

Conceptual design of an indirect-cooled superconducting magnet for the LHD-type fusion reactor FFHR

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The Large Helical Device (LHD) has provided experimental results indicating that LHD-type reactors are well suited for steady-state power plants. Based on the engineering and physics outputs from the LHD, the Force Free Helical Reactor (FFHR) study has been launched in the framework of interuniversity collaborative research at the National Institute for Fusion Science. In the FFHR study, a superconducting magnet system is one of the key issues because the magnet of the FFHR consists of continuous windings with a large diameter, a twisted configuration and large magnetic energy. The magnet system of the FFHR has a coil major radius of 14-17 m, the magnetic energy of 120-140 GJ and the maximum field of 13 T. We apply aluminum-alloy jacketed Nb₃Sn superconductors and an indirect-cooling concept using cooling panels inside the windings. The cooling panels are cooled by forced-flow liquid/supercritical helium. The aluminum-alloy jacket, which has higher thermal conductivity than stainless steel, can promote removal of a steady-state heat load due to nuclear heating. Heat removal performance depends strongly on the effective transverse thermal conductivity in the windings and the spacing between the cooling panels. We investigate the effective transverse thermal conductivity using conductor samples and a numerical analysis. For quench protection, we adopt a quench-back concept using the cooling panels as a heater. The quench-back can reduce the hot spot temperature in the superconductor and the maximum terminal voltage even though the magnet has large magnetic energy. This paper presents the conceptual design of the 100-kA class superconductor and the structure of the windings for the FFHR superconducting magnet.