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Structural Integrity Analysis considered Load Combination for the Conceptual Design of Korean HCCR TBM-set

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1. Introduction

HCCR TBM (Test Blanket Module) set is consist of 4-TBM sub module, one blanket manifold (BM), a shield, and 4-key, which has a function of a connection between BM and the shield. And it shall be installed in the equatorial port #18 of ITER inside the vacuum vessel directly facing the plasma and shall be cooled by a high-temperature helium coolant [1].

In addition, the HCCR TBM-set safety classification follows the ITER (international thermonuclear reactor) safety importance class (SIC) criteria [1], and satisfies a design requirement according to RCC-MRx [2].

In this study, some of load combination (LC) analysis for the structure integrity of TBM set were carried out based on the reference [3,4]. And the LC results showed that they satisfied the design requirement.

The material of TBM-set was used from the reference [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, but Eurofer [6] was used for the thermo-mechanical analysis because of insufficient data of ARAA material as a Korea strategy [1,7].

2. Load Combination Analysis for structure Integrity and Results

The LC loads are consisted of dead weight (DW), operating pressure (PresO), Operating temperature (THO), electromagnetic (EM), seismic, and TBM LOCA. And each single load condition has to satisfy the design requirement. Based on the satisfied single load, it was combined according to the event categories [3,4], and the LC result were also satisfied the design requirement.

In this study, some of LC analyses for the structure integrity of TBM set were carried out based on the reference [3,4] using ANSYS [8].

2.1 Event Category LC-I case

The event category I is a normal operation state and 30,000 of events are considered to be occurred by the probability analysis. And the considering LC-I condition in this study was consist of DW, PresO, THO and EM (steady Maxwell) load in the LC-I load combination conditions.

Fig. shows Tresca stress distribution of LC-I with ×100 scale of over deformed configuration. The maximum Tresca stress is 361.1 MPa, which is lower than $3S_m$ (378 MPa), and occurs at the upper connected region between BM and key. The maximum Tresca strain is 0.2351 %, and the maximum displacement was 0.707 mm.

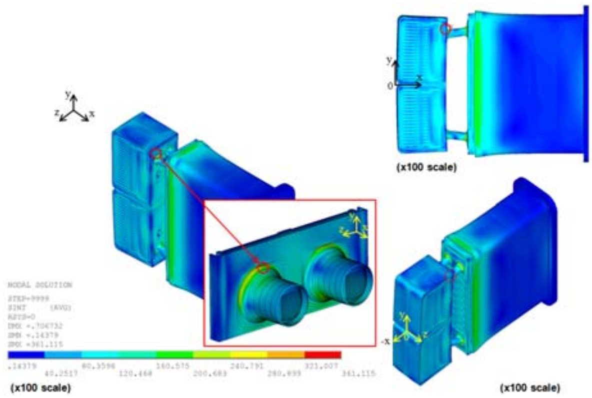


Fig. 1 Tresca stress distribution with the over deformation configuration (×100) in the event category LC-I case

2.2 Event Category LC-II case

The event category II is a normal operating, start-up and shutdown state, and has an incidents possibility. And the considering LC-II condition in this study was consist of DW, PresO, THO, EM (steady Maxwell), EM (major disruption, MD-I), and seismic (Level-1) loads in the LC-II load combination conditions.

Fig. shows Tresca stress distribution of LC-II load combination conditions with ×100 scale of over deformed configuration. The maximum Tresca stress is 420.2 MPa, which is occurred at the lower right key region close to shield, and it is higher than $3S_m$.

Fig. shows the results from the stress breakdown analysis at the maximum stress through the key thickness. The primary membrane stress (P_m) is 55.13 MPa, the sum of membrane and bending stress ($\overline{P_L+P_b}$) is 193.9 MPa, and the sum of primary and secondary stress ($\overline{P_L+P_b+Q}$) is 311.4 MPa, which is lower than $3S_m$. Though the maximum stress in TBM set gives a higher value than $3S_m$, but it is satisfied a design requirement from the stress breakdown analysis according to RCC-MRx. The maximum Tresca strain was 0.272 %, and the maximum displacement was 1.657 mm.

