§9. System Analysis of Helical Reactor Design Based on LHD

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Helical confinement system has an inherent merit for sustaining current-disruption-free steady-state fusion plasmas by external magnetic field with built-in divertor. For future helical reactors, reliable modular-coil system for easy system construction/maintenance and enough divertor-space for efficient ash exhaust should be required. The Modular Heliotron Reactor (MHR) is designed as an extension of the present LHD (Large Helical Device) physics concept including these requirements.

The design requirements for helical reactors are investigate[1] on (1) confinement improvement and effective helical ripple reduction, (2) plasma density regime and (3) beta limit, comparing with recent LHD (Large Helical Device) experimental data.

In its previous reactor design, about two times higher plasma confinement time than that of the conventional LHD scaling law was assumed, which has already been achieved experimentally as the "New LHD" confinement scaling. One and half times higher density than the conventional helical density-limit scaling law has been achieved, which condition is required in the start-up phase of reactors. Half of beta value required for reactors has been achieved experimentally in the inner-shifted magnetic configuration of LHD experiment. This experimental beta value is beyond the theoretical limit. This configuration might satisfy the high beta (~5%) and low effective helical ripple (<5%) operation required for reactors. Efficient helical divertor action for ash control is also anticipated in LHD-type reactors.

For reactor plasma analysis, radial profile distribution is important, and the 3-D equilibrium and 1-D transport code TOTAL (Toroidal Transport Linkage) has been used for LHD experimental analysis and reactor predictive simulation. Especially, neoclassical and anomalous transports, beta and density limits, radial electric field and magnetic configuration effects are crucial in the prediction of ignited helical reactor plasmas. The typical start-up and burn-sustained operation is analyzed by the TOTAL code in addition to simplified zero-dimensional global plasma prediction coupled with system code analysis.

For the realization of economical helical reactors, the confinement databases are checked and the system analysis has been performed in comparison with tokamak reactors[2)]. As for engineering design of helical and tokamak equivalent reactors, we assumed same thickness of blanket, shied and relevant gaps as shown in Fig.1. The reference magnet system is assumed to be made of Nb_3Sn conductor, and its maximum magnetic field strength is 13 Tesla. The coil current density, coil stress, wall loading and other engineering items are also evaluated. These assumptions and relevant physics/engineering models determine the plasma-coil space and the scale of the reactor system. By these analyses, the importance of re-circulating current-drive power and equipment replacement on cost of electricity are clarified [2].

References
1) K. Yamazaki and the LHD Experimental Group, "Reactor Plasma Design Based on LHD Experiments" Workshop on "Innovative Concepts and Theory of Stellarators (ITCS)" (28-31 May, 2001 Kiev, Ukraine) Th.1-OV
2) K. Yamazaki and the LHD Experimental Group, "Transport Simulation and System Analysis of Helical Reactors Based on LHD Experiments" 13th International Stellarator Workshop (25 Feb.–1 March 2002, Canberra, Australia) OV12

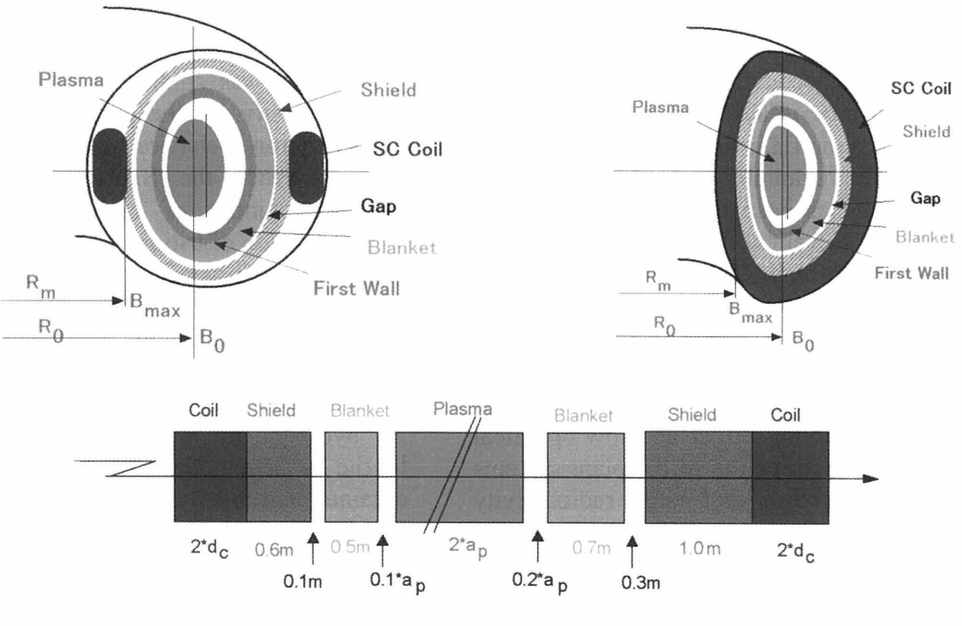

Fig. 1 *Comparative system design for helical and tokamak reactors with same radial build*