(2) Helical Reactor Design

Due to inherent current-less plasma and intrinsic diverter configuration, helical reactors have attractive advantages, such as steady operation and no dangerous current disruption. In particular, in the LHD-type reactor design, the coil pitch parameter γ of continuous helical winding can be adjusted beneficially to reduce the magnetic hoop force (Force Free Helical Reactor: FFHR) while expanding the blanket space.

On the basis of physics and engineering results established in the LHD project, the LHD-type D-T reactors have been studied with collaboration works in wide research areas on fusion science and engineering in the Fusion Research Network in Japan, because there are a lot of common issues to be developed for magnetic fusion energy MFE systems and inertia fusion energy IFE systems. The main purpose is to make clear the key issues required for the core plasma physics and the power plant engineering, by introducing innovative concepts expected to be available in this coming decades.

Reactor design activities on international collaborations are also increasing in many aspects and wide areas of physics and engineering in order to advance the reactor design studies. Results are presented in many international workshops and conferences.

Since 1993, collaboration works have made great progress in design studies, which was started as the Phase-1 for the concept definition prior to the present-day Phase-2 for the concept optimization and the cost estimation. There are two types of reference designs: 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). The design studies on the compact reactor FFHR2 was reported in the 17th IAEA Conference on Fusion Energy in 1998. Design studies on modified FFHR2m1 and 2m2 in the Phase 2 has been reported in the 20th IAEA Conference on Fusion Energy in 2004.

These FFHR designs have been studied from both aspects of physics and engineering: MHD equilibrium and stability analysis, alpha-particle confinement analysis, ignition access analysis using the simplest control algorithm, 3-D SC supporting structure analysis, SC magnet system design, advanced blanket and energy transfer system design, and system safety analysis. As for the blanket system, molten-salt Flibe has been selected as a self-cooling tritium breeder from the main reason of inherent safety.

In this fiscal year, design studies in wide areas of collaboration have been carried out on key issues and important subjects for the system integration of reactor design. In particular, intensive studies have been started on optimization of self-ignition startup time and minimization of heating power, high-density plasma control and heating methods, evaluation of α-particles confinement and selective ash evacuation, 3D edge transport evaluation in the divertor region, 3D engineering design and improvement of the SC magnet system, neutronics optimization of 3D blanket and shield, establishing a cost model, and hydrogen production as follows: (1) Integrated design studies on blanket replacement in LHD-type rector FFHR2, (2) Minimization of the heating power during the fusion power rise-up in FFHR, (3) Conceptual design of SC magnets of a helical reactor with CIC conductors, (4) Design of split-type helical coils for FFHR-2S, (5) Design windows analysis based on a cost model of helical reactor (HeliCos), (6) Controlling the cross-field-flux of cold α-particles with resonant magnetic perturbations in a helical fusion plasma device, (7) Alpha particle loss fraction in the FFHR, (8) Examination O-X-B mode conversion window in a FFHR-type plasma, (9) Active method of impurity control in LHD-type reactor FFHR, (10) Divertor configuration study of LHD and FFHR, (11) Conceptual design of an indirect-cooled superconducting magnet for the LHD-type fusion reactor FFHR, (12) Conceptual design of support post for FFHR cryogenic components, (13) Quench protection of high-temperature superconductors with indirect cooling for FFHR, (14) Hydrogen production by 1 GW electric power of the FFHR, (15) Analysis of tritium fluoride behavior and tritium recovery in a molten salt Flibe blanket, (16) Neutronics investigation on a Flibe/V-alloy blanket concept, (17) Development of novel heat transfer promoters for first-wall cooling in a heliacal type of fusion reactor, (18) Heat transfer of pebble bed considering strong volumetric heat generation inside pebbles, (19) Study on heat transfer region under MHD effect in a liquid blanket, (20) Feasibility of helium gas turbine system for molten salt blanket, (21) Comparison between various fusion reactor designs and discussion on critical issues.

(Sagara, A.)