Design Integration of the LHD-type Energy Reactor FFHR2 towards Demo

A. Sagara[1], S. Imagawa[1], Y. Kozaki[1], O. Mitarai[2], T. Tanaka[1], T. Watanabe[1], N. Yanagi[1], T. Goto[1], H. Tamura[1], K. Takahata[1], S. Masuzaki[1], M. Shoji[1], M. Kobayashi[1], K. Nishimura[1], H.Igami[1], T. Muroga[1], T. Nagasaka[1], M. Kondo[1], A. Nishimura[1], H. Chikaraishi[1], S. Yamada[1], T. Mito[1], N. Nakajima[1], S. Fukada[3], H. Hashizume[4], Y. Wu[5], Y. Igitkhanov[6], O. Motojima[1] and FFHR design group

[1]National Institute for Fusion Science, Toki, Gifu 509-5292, Japan
[2]Tokai University, 9-1-1 Toroku, Kumamoto 862-8652, Japan
[3]Kyushu University, 6-10-1 Hakozaki, Fukuoka, Fukuoka 812-8581, Japan
[4]Tohoku University, Sendai 980-8579, Japana
[5]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China.
[6]Max-Planck-Institut für Plasmaphysik, IPP-EURATOM Ass., Greifswald, Germany

E mail: sagara.akio@LHD.nifs.ac.jp

Design studies on LHD-type helical energy reactor FFHR have made continuous progress in broad research areas under a broad collaboration in the fusion engineering network in Japan and based on the LHD accomplishments: steady state (1hour, 1.6GJ input), high beta (5%), high density (1×10^{21}m^{-3}), superconducting magnet technology (high accuracy and over 8 year operation) etc.

On the reactor size optimization towards Demo, where the ergodized magnetic layer is important on both aspects for divertor and alpha-heating efficiency over 90 %, it is found that there is the optimum major radius of plasma around 16 m with a central toroidal field of about 5 T by taking into account the neutron wall loading kept below 2MW/m^2, cost analyses based on the ITER (2003) design and engineering feasibility on large scaled magnets, where the magnetic stored energy is about three times as large as ITER but the maximum magnetic field and mechanical stress can be comparable.

Standing on the replacement-free long-life liquid blanket concept [1] based on material corrosion experiments, the molten Flibe/ferritic steel blanket of 1m in thickness has been improved in 3D designs for heat transfer, tritium breeding/recovery and nuclear shielding for superconducting magnets.

For continuously wound large superconducting magnet systems under the maximum nuclear heating of 200W/m^3, cable-in conduit conductor (CICC) of current 90 kA with Nb_3Al are proposed with quench protection candidates and with a robust design of LHD-type cryogenic support posts. A mass based comparison of FFHR construction costs to the ITER cost database demonstrates economic viability and reasonable electricity cost.

For access to ignited plasmas, due to the advantage of external confinement field in helical systems, the external heating power has been minimized to 30 MW by a long rise-up time over 300 s. For the new ignition regime in a super dense core (SDC) plasma found in LHD, a new proportional-integration-derivative (PID) control of the pellet fueling can handle the thermally unstable plasma at high and low temperature operation, which is generally advantageous to reduce the divertor heat flux due to an enhanced radiation loss rate. Non-zero dimensional numerical simulation studies are planned.

[1] A. Sagara, S. Imagawa, O. Mitarai et al., Improved structure and long-life blanket concepts for heliotron reactors, Nuclear Fusion, 45 (2005) pp.258-263.