§6. Novel Divertor Design for FFHR-d1

Tamura, H., Tanaka, T., Goto, T., Miyazawa, J., Masuzaki, S., Watanabe, T., Yanagi, N., Sagara, A., FFHR Design Group,
Ito, S., Hashizume, H. (Tohoku Univ.)

In an LHD-type fusion reactor, the neutron load on the divertor can be mitigated by setting the divertor plate behind a blanket.[1,2] If neutron irradiation were sufficiently reduced, employing a copper alloy for divertor cooling pipe would be feasible. Although the irradiation damage for copper at the divertor region in the FFHR-d1 have a wide span, it would be relatively high when the HC is on the inboard side of the torus.[2] In this estimation, a maximum irradiation damage in the divertor region gave 1.6 dpa/yr. The copper alloy limit is supposedly below 1 dpa. So if a copper material is to be used, a further reduction in irradiation damage or a scheme for easy exchange of parts has to be developed. For FFHR-d1, the average heat flux could be as low as 8 MW/m^2 on average for 3 GW fusion power generation without assuming radiation dispersion. However, there is toroidal asymmetry that causes a nonuniform heat flux distribution along the divertor leg. The divertor components located at the peaks would experience more than ten times higher heat flux than the average value, which requires continuous realization of plasma detachment to secure high radiation dispersion of heat flux.[3]

To mitigate not only neutron irradiation but also the high heat load at inboard of the torus, we considered a modification of the coil-support structure. Moving the divertor to an area such as behind the HC can realize this idea. Fig. 1 shows a plan for changing the location of the divertor in the region inboard of the torus. Since the vacuum vessel is limited by the coil-support structure, which consists of the coil case, arm, and a torus-shaped shell, the arms would be partially removed to allow divertor components to be moved to behind the HC. Based on the results from the neutron transport and heat flux calculations, we made a conceptual model of the coil-support structure. In this model, the arms were removed when the center of the HC winding was in the inboard of the torus. The coil case and the torus shell remained throughout the torus with some modification to maintain rigidity. A stress analysis was performed on the modified structure.[4] In this analysis, the superconductor was assumed to be made of a high-temperature superconducting (HTS) conductor using a rare-earth barium copper oxide (REBCO) tape. The equivalent physical properties of the HC and VFC winding sections were calculated by a homogenization analysis using the geometry of the cross section and physical properties of the constituent materials[5]. The shape of the coil-support structure was rearranged so that the maximum von Mises stress would be within an acceptable value. Fig. 2 shows the resulting von Mises stress distribution and the amount of deformation. The maximum stress was within the permissible limit for the SS316LN.

By this modification of the coil-support structure, the vacuum vessel and the blanket could occupy the removed space of the coil-support structure. Divertor components could be placed in this open space. As the result, The damage of the divertor component will be reduced by nearly one order of magnitude. The proposed design also provides an additional access port, that the divertor could be accessed from the upper and lower side. This makes maintenance work easier. Even if the neutron irradiation issue were resolved, some divertor parts, such as the tungsten plate in front, would be damaged by the high heat flux. These divertor parts could be exchanged through the port directly from the top or bottom of the device. The divertor in the other section could be replaced, together with the first wall or with the breeding blanket, every several years.

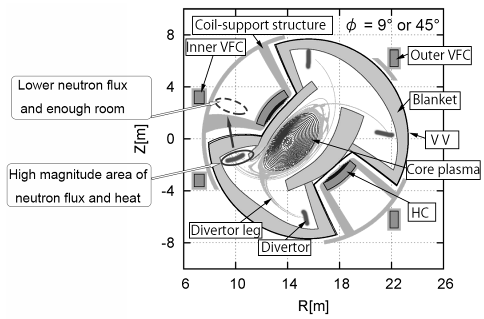

Fig. 1. Plan for changing the divertor location.

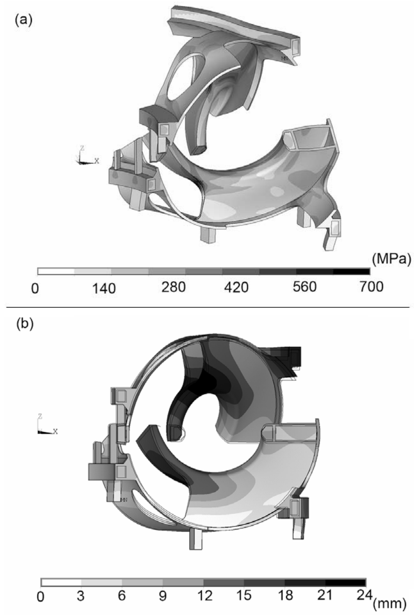

Fig. 2. Results from structural analysis calculations: (a) von Mises stress distribution. (b) Amount of deformation.

1) Sagara, A. et al.: Fusion Eng. Des. **89** (2014) 2114.
2) Tanaka, T. et al.: Fusion Eng. Des. **89** (2014) 1939.
3) Yanagi, N. et al.: 24th Fusion Energy Conference, (2012) FTP/P7-37.
4) Tamura, H. et al.: Fusion Eng. Des. in press (2015) doi:10.1016/j.fusengdes.2015.01.025.
5) Ito, S. et al.: Applied Superconductivity Conference, USA (2014) 3LPo2I-07.