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) 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, improving nuclear shielding efficiency, divertor designs with detachment or liquid divertor, modeling steady-state fueling efficiency, and so on in wide areas of collaboration as follows:

1. Conceptual safety design studies towards LHD-type helical DEMO reactors
2. System Design of the Helical Fusion Reactor FFHR-d1
3. Study on the ignition access by the heating power control during the pellet injection simulation in FFHR
4. Comprehensive Investigation on the Role of Numerical Simulations for Heat and Particle Control in Fusion Reactor
5. Effect of Nuclear Elastic Scattering on Burning Plasmas and Its Verification Scenario
6. Research on Advanced Operation and Control for Fusion Core Plasmas– SOL-Divertor Simulation –
7. Multi-scale Stress Analysis of Superconducting Coils for FFHR-d1
8. Evaluation of neutron irradiation damages for the novel divertor concept proposed in the FFHR-d1 design
9. A prototype design of replacement system of the mirror for measurement in the fusion reactor
10. Performance measurement of arbitrary waveform and arbitrary power factor matrix converter
11. Magnet Design with 100-kA HTS STARS Conductors for the Helical Fusion Reactor
12. Feasibility Study of React-and-wind Method for Helical Coils Wound from Cable-in-conduit Conductors
13. Study on the Irradiation Effect of Organic Insulation Materials for the Superconducting Magnet
14. Cryogenic Interlaminar Tension-Tension Fatigue Properties of Composite Insulation Systems for Superconducting Magnets
15. Tritium relating properties of Flinabe as a new candidate for molten salt blanket of FFHR
16. Fundamental Research for Cooling Channel Structure to Enhance the First Wall Cooling and Tritium Recovery
17. Ultrasonic Measurement of Velocity Profile of Lead-Lithium Duct Flow
18. Improvement of molten salt’s thermal properties by mixing nanoparticles
19. Investigation on the Magnetic Field Distortion by Ferromagnetism of the Blanket for the Helical Fusion Reactor
20. Tungsten coatings effects on hydrogen permeation through the first wall of a magnetic fusion power reactor
21. Study on thermal mixing of liquid-metal free-surface flow by obstacles installed at the bottom of a channel
22. New Combination of the Liquid Metal Divertor REVOLVER-D and the Cartridgetype Blanket FAST-B for FFHR-d1
23. Thermal Design of Water-Cooled Divertor Utilizing Copper Alloy Porous Media
24. Possibility of Divertor Cooling Design utilizing Water Impinging Jet Flow in a Metal Particle Bed
25. Optimum Material Design of Tungsten for Plasma Facing Component Using Numerical Simulation

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