§15. Consideration on Design Window for a DEMO Reactor

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Discussion beyond ITER is activated in the world, and design of DEMO reactor has been initiated in Japan and Europe. Based on the physical engineering knowledge and the reasonable extension from ITER, the DEMO might be designed and constructed. Here we considered design window for a DEMO reactor from viewpoints of following three issues; i.e., 1) Impact of TF coil design, 2) Feasibility on pulsed operation, and 3) Interrelation between plasma parameters. In this study, we have referred DEMO-CREST design。

The maximum magnetic field strength has a great impact on the tokamak fusion reactor design. Recently, S. Nishio and his colleagues have developed an excellent code for designing TF coils in tokamak. Here we analyzed TF coil of DEMO-CREST. Figure 1 shows the maximum magnetic field strength of Nb_3Al as a function of a major radius. To achieve the maximum magnetic field of 16 T, the major radius of around 7.5 m might be necessary. If the superconductor Nb3Sn is employed, the maximum magnetic field is very limited; e.g., around 1 T lower in Nb_3Sn than that in Nb_3Al.

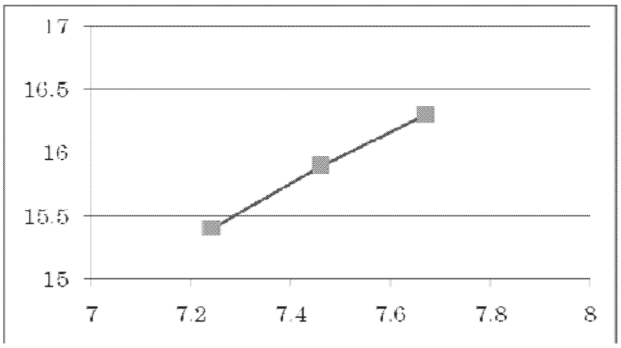

Fig. 1 The maximum magnetic field strength as a function of a major radius for Nb_3Al.

One of the critical issues is a steady-state operation in the ITER, and high performance plasma should be explored in many existing tokamak devices such as JT-60SA and so on. In order to lighten the burden for the steady-state operation in the DEMO, we have studied the feasibility of the pulsed operation for the DEMO reactor by using our system code.

Here we expected a quite long operation period; i.e., 5 hours or more, and the feasibility for the DEMO reactor size has been studied. We have introduced a non-inductively current drive with NBI, so as to prolong the pulse duration. Figure 2 shows the major radius to achieve a 5-hours operation as a function of the non-inductive current drive power. A remarkable decrease of the major radius can be seen as the moderate power is anticipated, and a device with a major radius of R = 8 ~ 8.5 m might become feasible. In addition, Figure 2 also shows that the operation temperature strongly affects the plasma major radius. For example, in case of R = 10 m reactor, without non-inductive current drive, plasma temperature must be 18 keV or more. Meanwhile, with 100 MW of current drive power, the operation at 14 keV is possible. While we should remark that the introduction of non-inductive current drive requires the development of high energy NBI.

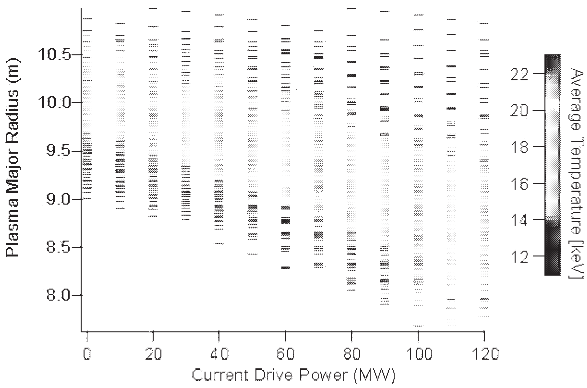

Fig. 2 Plasma major radius as a function of a non-inductive current drive power for different plasma temperature, so as to achieve an inductive operation period of 5 hours.

Operational plasma parameter regimes are sometimes interlinked. Figure 3(a) shows the achieved plasma parameters in the space of the confinement improvement factor HH and the normalized beta value β_N. While, Hiwatari et al. have analyzed an operational space in a wide range of plasma parameters, as shown in Fig. 3(b). If the present data shown in Fig. 3(a) are imposed on the operational space in Fig. 3(b), available design points might be very limited. If β_N*HH = 3, the operation regime is very limited even for the case of Pnet = 0, and there seems no space for the case of Pnet = 1GWe.

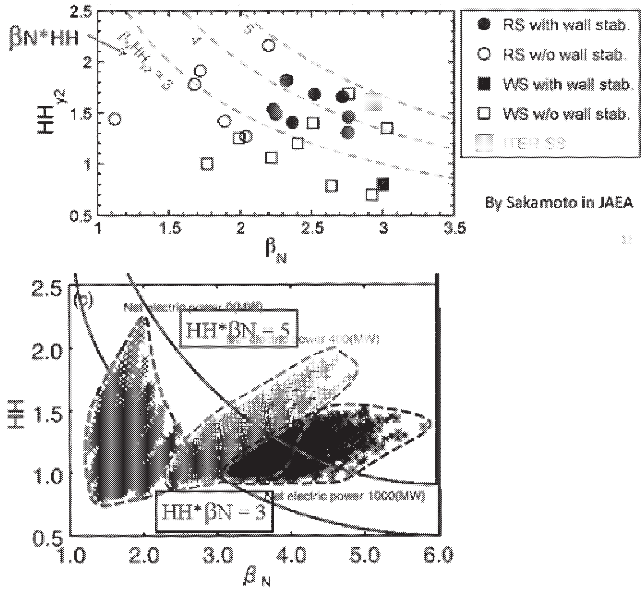

Fig. 3 (a) Experimentally achieved operation parameters in HH and β_N space, and (b) design windows for various plasma and engineering parameters.