§77. Modular Heliotron Reactor (MHR) Assessment

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The physics and engineering optimization studies are carried out for continuous-coil or modular-coil helical reactors based on the Large Helical Device (LHD) concept. Two reactor design candidates (Standard and Compact designs) are selected and the cost analysis suggests the effectiveness of the Compact design option [1].

As for physics design, ignition conditions of D-T burning plasmas in the LHD-type Helical Reactors (LHD-R) are studied using zero-dimensional power balance equations with profile corrections based on several empirical confinement scalings (LHD, gyro-reduced Bohm or Lackner-Gottardi scalings) and neo-classical ripple loss model (combined model of $1/\nu$, $\nu^{1/2}$ and ν regime). The 3-dimensional equilibrium / 1-dimensional transport analysis conformed the effectiveness of the zero-dimensional analysis. The reference magnetic configuration adopted here is based on LHD physics concept with closed helical divertor. The confinement enhancement factor of 2 and density limit factor of 2 (during startup phase only) are assumed in LHD scaling. To reduce neoclassical ripple loss and to ignite DT plasma, the averaged effective helical ripple should be less than 5 %. These results are also applicable to the design of the Modular Heliotron Reactor (MHR).

For engineering design, the system studies including superconducting helical coil analysis are carried out to fit the ignition plasma condition. The magnetic configuration and coil-divertor clearance are evaluated using simplified systematic scalings. The maximum magnetic field (B_{max}<16T) with coil current density (~30A/mm^2) is allowed for Nb_3Sn superconducting coil systems. Neutron wall loading (L_n<3MW/m^2), the coil-divertor clearance (Δ_{dc}>1m) for blanket space, and the coil stress limit (σ_{coil} < 250MPa) should be evaluated. The conditions of total fusion thermal power (P_{fusion} >1GW) and coil magnetic energy (W_{mag} < 500GJ) are also added to the criteria. Among these criteria we found a engineering design window, and selected two options; the standard design (MHR-S) with major radius of 16.5m, magnetic field strength of 5T, and the compact design (MHR-C) with major radius of 10.5m, magnetic field strength of 6.5T. The cost-of-electricity contour for Helical reactors is also obtained, and clarified the effectiveness of the Compact design.

References
[1] K. Yamazaki et al., 16th IAEA Conference on Fusion Energy Conference, Montreal, Canada, 7-11 October 1996, IAEA-CN-64/G1-5.

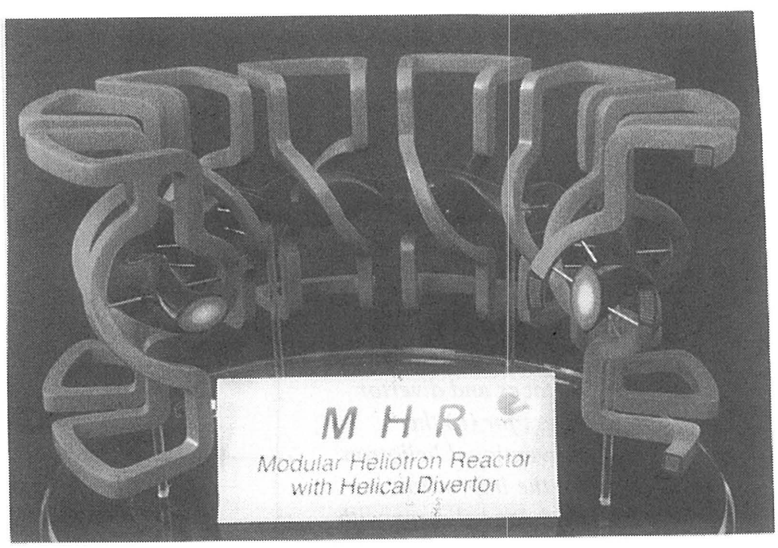

Fig.1 Model of Modular Heliotron Reactor (MHR)