Thermo-mechanical Analysis for the Conceptual Design of Korean HCCR TBM-set

Dong Won Lee[a*], Hyung Gon Jin[a], Eo Hwak Lee[a], Jae Sung Yoon[a], Suk Kwon Kim[a], Kyu In Shin[b*], Seungyon Cho[c]
[a]*Korea Atomic Energy Research Institute, Republic of Korea*
[b]*Gentec Tech.Co., Republic of Korea*
[c]*National Fusion Research Institute, Republic of Korea*
[*]*Corresponding author: dwlee@kaeri.re.kr, kyuinshin@hanmail.net*

1. Introduction

The HCCR TBM shall be installed in the equatorial port #18 of ITER inside the vacuum vessel, which is directly faced the plasma, and shall be cooled by a high-temperature He coolant of 300 °C. And the “shield”, which is a water-cooled low-temperature (70 °C), shall be placed behind the TBM and it shall be connected with the water-coolant system of the frame.
The TBM is composed of four sub-modules and a common BM (back manifold). And the shield shall be connected by bar type of “key”. But the detailed design of key is in progress, and evaluated to satisfy the design criteria. TBM-set refers the TBM and the associated shield and key, as shown in **오류! 참조 원본을 찾을 수 없습니다.** [1].

In this study the thermo-mechanical (TM) analysis was carried out to satisfy the design requirement [2] using ANSYS [3].

The material of TBM-set is obtained from the reference [4], and RCC-MRx [6] for the stress analysis. The HCCR TBM uses the RAFM steel, called Advanced Reduced Activation Alloy (ARAA) developed by Korea recently [6], as a structural material, but Eurofer [6] was used for the thermo-mechanical analysis because of insufficient data of ARAA material as a Korea strategy [1,6]. And other structure material such a s the shield, back manifold (BM), etc. in the TBM set has considered to be made by 316L(N)-IG [4].

2. Thermo-mechanical Analysis Results

Figure 1 shows TBM set model and the boundary condition with the connected key between BM and TBM-shield for thermo-mechanical analysis. The boundary condition was considered that *x*-, *y*-, and *z*-axis were fixed at the end of flange, which will be attached with the frame in TBM Port Plug (PP). The keys in BM side are considered to be welded, and penetrated through the shield. More detailed dimensions of TBM-set were explained in the reference [2-1].

The fillet (r = 25) was considered at the end of BM and shield sides to avoid the stress concentration in the key as shown in Figure 1. The diameter (D) of key dimension is 100 mm, the length is 225 mm, and the revised key model is in progress to construct and evaluate to satisfy the design requirement [2].

The thermo-mechanical analysis for TBM set was carried out, and Tresca stress distribution with ×10 scales of the over deformed configuration in TBM set is shown in Fig. . The maximum Tresca stress is 331.2 MPa, and it occurs at the right of lower BM region, which is connected to the key.

The temperature distribution of the key in TBM set was different from the BM to TBM-shield region from the thermal-hydraulic analysis result, and it causes a bending stress by thermal stress in the key. In addition the bending stress caused by the different temperature distribution in the key region gives a significant effect to BM and the front shield region.

But TM analysis result gives that the maximum Tresca strain is only 0.2%, and the total maximum displacement is 0.24 mm.

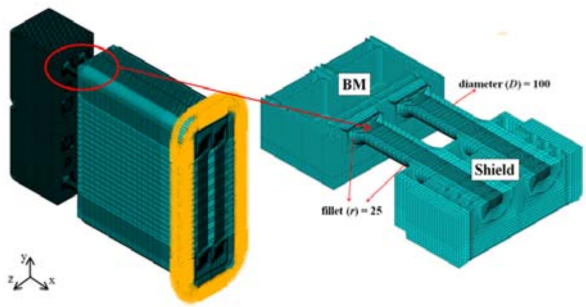

Figure 1 FEM model of TBM set and the boundary condition for TM analysis

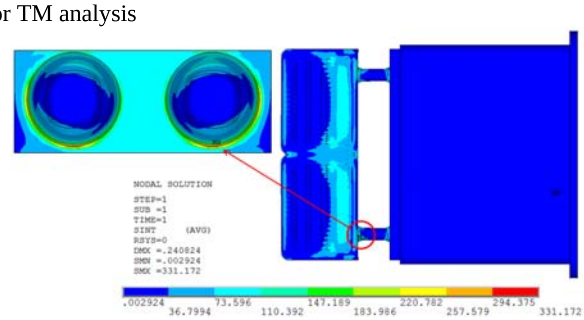

Fig. 2 Tresca stress distribution with over deformed configuration of TBM set (×10)

The stresses evaluation in each component was analyzed for TBM-set integrity, and Fig. shows Tresca stress distribution of TBM sub-module. The maximum Tresca stress is 131 MPa at, upper side wall in Group B, and the maximum Tresca stress in Group A is 130 MPa at upper FW in Group A.

Fig. **4** shows Tresca stress distribution of the back manifold (BM), and the maximum Tresca stress is

388.5 MPa at lower connecting key region. It is noted that the stress concentration influence was occurred between BM and key, and the bending stress caused by the thermal stress from the different temperature distribution in the key also gave a significant effect in BM region.

