2. Fusion Engineering Research Project

Fusion Engineering Research Project has been launched from 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 magnet, 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 design studies of the FFHR series for commercial power plants, the project is carrying out research on key components, such as the superconducting magnet 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.

Research activities on applied superconductivity and cryogenic engineering in NIFS focus on the large-scale superconducting magnet system and high-performance superconductors of 100 kA-class current capacities at high magnetic fields over 13 T. Research is being conducted for developing indirectly cooled low-temperature superconductor (LTS) and high-temperature superconductor (HTS). In order to examine the superconducting properties of such large conductors in real conditions, a new superconducting test facility with a 13 T magnetic field, a variable-temperature (4.2-50 K) large bore of 0.7 m, and 50 kA sample current has been installed. Using this facility, characteristics of superconductors are examined under realistic conditions. 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 correlation of neutron and ion irradiation effects. Also being carried out are fabrication and characterization of oxide dispersion strengthened ferritic steel (ODS steel). Both 9-Cr and 12-Cr ODS steels were fabricated and their characterization, including residual impurity effects and joining properties, was performed in 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 (Flinak and LiPb) facility "Oroshhi-2" was constructed equipped with a 3 T SC magnet, and collaborations with universities were started. 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 reactors is considered to be close to or even higher than 20 MW/m^2 in steady state. Three important subjects in the research and development are material selection, including liquid metal, 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, deuterium and tritium, will be utilized as a fuel in fusion power 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. Safety strategy for radiation facilities is also an important issue. Those collaboration experiments are performed using tritium facilities of universities.

In this fiscal year, as the third round of the reactor design integration, construction and replacing scenarios have been studied based on the primary design parameters of FFHR-d1A. Many challenging ideas on assembling units of blanket were examined using a 3D printer. Collaborations are also enhanced for numerical simulations on particle recycling in the divertor region.

On applied superconductivity and cryogenic engineering, various research collaborations have been carried out with universities. The superconducting properties and conductor performances including joints are examined on various materials, such as Nb_3Sn, Nb_3Al, MgB_2 and HTS. Cryogenic engineering research includes various categories, such as characterization of insulation materials in cryogenic environment and visualization of quantum vortex of turbulence in superfluid helium. .

As for in-vessel components, improvement of copper alloys were carried out in respect to high temperature mechanical properties and radiation resistance by applying a fabrication process of Mechanical Alloying and Hot Isostatic Pressing (HIP). 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.

(Sagara, A.)