(2) Helical Reactor Design

Due to inherent current-less plasma and intrinsic diverter configuration, helical reactors have attractive advantages, such as steady operation and no dangerous current disruption. In particular, in the LHD-type reactor design, the coil pitch parameter γ of continuous helical winding can be adjusted beneficially to reduce the magnetic hoop force (Force Free Helical Reactor: FFHR) while expanding the blanket space.

On the basis of physics and engineering results established in the LHD project, the LHD-type D-T reactors have been studied with collaboration works in wide research areas on fusion science and engineering in the Fusion Research Network in Japan, because there are a lot of common issues to be developed for magnetic fusion energy MFE systems and inertia fusion energy IFE systems. The main purpose is to make clear the key issues required for the core plasma physics and the power plant engineering, by introducing innovative concepts expected to be available in this coming decades.

Reactor design activities on international collaborations are also increasing in many aspects and wide areas of physics and engineering in order to advance the reactor design studies. Results are presented in many international workshops and conferences.

Since 1993, collaboration works have made great progress in design studies, which was started as the Phase-1 for the concept definition prior to the present-day Phase-2 for the concept optimization and the cost estimation. There are two types of reference designs: the large size reactor FFHR-1 (l=3, m=18) with the major radius R of 20m and a reduced size reactor of FFHR-2 (l=2, m=10). The design studies on the compact reactor FFHR2 was reported in the 17th IAEA Conference on Fusion Energy in 1998. Design studies on modified FFHR2m1 and 2m2 in the Phase 2 has been reported in the 20th IAEA in 2004, and improved ignition access, 3D neutronics design in the 21th IAEA in 2006, and magnet system concept, cost evaluation in the 22th IAEA Conference on Fusion Energy in 2008.

These FFHR designs have been studied from both aspects of physics and engineering: MHD equilibrium and stability analysis, alpha-particle confinement analysis, ignition access analysis using the simplest control algorithm, 3-D SC supporting structure analysis, SC magnet system design, advanced blanket and energy transfer system design, and system safety analysis. As for the blanket system, molten-salt Flibe has been selected as a self-cooling tritium breeder from the main reason of inherent safety.

In this fiscal year, design studies in wide areas of collaboration have been carried out on key issues and important subjects for the system integration of reactor design as follows:

1. Design Integration towards Size-Optimization of LHD-type Fusion Energy Reactor FFHR,
2. A Conceptual Design of Heliotron DEMO Plant,
3. Economical Potential of LHD-type Helical Power Plants,
4. Proposal of New Magnetic Scaling and Consideration of Poloidal Coil Position for Heliotron-type Reactors,
5. Control of LHD type fusion reactor by vertical field configurations and an operation scenario of FFHR,
6. Configuration Studies on Split-Type Helical Coils for FFHR-2S,
7. Design Studies on High-Temperature Superconducting Coil Option for FFHR,
8. Design study of an indirect cooling superconducting magnet for a fusion device,
9. Conceptual Design of an Indirect-cooled Superconducting Helical Coil in FFHR,
10. Synergistic Effect for Hydrogen Fuel Production in LHD-type Power Reactor,
11. Impact of structural material on tritium breeding in Flibe cooled blanket system,
12. Investigation of feasibility of remountable superconducting magnet for helical reactor,
13. Standardization of the fracture toughness test method by round bar with circumferential notch,
14. Comparative Design Analysis between Helical and Tokamak Reactors,
15. Consideration on Design Window for a DEMO reactor,
16. Large-scale in-silico experiment for thermal-hydraulic and thermo-mechanic characteristic of pebble bed,
17. The high-density and low temperature ignited operation in the FFHR helical reactor,
18. Heat removal characteristics on high - thermal - conductivity sphere - packed pipe applied for a spectral - shifter's first wall and approach to designing it into the blanket,
19. Study on heat transfer mechanism under magnetic field in a liquid blanket,
20. Experimental study of counter-current extraction tower to remove tritium in Flibe blanket loop of fusion reactor.
21. Fusion Power and Neutron Yield from Toroidal Magnetically Confined Plasma

(Sagara, A.)