Fig. shows Tresca stress distribution with a true scale in the (a) upper and (b) lower of keys. The maximum Tresca stresses of the upper and lower keys are 328.4 MPa and 331.2 MPa, respectively at the connecting region to the BM.

Fig. shows Tresca stress distribution with the over deformation configuration of TBM-shield. The maximum Tresca stress is 87 MPa.

Generally the thermal stress is a secondary stress, and the dead weight is a primary stress. But Tresca stress by a dead weight of TBM set was only 4.12 MPa, which is a small value compared with the thermal stress. In this analysis, the stress by the dead weight was not considered in this stress breakdown analysis. RCC-MRx [2] is stated that the secondary stress (Q) may be broken down into membrane stress, Q_m, and bending stress, Q_b: $Q = Q_m + Q_m$.

Fig. shows the "PATH" for stress breakdown analysis at the maximum stress point trough the key thickness region [2]. The membrane stress (Q_m) was 23.55 MPa, and the sum of the membrane stress (Q_m) and bending stress (Q_b) was 92.31 MPa which is less than 1.5S_m (189 MPa of Eurofer at 550 ^oC). The sum of $\overline{Q_m + Q_b + F}$, where F is a peak stress by a thermal stress, was 270.1 MPa, which is also less than 3S_m (378 MPa MPa) according to the RCC-MRx. The results also meet the design criteria.

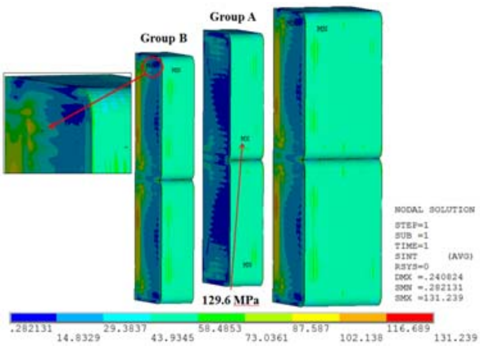

Fig. 3 Tresca stress distribution with over deformed configuration of sub-module part in TBM

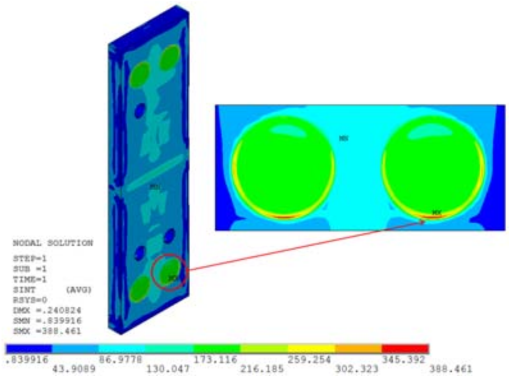

Fig. 4 Tresca stress distribution with over deformation configuration of BM part in TBM set

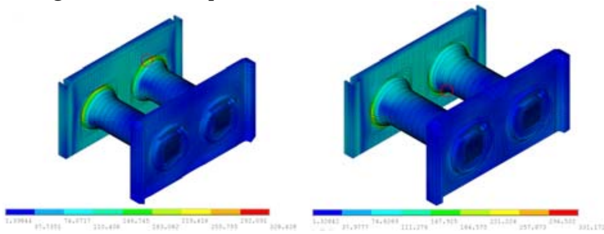
(a) Upper region in key (b) Lower region in key

Fig. 5 Tresca stress distribution of the key component in TBM set

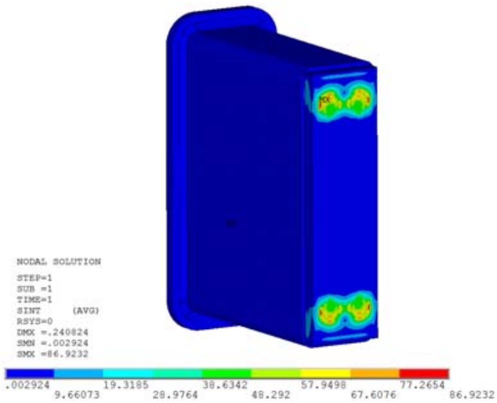

Fig. 6 Tresca stress distribution with the over deformed configuration of the shield part in TBM set

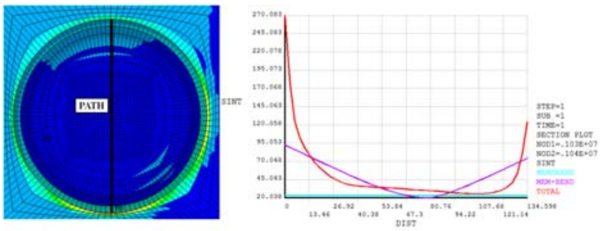

Fig. 7 PATH for stress breakdown analysis and its result in TBM

3. Conclusions

The thermo-mechanical analysis with TBM-set was performed. It was concluded that the current design of HCCR TBM-set meet the design criteria according to RCC-MRx from the investigation of stress distribution from each component in TBM-set, and stress breakdown analysis.

REFERENCES

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