2-1. Helical Reactor Design

As the result of progress in high-density and high-temperature plasma experiments in the Large Helical Device (LHD), a broad range of fusion engineering studies are being conducted under the Fusion Engineering Research Project launched newly from the FY2010 in NIFS with domestic and international collaborations. This project advances a conceptual design of the helical DEMO reactor FFHR-d1 by utilizing design bases established so far on the conceptual designs of the FFHR series for commercial power plants and by integrating wide-ranged R&D activities on core plasmas and reactor technologies through cooperative researches in NIFS.

Since 1993, collaboration works in the Fusion Research Network in Japan have made great progress in design studies, which was started as the Phase-1 for the concept definition prior to the Phase-2 for the concept optimization and the cost estimation of commercially competitive reactors. 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.

In the series of FFHR-1, 2, 2m1 and 2m2 designs, the coil pitch parameter of continuous helical winding and the major radius R with poloidal coil positions have been optimized to reduce the magnetic stored energy while expanding the blanket space, and a self-cooled Flibe blanket has been proposed as a long-life blanket under neutron wall loading less than 2 MW/m^2.

In this fiscal year, the design integration for FFHR-d1 has been initiated. There were many progresses on developing a helical system code to analyze robustness in the design window, proposing a direct extrapolation method of plasma profiles from the LHD experiments, advancing new ideas of using High-T_c superconductors (HTS) as a counter option to low-T_c superconductors (LTS), performing a poloidal optimization of the liquid blanket thickness with an adequate placement of materials under radial-build calculations with the neutron wall loading < 2 MW/m^2, modeling a steady-state tritium efficiency with pellet fueling, feasibility of enhancing fusion reactivity with ICRF heating, ignition analyses for non-Maxwellian plasma profiles, and so on. Divertor design, external heating design and unscheduled blanket replacement are engineering key issues.

The design studies have been carried out in wide areas of collaboration on key issues and important subjects towards the system integration of reactor design as follows:

1. Conceptual design studies towards LHD-type Demo Reactors
2. System Design of an LHD-type Heliotron DEMO Reactor
3. Development of Direct Profile Extrapolation Method
4. Ignition study on the compact FFHR helical reactor
5. Study on standardization of fusion reactor system based on an integrated design code
6. Economic and Environmental Assessment of Helical and Tokamak Reactors
7. Strike Point Sweeping for the Heliotron Fusion Energy Reactor Using Helical Divertor Coils
8. Design Progress on the High-Temperature Superconducting Coil Option for FFHR
9. Study on remountable joint of YBCO conductor for remountable high-temperature superconducting magnet
10. Estimation of mechanical behavior of helical coil and support structure for FFHR2m2
11. Development of Thermal Analysis Code for Peltier Current Lead
12. Investigation of Low Loss Cryogenic Tube for Hybrid Energy Transfer Line
13. Investigation of neutronics performances of Flinak/Pb breeder blanket
14. Study on detailed liquid cooled blanket design based on neutronics investigation
15. Experimental study on enhancement of recovery rates of hydrogen isotope and decrease of its permeation in Flibe blanket of fusion reactor
16. Applicability study of radiophotoluminescence (RPL) glass dosimeter to fusion neutronics experiments
17. Development of lithium recovery technology for resource supply to nuclear fusion reactor
18. Study on heat transfer mechanism under magnetic field in a liquid blanket
19. Investigation of hybrid-evaporator for FFHR divertor cooling
20. Tritium balance in a DT fusion reactor
21. Study of Fuel Particle Balance in a Fusion DEMO Reactor: Preliminary Results
22. Hydrogen isotope circulation for burning plasma sustainment
23. Feasibility of reduced tritium circulation in the heliotron reactor by enhancing fusion reactivity using ICRF
24. Ignition Analysis for D Plasma with non-Maxwellian ^{3}He Minority in Fusion Reactors

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