§4. Design and Optimization of Support Post in FFHR

Tamura, H., Sagara, A.

FFHR is a concept design of a steady-state fusion reactor that has been studied to demonstrate a LHD-type fusion power plant. The total weight of the superconducting coils and support structure exceeds 16,000 tons. The maximum displacement caused by thermal contraction is almost 55 mm. The weight and deformation are sustained by support posts. The LHD had a “folded multi plate” type post consisted of carbon fiber reinforced plastic (CFRP) and stainless steel (SS) plates[1)]. This type of post can also be used as the support post of the FFHR. We investigated the post in mechanical and thermal points of view.

Considering a symmetrical and homogeneous distribution of the gravitational load, the number of the posts was chosen as 30; 20 posts were located under the outer poloidal coil and the remaining were set under the inner poloidal coil. The CFRP plates in the folded multi plate type post are subjected to a compressive load while the SS plates are subjected to a tensile load. The geometrical dimensions of the CFRP plates were chosen according to buckling load estimation against a gravitational load with a bent long column model.

Fig. 1 shows the setup of the support post and its dimensions. Using the basic geometrical design of the folded multi plates, the stress distribution and the natural frequency of this structure were calculated by performing FEM analysis. Here, we introduce three operating situations and calculate the stress distribution for each case.

(a) Gravity only: This situation simulated a normal condition before cooling. The top of the post was bent outward by 27.5 mm and had no thermal contraction. In this case, the maximum von Mises stresses in the CFRP and SS plates were 147 and 340 MPa, respectively.

(b) Gravity + cool down + 0.2 G of transverse acceleration: This situation simulated the application of 0.2 G of transverse seismic load on the device when the cryogenic components are cooled down to 4 K. The maximum von Mises stresses in the CFRP and SS plates increased to 159 and 390 MPa, respectively.

(c) Gravity + cool down + 0.7 G of transverse acceleration: In the case of 0.7 G of transverse acceleration, the maximum von Mises stresses in the CFRP and SS plates were 322 and 681 MPa, respectively.

Fig. 2 shows the first four modes of natural vibration and their frequencies. The natural frequencies of the structure were in the range of 3 to 8 Hz. The higher natural frequencies exceeded 15 Hz and the deformation modes were applied mainly in the cryogenic components. The safety of the structure against an earthquake depends on the frequency and magnitude of seismic acceleration. Since a typical earthquake has a frequency range of 0.5 to 20 Hz, a structure that has a natural frequency close to this range may resonate. A response spectrum analysis of typical earthquakes, such as El Centro, TAFT, etc, revealed that the response accelerations of the frequency would range from 1.0 to 1.5 G. The analytic result for transverse acceleration load of 0.7 G represents a reasonable limit, since the maximum von Mises stress did not exceed the permissible stress. One approach is to set a limit of 0.7 G for the response acceleration of the building.

1) Tamura, H., et al., Fusion Technology **1996**, (1996) 1019

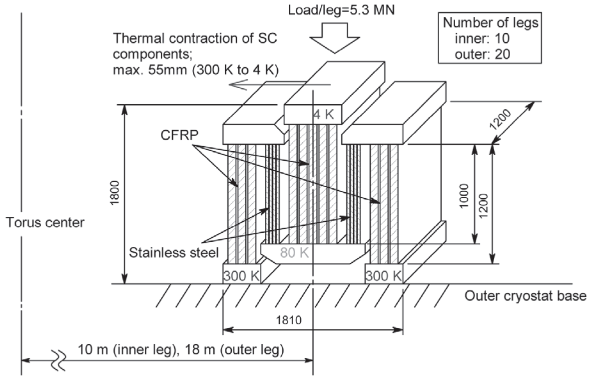

Fig. 1. Schematic draw of the support post for the FFHR.

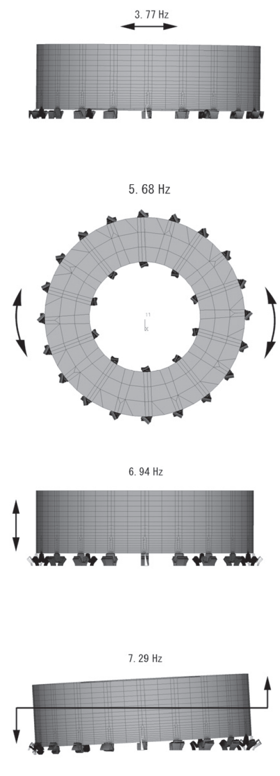

Fig. 2. Results of modal analysis.