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タグチメソッドを用いた核融合炉第一壁の構造最適化
Optimization of the first wall structure of fusion reactor by Taguchi method

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1. Introduction

The first wall (FW) of the fusion reactor blanket (BLK) requires the resistance to high heat load and the tritium breeding capability. From the view point of thermal stress induced by the heat load and the tritium breeding ratio (TBR), a thin structure is suitable. On the other hand, a thick structure is suitable to endure the excess increase of internal pressure due to accidental rupture of the cooling channel and so on.

The present design of FW proposed by JAEA has rectangle cooling channels taking account into manufacturability with hot isostatic pressing (HIP) method, and the configuration is not optimized from the thermo-mechanical aspect. Therefore, further structural optimization for them is desired.

For optimizing the complicated structure like BLK and FW, the Taguchi method (TM), which is one of the methods to obtain the optimized robust design, has been applied in various product fields. Thus, the structural optimization of the FW was carried out in this study by using the finite element analysis (FEA) and the TM.

2. Calculation and analysis

The partial FE model of the FW was used for the calculation. Seven control factors each at three levels were considered for the TM as shown in fig. 1 and table 1.To mitigate the compressive thermal stress on the top surface of the FW, a slit (control factors: w4, r3, and θ) was introduced into the model to relax the thermal stress.

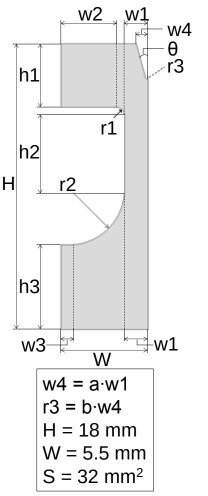

Fig. 1 Control factors

Table 1 L_{18}-OA in this work

	Values for control factors							
No.	A	h1	w1	r1	r2	θ	a	b
1	-	1	1	0.5	0.5	15	0	0.5
2	-	1	1.5	1.5	1.5	30	0.5	0.33
3	-	1	2	3.5	3.5	45	1	0.25
4	-	2	1	0.5	1.5	30	1	0.25
5	-	2	1.5	1.5	3.5	45	0	0.5
6	-	2	2	3.5	0.5	15	0.5	0.33
7	-	4	1	1.5	0.5	45	0.5	0.25
8	-	4	1.5	3.5	1.5	15	1	0.5
9	-	4	2	0.5	3.5	30	0	0.33
10	-	1	1	3.5	3.5	30	0.5	0.5
11	-	1	1.5	0.5	0.5	45	1	0.33
12	-	1	2	1.5	1.5	15	0	0.25
13	-	2	1	1.5	3.5	15	1	0.33
14	-	2	1.5	3.5	0.5	30	0	0.25
15	-	2	2	0.5	1.5	45	0.5	0.5
16	-	4	1	3.5	1.5	45	0	0.33
17	-	4	1.5	0.5	3.5	15	0.5	0.25
18	-	4	2	1.5	0.5	30	1	0.5

The Control factors and its levels were applied to the L_{18} orthogonal array (OA) as shown in table 1.

Thermo-mechanical analysis for the 18 models of L_{18}-OA and the optimized model by TM was performed using the ANSYS general-purpose FEA solver. The 2-dimensional generalized plane strain elements were used for the calculation. The temperature-dependent thermal and mechanical material properties of F82H with elasto-plasticity were used for the calculation. The heat load to the FW top surface, the cooling water temperature, and the heat transfer coefficient of the F82H were 1 MW/m^2, 573 K, and 0.024 $W/m^2/K$, respectively.

3. Results and discussions

Figure 2 show the temperature and Tresca stress distributions of the reference FW model by JAEA (a, b) and the optimized FW model in this study (c, d), respectively. The maximum temperature and stress of the reference model were calculated into 763 K and 543 MPa, respectively. In the optimized model, the maximum temperature and stress decreased approximately 7% (763 K → 709 K) and 65% (543 MPa → 191 MPa) compared with the reference model, respectively. The slit in the FW surface, which was not applied to the reference model, was effective for reducing the surface stress. Details of the Taguchi method, optimization procedure, and result of the optimization will be discussed.

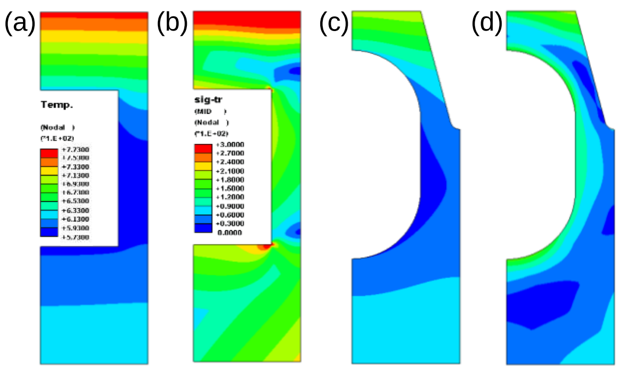

Fig. 2 Temperature and Tresca stress distributions of the partial FW models. (a) and (b): reference model, (c) and (d): optimized model.