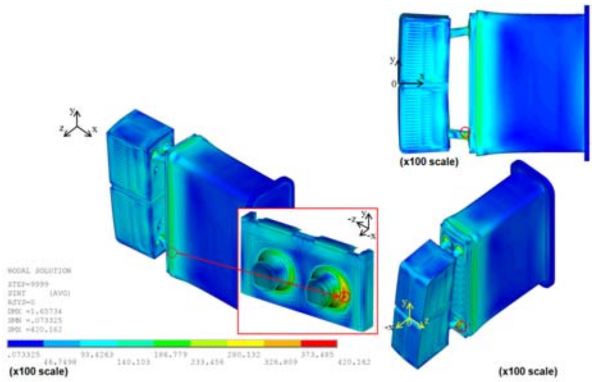
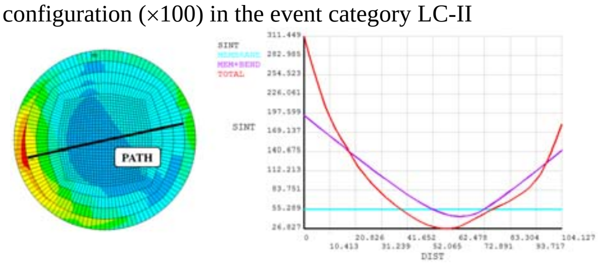


Fig. 2 Tresca stress distribution with the over deformed configuration (×100) in the event category LC-II



(a) PATH (b) stress breakdown analysis result

Fig. 3 Result of stress breakdown analysis in the event category LC-II case

2.3 Event Category LC-III

The event category III is an emergency condition as an exceptional operation condition. The considering LC-III condition was consist of DW, PresO, THO, EM (steady Maxwell), and seismic (SMHV) loads in the LC-II load combination conditions. The SMHV, which is maximum historically probable earthquakes, is the most penalising earthquakes liable to occur over a period of about 1000 years.

Fig. shows Tresca stress distribution of No. 10 of the load combination case with ×100 scale of over deformation configuration. The maximum Tresca stress is 404.8 MPa, which is occurred at the lower right key region closed to the shield, and is lower than $3S_{mC}$ (510 MPa of Eurofer at 550°C). The maximum Tresca strain was 0.27%, and the maximum displacement was 1.557 mm.

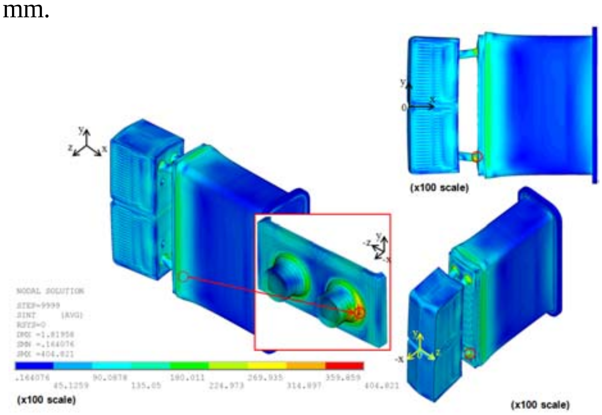


Fig. 4 Tresca stress distribution with the over deformed configuration (×100) in the event category LC-III case

2.4 Event Category LC-IV case

The event category IV is a highly improbable condition as an exceptional operation unless provided in the equipment specification state. And the considering LC-III condition in this study was consist of DW, PresO, THO, EM (steady Maxwell), and seismic (SL-2) loads combination conditions.

Fig. **5** shows Tresca stress distribution of the load combination case with ×100 scale of over deformed configuration. The maximum Tresca stress is 438.3 MPa, which is occurred at the lower right key region closed to the shield, and it is lower than $3S_{mD}$ (714 MPa of Eurofer at 550°C). The maximum Tresca strain was 0.2824%, and the maximum displacement was 2.403 mm.

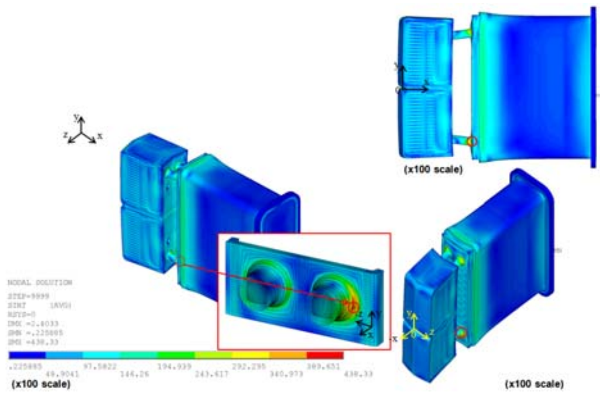


Fig. 5 Tresca stress distribution with the over deformed configuration (×100) in the event category LC-IV case

3. Conclusions

Some cases of the load combination analysis for structural integrity of TBM set were carried out. In this study, the load combination results were met a design requirement. But some load combination case gave a higher maximum stress value than a design requirement and in these case the stress breakdown analysis according to RCC-MRx was performed, and the result were satisfied the design requirement.

REFERENCES

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