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次世代型核融合炉(FFHR)におけるコンピュータ設計
Computational Design of Next Generation Fusion Rector, FFHR

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1. Introduction

Automation technologies for the computational design of nuclear fusion reactor including – from CAD/ CAM/ CAE with AI to robotic process automation, physical robotics, and more – are transforming design processes and operating models. Recently, computational design of the next generation of the force-free helical fusion reactor(FFHR) has been conducted based on the achievement of the large helical device in National Institute for Fusion Science, in Japan. FFHR is required as a stationary fusion reactor capable of steadily holding high-performance plasma for one year. Figure 1 shows schematic view of FFHR.

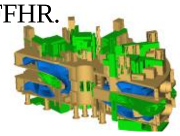

Fig. 1. Schematic view of FFHR.

2. Methods

In this presentation, we introduce (1)detailed 3D design of FFHR, (2)tracing of the magnetic field lines, (3)a blanket structure of double helix.

Firstly, "Kumiki" type model which is like a mosaic by combining various woods in Japan is applied to the design of FFHR.

Secondly, our toolkit constructs the assemblage of the magnetic field lines, the blanket structure, and the supper conducting coil by using CATIA and the feedback of plasma stability simulation(VMEC).

Finally, the blanket structure of the double helix with refractory bricks is a good candidate (1)to be a long pathway of the 2LiF-BeF_2(FLiBe), which becomes the coolant for advanced nuclear fission and fusion reactors, (2)to shield radiation expect for neutron and (3)to be heat conduction. Then we analyze compressive and torsional strength of the structure, respectively. In the accidental case of breaks of pipes where this molten salt at high temperature, is flowing, some mechanism is needed to keep the outflow with highly toxic of Be and T from escaping out of the blanket system. In the normal operation, molten salt is 450 degrees Celsius, but in this case, we suppose the 1000 degrees and analyze the heat conduction. Figures 2 and 3 show the double helix structure and the layered structure.

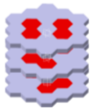

Fig. 2. Double helix structure.

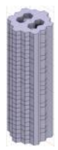

Fig. 3. The layered structure. It has 9 layers of the double helix structure.

3. Results

Figures 4 and 5 show assembly design of FFHR and each part of FFHR which has 19 inner modules, 19 outer modules and a super conducting coil

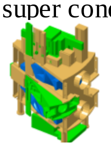

Fig. 4. Assembly design of FFHR.

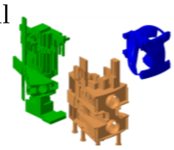

Fig. 5. Each part of FFHR.

Figures 6 and 7 show tracing of the magnetic field lines and the assemblage of the magnetic field lines and the super conducting coil, respectively.

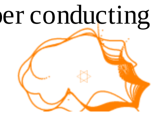

Fig. 6. Tracing of the magnetic field lines.

Fig. 7. The assemblage of the magnetic field lines and the super conducting coil.

Figure 8 shows the direction of the strength, which loads side surface with 1N, and the result of compressive strength. Its maximum placement is 7.961×10^{-8} mm and minimum is 0 mm. Figure 9 shows the direction of the strength with 1N, and the result of torsional strength. Its maximum placement is 6.067×10^{-12} mm and minimum is 0 mm. Figure 10 shows the result of heat conduction. The top of the structure temperature is 1000 degrees, and others is 100 degrees. Its maximum thermal gradient is 45 Celsius/mm and minimum is 1.57×10^{-12} Celsius/mm.

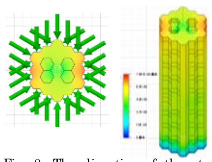

Fig. 8. The direction of the strength and the result of compressive strength.

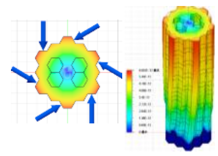

Fig. 9. The direction of strength and the result of torsional strength.

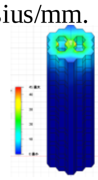

Fig. 10. The result of heat conduction.

4. Conclusions and Future works

Therefore, the double helix structure with refractory bricks is a good candidate design because it is strong in compressive and torsional strength and heat.

Our future works is to develop the automation technologies toolkit with mixed-reality, including the feedback the magnetic field lines, path-planning by using robot operation, simulation results and more.

Reference

[1] J. Miyazawa, et al., https://doi.org/10.1016/j.fusengdes.2018.04.118.
[2] J. Miyazawa, et al., Plasma Fusion Res., 12 (2017) 1405017.
[3] T. Goto, et al., Plasma Fusion Res., 12(2017) 1405016.
[4] H. Ohtani, et al., 36th JSST Ann. Conf. Simulation Tech., (2017) 194.