2. Fusion Engineering Research Project

Fusion Engineering Research Project has been launched from the FY2010 in NIFS. This project focuses on both the conceptual design of a steady-state fusion demonstration reactor and various engineering research and development, which are needed before entering into the engineering design activities for DEMO. Therefore, this project consists of three research groups, (1) reactor system design, (2) superconducting magnets, and (3) in-vessel components, with the total 13 task and 44 sub-task groups.

The LHD-type device does not need plasma current, and this excellent feature gives a great advantage for realizing a steady-state reactor. Therefore, along with a conceptual design of the helical reactor FFHR-d1 towards DEMO by integrating design bases established so far on the designs of the FFHR series for commercial power plants, the project is carrying out research on key components, such as the superconducting coil system, high performance blanket, first wall and divertors, and so on. As the center of fusion engineering research for universities, the project enhances domestic and international cooperation to advance reactor design studies and R&D activities as well as to expand basic research lying in interdisciplinary areas.

The large-scale superconducting magnet system requires high-performance superconductors of 100 kA-class current capacities at the high magnetic fields over 13 T. Research is being conducted for developing advanced conductors of indirectly cooled low-temperature superconductor and high-temperature superconductor. In order to examine superconducting properties of such large conductors in real conditions, a new superconducting test facility of 13 T magnetic field with a variable-temperature bore of 0.7 m has been installed. Actual environment testing is also carried out to estimate the characteristics of superconducting materials under conditions with cryogenic temperatures, intense magnetic field and neutron irradiation. Components in the magnet systems are subject to huge electromagnetic force. Research is ongoing so as to precisely evaluate the expected stress on component materials and to seek the optimum coil supporting structure. The engineering design of the winding and fabrication method for magnets is also in progress.

It is essential in fusion blankets to use structural materials whose radioactivity is low and decays swiftly after irradiation by neutrons. Vanadium alloys are one of the major candidate materials. A low-activation vanadium alloy (NIFS-HEAT) was produced and its evaluation has been carried out in collaboration with universities, including development of component fabrication technology. Also being carried out are fabrication and characterization of oxide dispersion strengthened ferritic steel (ODS steel). Both 9Cr- and 12-Cr ODS steels were fabricated and characterization, including radiation effects and joining property, were performed by collaboration with universities.

The blanket is a key component to shield neutrons, to convert fusion energy to thermal output, and to breed tritium fuels. In order to develop liquid breeder blankets, a large-scale forced-convection twin-loop for Flinak and LiPb (Oroshhi-2) was constructed with a 3 T SC magnet. In this work, studies on material science including chemistry, fluid dynamics, MHD effects and thermo-mechanical engineering are integrated.

Divertor heat flux in fusion demonstration reactor is considered to be maximum 20MW/m^2 in a steady state. Three important subjects in the research and development are material selection, development in bonding technology between armor tiles and coolant systems, and design studies of the 3D-shape of the helical divertor with neutronics analyses.

Hydrogen isotopes such as deuterium and tritium will be utilized as a fuel in fusion plants. Tritium is a radioactive isotope and therefore should be managed with safety. The project includes development of tritium handling and safety technologies, such as tritium decontamination and an advanced tritium removal system. Tritium production is under development for the fuel of fusion reactor. Safety strategy for radiation facilities is also important issue. Those collaboration experiments are performed using tritium facilities of universities.

In this fiscal year, as the second and third round of design integration, detailed 3-D designs of in-vessel components, mechanical supporting structures, divertor detachment configurations, construction and replacing scenarios have been studied based on the primary design parameters of FFHR-d1A. In particular, 3D mechanical and neutronics analyses are in progress to enhance the merit on divertors which can be placed to avoid direct irradiation of fast neutrons. Collaborations are also enhanced for numerical simulations on MHD at high beta and confinement of alpha particles.

On superconducting magnets various research collaborations have been carried out, such as MgB_2 wires, A15 phase metallic superconducting wires, stress/strain effects, making high performance of High Temperature Superconductor (HTS), HTS current leads, joint section of a HTS conductor, analysis of joints between CIC (Cable in Conduit) conductors, inter-strand resistance in CIC conductor, testing methods for joints of large-scale CIC conductors, series compensated thyristor converters, low frequency power transmission, partial discharge protection technology, boiling process in quench of superconducting coil, a regenerator material for GM cryocooler, heat transfer across the interface of phase transition (He II/He I), dynamic simulator, and so on.

As for in-vessel components, low activation vanadium alloys and copper alloys were improved in respect of high temperature mechanical properties and radiation resistance by means of compositional and microstructural control. Characterization of weld and HIP joints was also carried out for ODS steels and ferritic steels. Coating and surface modification methods were investigated for MHD pressure drop mitigation, tritium permeation reduction and corrosion protection for liquid breeder blankets.

Regarding tritium handling and safety technologies, many kinds of investigations have been successfully carried out as collaboration with many universities, research institutes and companies on hydrogen isotope separation and removal technology, tritium measurements, fueling in fusion reactor, safety in environment, and so on.

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