8P09

ヘリカル型核融合炉用超伝導マグネットシステムの トポロジー最適化と振動解析

Topology optimization and seismic analysis of superconducting magnet system in helical fusion reactor

田村　仁[1,2], 後藤拓也[1,2], 宮澤順一[1,2], 柳　長門[1,2]
TAMURA Hitoshi[1,2], GOTO Takuya[1,2], MIYAZAWA Junichi[1,2], YANAGI Nagato[1,2]

1) 核融合研, 2) 総研大
1) NIFS, 2) SOKENDAI

Huge electromagnetic (EM) force is generated in the superconducting magnet system of a fusion reactor. In the case of the helical fusion reactor FFHR-c1 (major radius 10.92 m, magnetic field at plasma center 7.3 T, and magnet stored magnetic energy 160 GJ), which aims to demonstrate power generation, the EM force acting on the superconducting helical coil reaches 120 MN/m at maximum. The magnets are supported by a strong support structure to ensure that stress and deformation do not exceed the allowable values. According to extrapolations based on the results of fusion experimental devices comprising superconducting magnets, the total weight of DEMO class fusion magnet was expected to exceed 20,000 tons. On the other hand, it is desirable to reduce the magnet weight as much as possible from the viewpoints of material procurement, weight to be cooled, and reduction of radioactive materials after decommissioning. As a design method to achieve weight reduction, the topology optimization technique was proposed. A topology optimized structure (Fig. 1) was found to be much lighter than expected. Compared to conventional designs, a weight reduction of more than 25%, which translates into a weight reduction of several thousand tons, can be realized with assurance of soundness [1].

The topology-optimized structure has many apertures and thinning wall in appearance, there is concern that it may be sound under normal operation but sensitive to abnormal loading, such as earthquakes. Modal analysis revealed that the entire structure yields vibration modes below 10 Hz (Fig. 2), which might resonate with earthquake waves. Therefore, the structural integrity of the structure was evaluated using the mode superposition method with the most severe acceleration envelope from the seismic waveforms of the giant earthquakes that has occurred in Japan. The calculation results showed that damage occurred at the gravity support legs, but that the magnet itself was not significantly affected (Fig. 3). Furthermore, if a seismic isolation system is used in the building where the main body is installed, the load is expected to be reduced to about 1/200 of the original load [2].

[1] H. Tamura et al., *J. Phys.: Conf. Ser.* **1559** (2020) 012108.
[2] H. Tamura et al., *IEEE Trans. Supercond.* **32** (2022) 4900504.

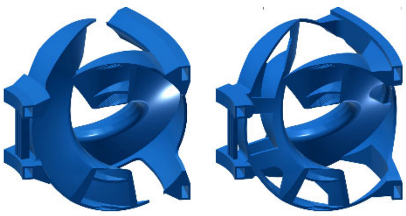

Fig. 1 Original (left) and topology optimized (right) structure.

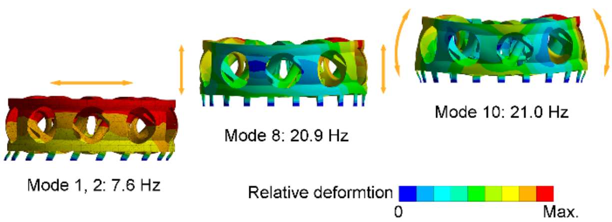

Fig. 2 Typical eigen vibration mode.

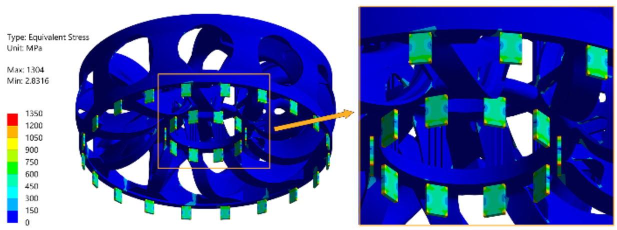

Fig. 3 Result of mode-superposition analysis.