$= fusion power/heating power) and ignition, we have conducted the sensitivity analysis of the plasma parameter on the machine size R/a, the magnetic field strength B_o, the confinement enhancement factor γ_{HH} over the ISS95 scaling, and alpha particle confinement fraction η_α (=0.7~1.0).

We have used the following two reactors:

[1] FFHR power generation demo-reactor with R=10 m, a=1.0 m, B_o=10 T, and P_f=1 GW,

[2] FFHR commercial reactor with R=15 m, a=1.8 m, B_o= 6 T and P_f= 3 GW.

In this calculation, the heating power is applied so as to keep the density limit over the operating density based on the LHD experiments.

In Fig.1 are shown the dependencies of the operation density and the inverse Q on the confinement enhancement factor for FFHR demo-reactor with R=10 m, a=1.0 m and B_o=10 T, for η_α=0.7~1.0 (Alpha confinement fraction is shown in Fig.1) and P_f=1 GW. As the magnetic field strength is large in FFHR demo-reactor, the confinement time is long and hence ignition is possible. The confinement factor γ_{HH} (x-axis) required for this reactor is only slightly larger than 1.6 achieved in LHD. It has been seen that the required confinement factor for ignition strongly depends on the confinement fraction of high energy alpha particles (the prompt alpha loss fraction). As the FFHR demo-reactor is compact, the high density operation around 3~5x10^{20} m^{-3} should be done to obtain 1 GW. As the high density plasma of 3x10^{20} m^{-3} has been already achieved in W7-AX, such high density of 3~5x10^{20} m^{-3}might be possible in the FFHR demo-reactor.

In Fig.2 are shown the dependencies of the operation density and the inverse Q on the confinement enhancement factor for the FFHR commercial reactor with R=15 m, a=1.8 m and B_o=6 T for η_α=0.7~1.0 and P_f= 3GW. Although the magnetic field strength is weaker, it is possible to operate in the low density of 3x10^{20} m^{-3} because the confinement time itself is long due to the large machine size. It is also seen that the high energy alpha particle confinement fraction has a large influence on ignition. Therefore, it is important to study how much fraction of the high energy alpha particle is confined. It should be evaluated the point where the alpha loss takes place and how much is lost in order to estimate the heat flux to the first wall accurately.

In addition, it may be possible that the bootstrap current of 1~6 MA appears in these FFHR demo and commercial reactors. Therefore, its influence on the high energy particle confinement should be taken into account.

Although it is necessary to know the magnetic field profile in a helical system, it is a time consuming to calculate the magnetic field configuration in each case with the different coil size. If the size similarity is taken into account based on the present LHD system (R=3.9 m, a=0.6 m and B_o=3 T), it is relatively easier to calculate the magnetic field profile and the maximum field in a LHD type magnetic field configuration. In this respect, the physics design can be done relatively simply for FFHR reactors with the major radius of R= 10 m with the 2.5 times and R= 15 m with 4 times larger than that in the LHD system. Further detailed studies are needed with collaboration.

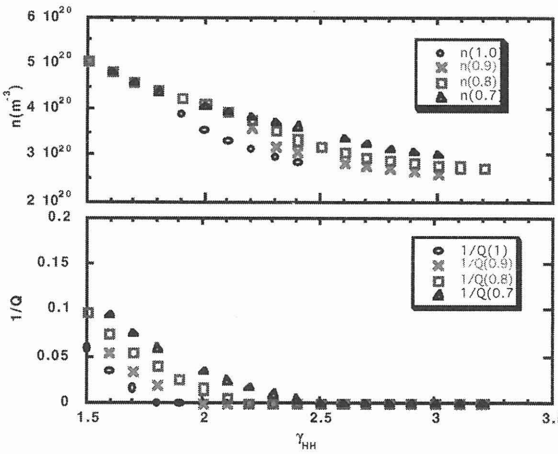

Fig.1. Ignition characteristics in the FFHR with R=10 m

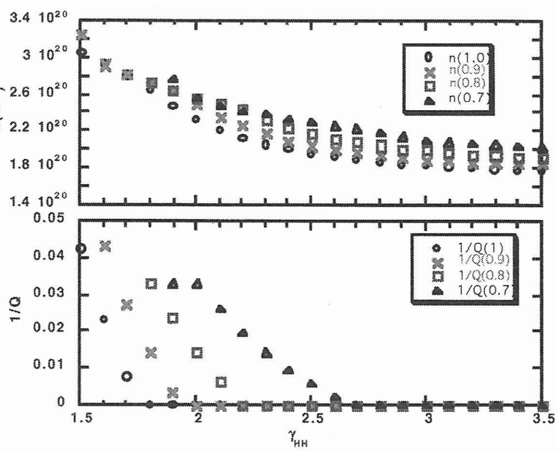

Fig.2. Ignition characteristics in the FFHR with R=15 m