§10. Estimation of Mechanical Behavior of Helical Coil and Support Structure for FFHR2m2

Tamura, H., Yanagi, N., Takahata, K., Goto, T., Imagawa, S., Sagara, A.

Aiming for a demonstration device of a fusion power reactor, the LHD-type helical reactor FFHR is being studied. The components of a magnetic confinement type fusion reactor work under a huge electromagnetic force. Clarifying the mechanical behavior considering geometry of coils and the electromagnetic force is needed to design the system. Simple calculation method is useful for an estimation and comparison among several design parameters. An axisymmetric model has been proposed for the fundamental estimation of a mechanical behavior of the helical coil.[1)] The precision of calculation using the axisymmetric model was investigated by comparing deformation, stress, and strain with a quasi-three-dimensional model which was made of three-dimensional finite elements. The quasi-three-dimensional model had no support structure but was applied an additional boundary condition which restricted an out-plane deformation of the cross section of the coil simulating a condition that the coil was surrounded by a thick torus support. Further research on a relationship between a configuration of the support structure and the mechanical behavior was needed to determine precision of the simplified model.

To estimate a detail mechanical behavior of the helical coil and the support structure and to evaluate the precision of the calculation methods, four kinds of analytic models were prepared. Those were, full torus shell without port, torus shell with standard port section, widely divided torus shell, and a quasi-three-dimensional model. The models were based on FFHR2m2 (coil major radius: 17 m, minor radius: 4.08 m, maximum field on coil: 11.9 T, magnetic energy 160 GJ). The coil and the support structure were assumed to be made of isotropic materials. Young's module / Poisson's ratio of the coil and the support structure were set as 100 GPa / 0.3 and 200 GPa / 0.3, respectively. The thickness of the support structure was assumed to be 300 mm. Electromagnetic force shown in fig. 1 was transformed to a pressure on a surface of every single element of the coil.

Figs. 2-4 show example results. Fig. 2 represents the Von Mises stress distribution on the support structure. The maximum stress on the structure was about 500 GPa, which was an allowable level for high strength structural material. Fig. 3 shows the hoop strain distribution in the helical coil for the same model. The maximum strain appeared at the bottom area of the coil in an inner equatorial region. The maximum strain of 0.27% was reasonable level for Nb_3Sn or Nb_3Al superconductor. Almost all superconductors seemed to be subject to tensile strain. Fig. 4 shows the hoop strain distribution calculated by using the quasi-three-dimensional model. Comparing the results among models, it was confirmed that the quasi-three-dimensional model could estimate a stress / strain distribution in the coil section well.

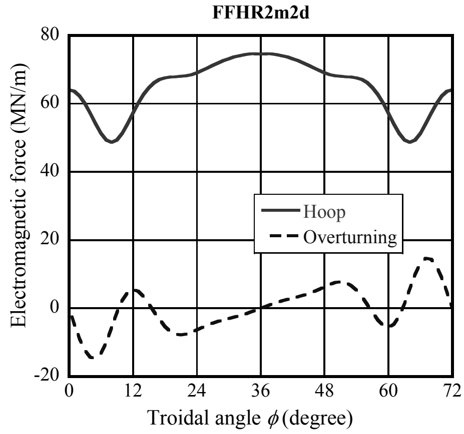

Fig. 1. Total electromagnetic force on the helical coil of FFHR2m2.

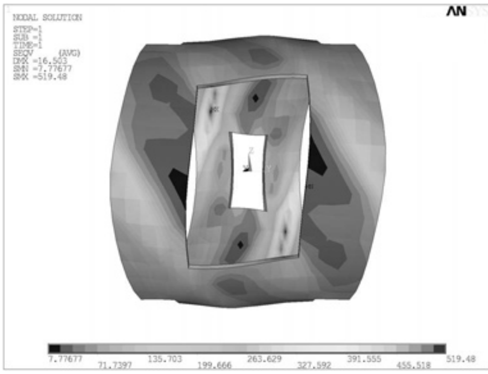

Fig. 2. Von Mises stress distribution on the support structure for the torus shell with standard port model.

Fig. 3. The hoop strain distribution in the helical coil for the torus shell with standard port model.

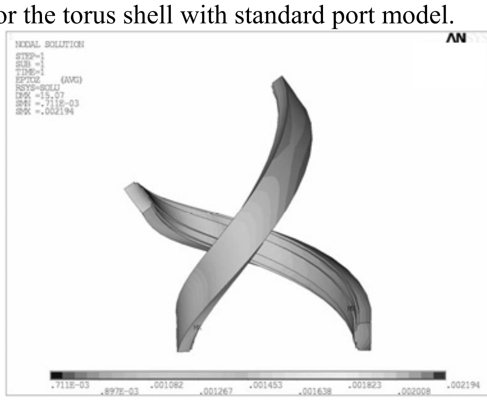

Fig. 4. The hoop strain distribution in the helical coil for the quasi-three-dimensional model.

1) Tamura, H. et al.: Plasma and Fusion Research **5** (2010) S1035.