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. The interim report on those results has been published in NIFS-MENO-64 (2013).

There are many progresses on developing a helical system code with the DPE method for start-up scenario and cost estimations, advancing new ideas of using High-T_c superconductors (HTS) with jointing as a counter option to low-T_c superconductors (LTS), performing mechanical analyses for a novel divetor structure, proposing new ideas on liquid blankets with mixed metal powders to effectively control hydrogen solubility of molten-salt Flinabe, improving nuclear shielding efficiency, divertor designs with detachment and porous media, modeling steady-state fueling efficiency, and so on in wide areas of collaboration as follows:

1. Conceptual design studies towards LHD-type DEMO reactors
2. Towards Establishment of Technology Bases for Fusion Demonstration Reactor
3. Research on Advanced Operation and Control for Fusion Core Plasmas
   – SOL-divertor Simulation –
4. System Design of the Helical Fusion Reactor FFHR-d1
5. Engineering Optimization of Magnetic Configuration for the Helical Fusion Reactor Design FFHR-d1C
6. Novel divertor design for FFHR-d1
7. A New Concept of Liquid Metal Helical Divertor for FFHR-d1 and c1
8. Investigation of Radiation Shielding Performance of Metal Hydride Materials in FFHR-d1 Design
9. Study on the characteristics of ignition shutdown in FFHR
10. Development of Mobile Robots for Remote Maintenance in FFHR
11. Effect of Nuclear plus Interference Scattering and Its Verification Scenario in Burning Plasmas
12. Bench testing of a Nd:YAG laser dispersion interferometer on FFHR-d1
13. Design study on heat engine for fusion reactor
14. Measures to Radioactive Waste arising from Fusion Reactor Operation
15. Comprehensive Investigation on the Role of Numerical Simulations for Heat and Particle Control in Fusion Reactor
16. Performance measurement of arbitrary waveform and arbitrary power factor matrix converter
17. Applicability of gas divertor using a porous medium with high thermal conductivity material
18. Optimum Material Design of Tungsten for Plasma Facing Component Using Numerical Simulation
19. Hydrogen and heat simultaneous transport through molten salt Flinabe
20. Fundamental Research for Cooling Channel Structure to Enhance the First Wall Cooling and Tritium Recovery
21. Study on the Irradiation Effect of Organic Insulation Materials for the Superconducting Magnet
22. Cryogenic Interlaminar Tensile Properties of Composite Insulation Systems for Superconducting Magnets

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