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Electro-magnetic Structural 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*], Jai Hak Park [c]
Seungyon Cho [d]
[a]*Korea Atomic Energy Research Institute, Republic of Korea*
[b]*Gentec Tech. Co., Republic of Korea*
[c]*Chungbuk National University*
[d]*National Fusion Research Institute, Republic of Korea*
[*]*Corresponding author: dwlee@kaeri.re.kr, kyuinshin@hanmail.net*

1. Introduction

The ITER machine is subjected the versatile loads during operation, and the electromagnetic (EM) force due to the magnetic field is one of the most crucial types of loading [1-3].

In this study, the electromagnetic (EM) structural analysis on Korean Helium Cooled Ceramic Reflector (HCCR) Test Blanket Module Set (TBM-set) was described. If the electromagnetic fast transient events such as major disruption (MD), vertical displacement event (VDE) or magnet fast discharge (MFD) were occurred in tokamak system, the eddy current can be induced eventually in the conducting components including TBM-set. As a result, the magnetic field and induced eddy current produce extremely huge Lorentz load (force and moment) on the TBM-set. Furthermore, the effect of the material magnetization also produces large Maxwell load on the TBM structure. Therefore, the electromagnetic load is one of the most important factors for optimized design of TBM-set [1-3].

Fig. **1** shows 20° sector model for the reduction of computational time and it was included the central solenoid (CS) coil, poloidal field (PF) coil, toroidal field (TF) coil, vacuum vessel, TBM-set, TBM Frame and the neighbouring shield blankets surrounding the equatorial port [3].

From the EM analysis results [3] using a coarse model by EM analysis were converted to the fine mesh for stress analysis in which KO own developed program was used, and then stress analysis was performed with ANSYS 14.5 as shown in Fig. 2 [4].

2. Methods and Results

The FE model used for EM analysis and EM stress analysis were in shown Fig. . The number of model of TBM was 1,889,600 elements, 1,868,488 element of TBM-shield, and 113,760 element of the key in EM stress analysis model.

The material of TBM-set is obtained from the ITER Material Properties Handbook data [5], 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 [7], as a structural material. However, in this study the Eurofer [6] was used for EM stress analysis because of insufficient data about ARAA material as a Korea strategy [3,7]. 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 [5].

Fig. **3** shows Tresca stress distribution of a steady Maxwell (MXD) condition in TBM-set. The maximum Tresca stress is 235.2 MPa at the inner and upper surface at graphite reflector region in the breeding zone. And it is higher than $1.5S_m$ (189 MPa) of Eurofer at 550 ^{o}C. The maximum Tresca strain is 0.167% with 0.605 mm of the maximum displacement.

Fig. **4** shows Tresca stress distribution of MD-I with steady MXD condition in TBM-set. The maximum Tresca stress is 233.7 MPa, and it also is higher than $1.5S_m$ (189 MPa) of Eurofer at 550 ^{o}C. The maximum stress location is the similar region in steady MXD condition. And the maximum Tresca strain is 0.166% with 1.08 mm of the maximum displacement.

Fig. shows Tresca stress distribution of MD-II with Steady MXD condition in TBM-set. The maximum

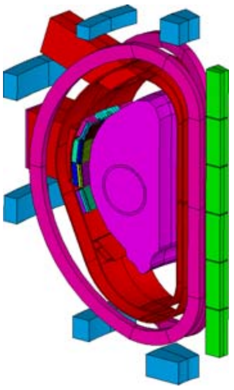

Fig. 1 Overall geometry of 20° sector in ITER model [4]

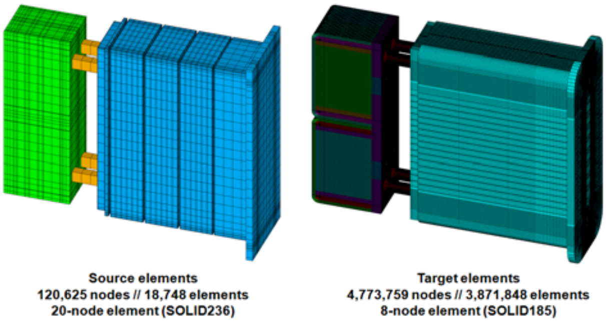

Fig. 2 FE Model of comparison for EM and stress analyses [4]

Tresca stress is 235.2 MPa, and it is higher than 1.5S_m (189 MPa) of Eurofer at 550 ^{o}C. The maximum stress location is the similar region in Steady MXD condition. The maximum Tresca strain is 0.167% with 0.998 mm of the maximum displacement

