

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 reactor FFHR-d1 towards DEMO 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 ($I=3$, $m=18$) with the major radius R of 20m and a reduced size reactor of FFHR-2 ($I=2$, $m=10$), 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 reactor FFHR-d1 towards DEMO. 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 $< 160\text{GJ}$. 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, 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 $< 2 \text{ MW/m}^2$, proposing new ideas on liquid blankets, improving nuclear shielding efficiency, divertor designs on cooling and pumping, modeling 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 Fusion Reactor FFHR-d1
3. Core Plasma Design of a Compact Sub-Ignition Helical Reactor FFHR-cl II
4. Study on the characteristics of ignition access to the density and temperature profile variation in FFHR
5. Design of structural components for FFHR-d1
6. Evaluation of neutron environment at divertors in FFHR-d1
7. LHD-type magnetic configuration with large blanket space1)
8. Gas absorption and desorption behaviors of PbLi
9. Prediction study of hydrogen transport properties for molten salt Flinabe
10. Conceptual design of heat engine of fusion reactor
11. Study on the Irradiation Effect of Organic Insulation Materials for the Superconducting Magnet
12. Multi-Input Multi-Output (MIMO) control system for the fusion reactor with the state equation
13. Cryogenic Tensile Fatigue Strength Evaluation of Composite Insulation Systems for Superconducting Magnets using the Open Hole Specimens
14. Applicability of gas divertor using a porous medium with high thermal conductivity material
15. Numerical Simulation of Heat Load Response of Plasma Facing Component
16. Development of CT Injection and Neutralization Technology towards Pulse Heat Flux Material Tests
17. Development of Mobile Robots for Remote Maintenance of the LHD-Type Reactor.
18. Tritium balance in a DT fusion reactor
19. Investigation of lithium isotope ratios in natural water for resource supply to nuclear fusion reactor
20. Measures to Radioactive Waste arising from Fusion Reactor Operation
21. Performance measurement of arbitrary waveform and arbitrary power factor matrix converter.

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