§1. Study of the Plasma Physics Issues in the Burning Plasma in Helical Reactors

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Based on the inwardly shifted plasma of R=3.6 m in LHD (a=0.6 m, B_o=3 T), where the best confinement has been achieved so far, we have determined the FFHR reactor size using the LHD size scaling for taking the blanket thickness into account, and conducted the sensitivity analysis of the ignition on the machine size R/a, the magnetic field strength B_o, the confinement enhancement factor γ_H over the ISS95 scaling, and alpha particle confinement fraction η_α(=0.7~1.0). Ignition is described by the Q value ($Q=P_f/P_{EXT}$= fusion power/heating power). In addition, we have surveyed the possibility of a D-^{3}He helical reactor. For both studies, we have used the FFHR reactor with R=14.47 m, a=2.58 m, B_o=6 T and the blanket thickness Δ_B=0.93 m

In Fig.1 are shown the temporal evolution of the plasma parameters in the FFHR with complete alpha confinement of η_α=1 and the fusion power of P_f=3 GW. Ignition is reached with γ_H =1.6 (without any confinement improvement compared to the present LHD) because the external heating power of 70 MW is reduced to zero at ~60 s. The beta value is β=2.8 %, which has been already achieved in LHD. It is seen that the parameter range has a more room for ignition because the heating power is quickly dropped before the fusion power rise-up time. In this case when the impurity contents are increased from Z_{eff}~1.36 to 2, ignition is still possible. If the alpha particle is confined 100 %, it is found that the ignition is possible within the present database in this FFHR.

As the experimental result on the helium ash exhaust such as the helium particle confinement time τ_α* is lacking in a present helical experiment, it is yielding the uncertainty in the helical reactor conceptual design study. In Fig.2 are shown the dependencies of the inverse Q, supplied and net consumed tritium and deuterium quantities to generate 3 GW fusion power for 24 hours on the helium ash particle confinement time to the energy confinement time ratio τ_α^*/τ_E. It is found that ignition exists for $\tau_\alpha^*/\tau_E \leq 7$. Here, as we are assuming $\tau_\alpha^*/\tau_E=3$ in this calculation, a more room remains for ignition. On the other hand, while actually consumed D and T quantities are the same due to the fixed fusion power when τ_α^*/τ_E decreases (Fig.2-(c)), supplied and exhausted tritium quantities are both increased (Fig.2-(b)).. It is of safety concern and needs the efficient tritium processing unit. Therefore, it is urgent to measure τ_α^*/τ_E in LHD experiments.

In addition, we have examined the FFHR type D-^{3}He helical reactor with R=14.47m, a=2.6 m and B_o=6 T. The confinement enhancement factor of 3.0 times larger than the present LHD confinement time, the high beta of β~21 %, the heating power of 200 ~300 MW are necessary, and the neutron power is ~50 MW. However, the divertor heat load is as large as 10 MW/m^2 for the divertor plate with 1m wetted width and incident angle of 5.7 degree to the field line.

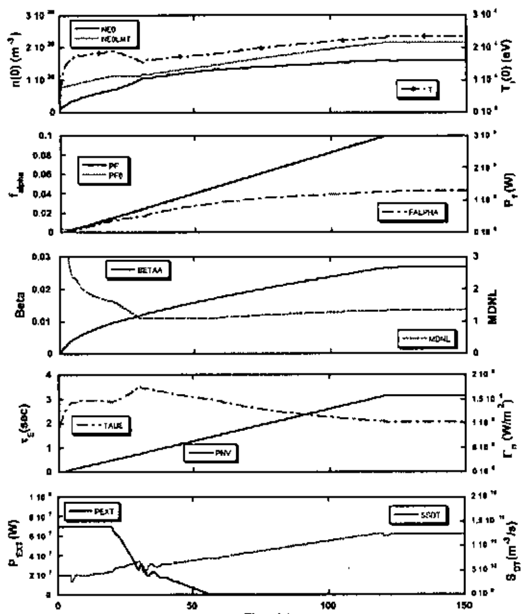

Fig. 1

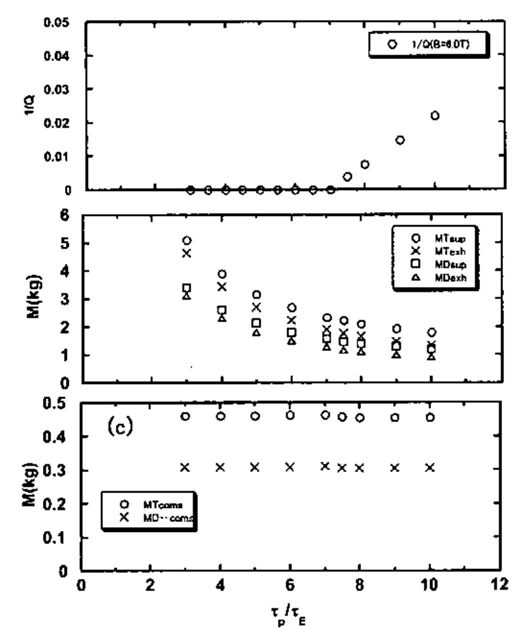

Fig. 2