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. Two types of reference designs were proposed with a long-life and self-cooled Flibe blanket under neutron wall loading less than 2 MW/m^2: 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), which was reported in the 17th IAEA Conference on Fusion Energy in 1998. Modified FFHR2m1 and 2m2 designs in the Phase 2 have 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 in 2008.

Based on those activities on FFHR series, Fusion engineering Research Project has initiated “re-design” studies for the DEMO reactor FFHR-d1. In the first round of design integration with collaboration studies, primary design parameters of FFHR-d1 have been selected by introducing core plasma design with the Direct Profile Extrapolation (DPE) from LHD experimental data and by reducing blanket thickness with advanced shielding materials, resulting in reactor size optimization for blanket space and magnetic stored energy < 160GJ. The detailed 3-D design of in-vessel components, mechanical supporting structures, divertor pumping configurations and replacing scenarios are in progress as the second round.

There were many progresses on developing a helical system code with the DPE method, 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 radial-build calculations with the neutron wall loading < 2 MW/m^2, modeling a steady-state tritium efficiency, and so on in wide areas of collaboration as follows:

1. Conceptual design studies towards LHD-type DEMO reactors
2. System Design of the Helical DEMO Reactor FFHR-d1
3. Search for the feedback control method of the heating power during the access to the thermally unstable ignition in FFHR
4. Study on standardization of fusion reactor system based on an integrated design code
5. Evaluation of Energy Payback Ratio (EPR) of Tokamak Reactors
6. Formularization of the Confinement Enhancement Factor as a Function of the Heating Profile
7. Getting High-Beta Profile Data in LHD for Extrapolation to FFHR-d1
8. Detailed Physics Analyses of FFHR-d1 Core Plasma in Collaboration with the Numerical Simulation Research Project
9. Pellet fueling requirements to allow self-burning on helical type fusion reactor
10. Progress of the superconducting magnet design for the helical DEMO reactor FFHR-d1
11. Cryogenic Shear-Mode Fatigue Delamination Growth of Composite Insulation Systems for Superconducting Magnets
12. Study on Degradation Process of Organic Insulation Materials for Fusion Superconducting Magnet by Exposure to Radiation
13. Cooling owing to high thermal conduction plastic and stability of coil
14. Numerical analysis on temperature rise and pressure drop of supercritical helium in cable-in-conduit conductor of helical coils for helical DEMO reactor FFHR-d1
15. Methodological study of structural analysis for helical coil
16. Experimental study of cryogenic oscillating heat pipes for superconducting magnets
17. Measurement of the Joint Resistance of Large-Current YBCO Conductors
18. Investigation of neutronics design of FFHR-d1
19. Estimation of technological measures to decrease tritium permeation and to increase tritium recovery through Flibe blanket of fusion reactor
20. Development of lithium recovery technology for resource supply to nuclear fusion reactor
21. Development of the R curve fracture toughness test of round bar with circumferential notch by using hardening curves of each virtual crack length
22. Bi-directional hydrogen isotope permeation through the first wall of a DEMO reactor
23. Study of Fuel Particle Balance in a Fusion DEMO Reactor: Aspect of Tritium Safety Management
24. Tritium balance in a DT fusion reactor
25. Development of efficient heat removal technology using functional porous media for FFHR divertor cooling
26. Design study of dc power supply of superconducting coils for helical reactor
27. R&D of arbitrary waveform, arbitrary power factor and fast-response matrix converter
28. Conceptional Design of Fusion Power Plant

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