§5. Design of Structural Components for FFHR-d1

Tamura, H., Goto, T., Tanaka, T., Masuzaki, S.,
Yanagi, N., Miyazawa, J., Sagara, A.,
FFHR Design Group

In parallel with the design activities for FFHR-d1, modifications for the fundamental design parameters have been investigated, aimed at advancing the core plasma design, ignition and fueling scenario, engineering realization, etc. FFHR-d1A is a key design strategy that has modified the aspect ratio by changing the helical pitch parameter from 1.25 to 1.20 to improve high energy confinement [1]. The main difference between FFHR-d1 and d1A structural components is that the minor radius of the HC is changed from 3.9 to 3.744 m. The major radius (15.6 m) and geometrical position of the vertical field coils (VFCs) is the same. Analyses to evaluate the EM force and stress distribution on the magnet system, the optimal design for the coil support structure and the optimal access port size for maintenance are conducted for the FFHR-d1A.

The magnetic field distributions were calculated defining the coil cross-sectional shape as shown in Fig. 1. The calculated maximum overall EM hoop force and the overturning force were 64 and ±8 MN/m, respectively. These results were slightly lower than those of the original FFHR-d1, because the force depends on the shape of the helical coil (HC) cross-section and the distance between the HC and VFC.

A design study of the FFHR-d1A coil support structure was initiated on the basis of the following concepts: (1) the support was made of 250-mm-thick SS 316LN, (2) VFCs were connected to the support, (3) the support had a continuous structure throughout the circumference of the device, and (4) apertures were as large as possible. Consequently, the maximum stress of 660 MPa appeared at the inner VFC support region. The stress level was within the permissible limit for the SS 316LN. The maximum deformation of 28 mm appeared at the inner VFC region. Deformation at the bottom of the HC was 6.9 mm.

The thickness of the VV is 35 mm according to the radial build design [2]. This thickness implies a spatial occupancy with a flexible connection such as bellows, as shown in Fig. 2. The VV works as a vacuum boundary for the in-vessel components. Unlike other types of fusion devices, the VV of the FFHR-d1A does not act as a base wall that supports the in-vessel components. The blanket system has its own support frame, and the VV is attached on this blanket frame.

The temperature of the VV rises by approximately 373 K during plasma operation, while the coil support structure is cooled down to 4 K (or 20 K in the case of a high-temperature superconductor coil). There must be enough clearance between the VV and the coil support structure to avoid thermal/mechanical interference. With the exception of the radial build region and port sections, the distance between the VV and the coil support structure was set as 200 mm. Here, there is a thermal radiation shield and space for an adiabatic condition. The distance at the port section was set from 750 to 850 mm depending on the shape of the aperture of the coil support structure. Of this distance, 500 mm was allotted for the divertor exhaust. Fig. 3 is a schematic view of the VV with main port dimensions. The outer, upper, and inner ports can be used to maintain the in-vessel components. The lower port can be used for setting a gravity support for the blanket system and for various other applications.

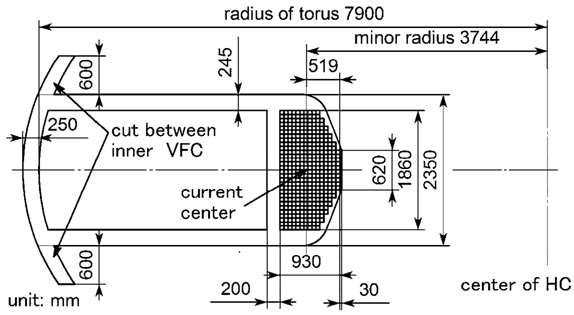

Fig. 1. Cross-section of HC perpendicular to the coil winding direction.

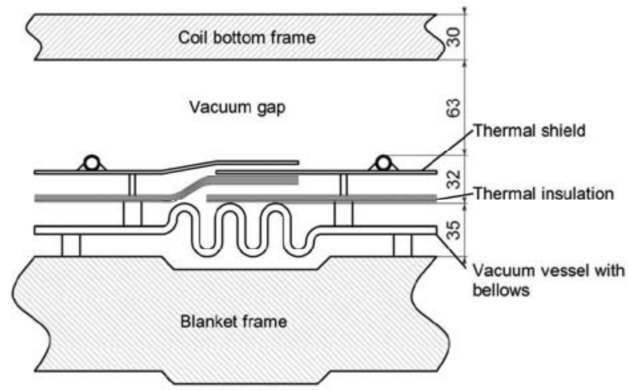

Fig. 2. Schematic of structure at between the blanket and the coil.

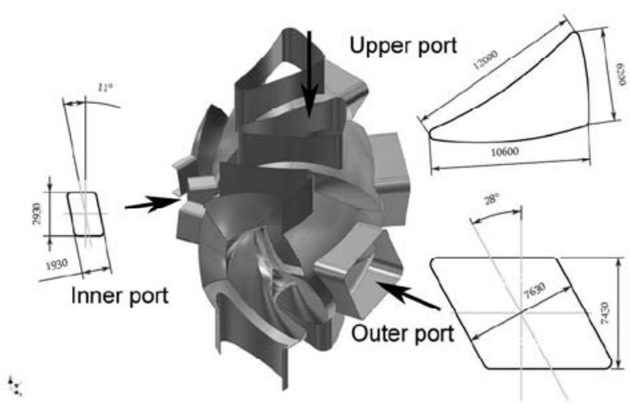

Fig. 3. Schematic of the VV and the port dimensions.

1) Sagara, A. et al.: Fusion Engineering and Design (2014) doi:10.1016/j.fusengdes.2014.02.076.
2) Tamura, H. et al.: Fusion Engineering and Design **88** (2013) 2033.