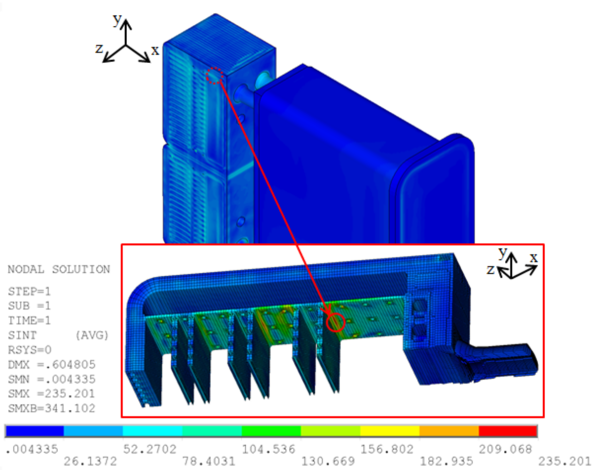

Fig. 3 Tresca stress distribution of Steady MXD condition in TBM-set

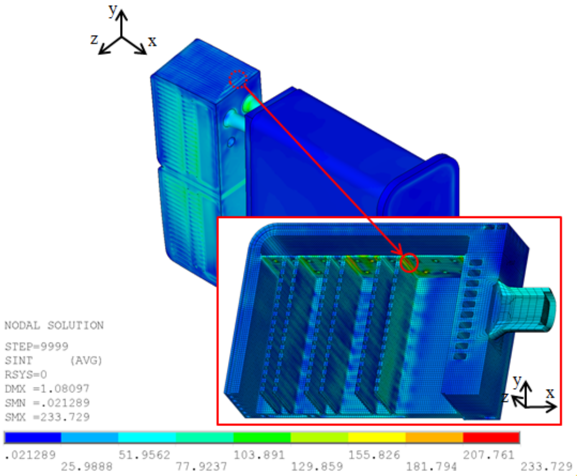

Fig. 4 Tresca stress distribution of MD-I with steady MXD condition in TBM-set

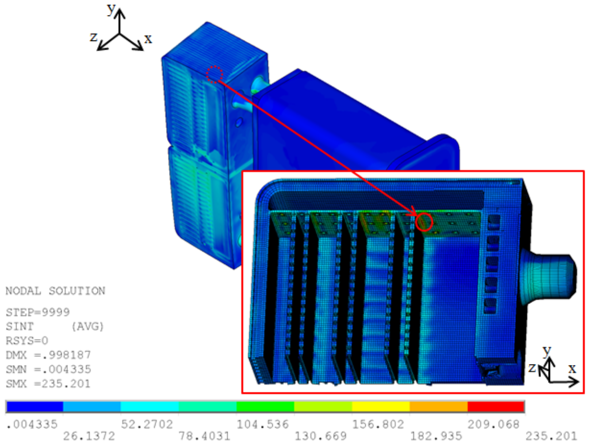

Fig. 5 Tresca stress distribution of MD-II with Steady MXD condition in TBM-set

Figure 6 shows Tresca stress distribution of MD-IV with Steady MXD condition in TBM-set. The maximum Tresca stress is 234.0 MPa, and it is lower than 2.4S_m (238 MPa) of S_{mD} in Eurofer at 550 ^{o}C. The maximum stress location is the similar region in Steady MXD condition. The maximum Tresca strain is 0.1662% (1.096 mm of the maximum displacement).

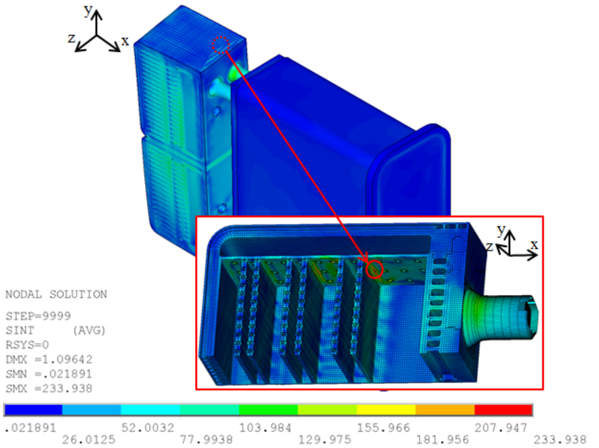

Figure 6 Tresca stress distribution of MD-IV with Steady MXD condition in TBM-set

3. Conclusions

In this stress analyses by EM loads, the maximum stresses does not meet the design criteria except for MD-IV including steady MXW. In the real design of HCCR TBM, there is a He purge line at upper and lower region of breeding zone box including graphite reflector region. In this model it was not considered the support function. If it will be considered, the maximum stress can be reduced and satisfies a design requirement.

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