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, 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, 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 DEMO Reactor FFHR-d1
3. Study on the dependence of the ion to electron energy confinement time ratio during 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. Detailed Physics Analyses of FFHR-d1 Core Plasma in Collaboration with the Numerical Simulation Research Project II
7. Core Plasma Design of the Compact Sub-Ignition Helical Fusion Reactor FFHR-c1
8. Pellet refueling scenario to allow self-burning on FFHR-d1
9. Fueling requirements of super-high-density plasmas towards innovative ignition regime
10. Superconducting magnet and support structure of the FFHR-d1
11. Study on Degradation Process of Organic Insulation Materials for Fusion Superconducting Magnet by Exposure to Radiation
12. Non-metallic structural bobbin and thermal stability of superconducting coil
13. Cryogenic Tensile Strength Evaluation of Composite Insulation Systems for Superconducting Magnets Using the Open Hole Specimens
14. Neutronics evaluation of FFHR-d1 with 3-D calculation model
15. Proposal of Flinabe mixed with metal powders for liquid blanket
16. First plan of the divertor component arrangement and the divertor pumping scenario for FFHR-d1
17. Development of efficient heat removal technology using functional porous media for FFHR divertor cooling
18. Numerical Simulation of Heat Load Response of Plasma Facing Component
19. Conceptual Design of dc Power Supply for FFHR Superconducting Coils.
20. R&D of arbitrary waveform, arbitrary power factor and fast-response matrix converter
21. Development of Mobile Robots for Remote Maintenance of the LHD-Type Reactor
22. Measures to Radioactive Waste arising from Fusion Reactor
23. Investigation of lithium isotope ratios in natural water for resource supply to nuclear fusion reactor

(Sagara, A.)