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Development of Tokamak Reactor System Code and Performance for Early Realization of DEMO

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1. Introduction

To develop the concepts of DEMO and identify the design parameters, dependence on performance objectives, design features and physical and technical constraints have to be considered. System analyses are necessary to find device variables which optimize figures of merit such as major radius, ignition margin, divertor heat load, neutron wall load, etc.

Demonstration fusion power plant, DEMO is regarded as the last step before the development of a commercial fusion reactor in Korea National Basic Plan for the Development of Fusion Energy. The DEMO should demonstrate a net electric power generation, a tritium self sufficiency, and the safety aspect of a power plant. Performance of DEMO for early realization has been investigated with a limited extension from the plasma physics and technology in the 2nd phase of the ITER operation (EPP phase).

2. System Code Development

For the system analyses, we have been developing the system code. The system code finds the design parameters which satisfies the plasma physics and engineering constraints or optimizes the design depending on the given figure of merits. It includes a wide range of effects simultaneously and captures the range of likely outcomes of development in plasma physics and technology. The parameters arising from the system studies will be used as the basis for further development of DEMO conceptual designs. In system code, the mathematical model to capture physics and technologies are overall plant power balance equation and the plasma power balance equation.

For physics modeling, plasma beta limit, plasma current limit, density limit, etc. are used and the plasma power balance equation is represented as

$$P_{con} + P_{rad} = P_{OH} + P_{\alpha} + P_{CD}$$

$$\tau_E = H\tau_E^{IPB98(y,2)}$$

$$\tau_E^{IPB98(y,2)}$$

$$= 0.0562 I_P^{0.93} B_0^{0.15} (P_{con} vol)^{-0.69} n_{19}^{0.41} M^{0.19} R_0^{1.97} (\frac{a}{R_0})^{0.58} \kappa^{0.78}$$

and H-mode IPB98y2 scaling law [1] with the confinement improvement factor, H was used for the energy confinement.

Various engineering constraints such as radial/vertical build, ripple condition, coil critical current density, startup & burn volt-sec capability, stress limit, divertor heat load limit, shield requirements, maximum TF field, etc. are considered.

In system code, n variables (usually, physical parameters or device parameters) are found with given n constraints (physical or engineering constraints), or a set of variables which optimize the given figure of merit (object function) are found. In latter case, number of variables is bigger than the number of constraints.

3. Operational Space of DEMO

As a part of feasibility study for early realization of DEMO, we investigate requirements for ITER-like tokamak reactor 1) to demonstrate tritium self-sufficiency, 2) to generate net electricity, and 3) for steady-state operation.

Performances of DEMO with a limited extension from the improved plasma physics and technology in the 2nd phase of the ITER operation (EPP phase) are investigated. In this study, we chose the size of plasma to be same as that of ITER. To estimate possible plasma performance, the plasma parameters which characterize the performance, i.e. normalized beta value, β_N, confinement improvement factor for the H-mode, H and the ratio of the Greenwald density limit n/n_G are assumed to be improved beyond those of ITER: $\beta_N \geq 2.0$, $H \geq 1.0$ and $n/n_B \geq 1.0$.

Required operational space for the net electric power

The engineering conditions are maximum magnetic field of 13 T, thermal efficiency of 30% and current drive efficiency of 50%. Space of 1.5m for the He Cooled Molten Lithium (HCML) blanket and the shield is allocated to provide a tritium breeding ratio larger than 1.0.[2].

With these conditions, we investigated required operational space for the net electric power and results are shown in Fig. 1. When n/n_B =1.0, β_N > 2.5 and H > 1.05 is required for electric power generation and for the divertor heat load, $H_{div} \leq 15$ MW/m^2. When n/n_B =1.2, net electric power up to 600 MW is possible with β_N > 4.0 and H > 1.2. To access operation space for higher electric power, main restriction is given by the divertor heat load. Both advanced plasma and technology are required to handle high heat load.

With plasma size same as that of ITER, net electric power up to 600 MW is possible with β_N > 4.0, H > 1.and divertor heat load, H_{div} < 15 MW/m^2.

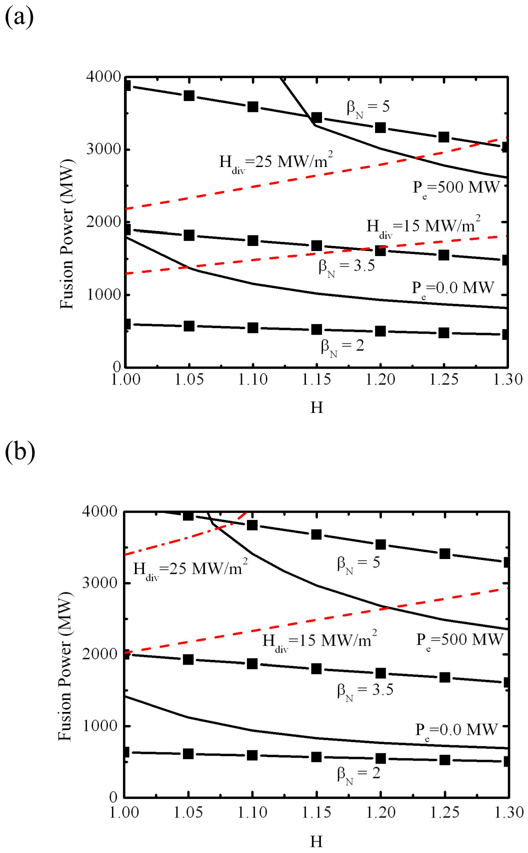

Figure 1 Plasma performance for net electric power (a) in case of $n/n_B = 1.0$, and (b) in case of $n/n_B = 1.2$

4. Conclusion

We have investigated the operational space for early realization of DEMO with plasma size same as that of ITER and with a limited extension from the plasma physics and technology in the 2nd phase of the ITER operation. When $n/n_B = 1.0$, βN > 2.5 and H > 1.05 is required for a net electric power generation and for the divertor heat load. When $n/n_B = 1.2$, net electric power up to 600 MW is possible with βN > 4.0 and H > 1.2. To access operation space for higher electric power, main restriction is given by the divertor heat load. Both advanced plasma and technology are required to handle high heat load.

REFERENCES

[1] ITER Physics Basis, Nucl. Fusion 39 (1999), 2175.
[2] Y. Kim, B.G. Hong and C.H. Kim, “A neutronic investigation of He-cooled liquid Li-breeder blankets for fusion power reactor”, Fusion Eng. And Design 75-79 (2005), 1067.