Thermal Characteristics of HCCR Test Blanket Modules during a Loss of Flow Accident

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1. Introduction

When the loss of off-site power (LOOP) accident occurs in the ITER, the plasma and the related auxiliary facilities will be stopped. . For the HCCR TBM, thermal load coming from the plasma facing surface will disappear and the coolant flow will be stopped, which is called the loss-of-flow accident (LOFA). This transient thermal analysis were performed for the conceptual design (CD) model of TBM [1]. To operate the cooling system connected to TBM, estimated time is about 90 seconds. At 90 s after LOFA for conceptual model, the maximum temperature of the structure is about 592 °C. The design temperature of the structure is 650 °C. The TBM model have been designed. Current TBM model is preliminary design (PD) model with some improving cooling performance. In this work, the numerical analysis results for the PD model is presented at LOFA condition.

2. Model and assumptions

The model in the conceptual design of HCCR-TBM was used as shown in Fig. 1 [2]. The HCCR-TBM consists of four sub-modules, and the main components are first wall (FW) and breeding zone (BZ) in each sub-module and common BM. In HCCR-TBM, the reduced activation ferritic/martensitic (RAFM) steel is used as structural material, and the lithium ceramics, beryllium and graphite are used as functional materials such as breeder, multiplier and reflector, respectively. The BZ comprises total seven layers, i.e. three breeder layers, three multiplier layers and one reflector layer. Between the layers, BZ cooling plates with cooling passage inside are located to cool each layer within the temperature limit. In the conceptual design phase, the steady-state thermal analysis for integral module (INT-TBM) was performed [3], and this model and input for CFD code were used in the present analysis [4].

Total analysis time was 300 s after LOOP accident, in which the IP circulator starting time, 90 s can be used for inferring the temperature evolution assuming the circulator replacement. The initial temperature condition was used from the results of the steady-state analysis of INT-TBM. There is no helium coolant in the cooling channel of the structure due to the LOFA and it was assumed to stay in a stationary state. Radiative cooling is not considered for the conservative approach. The thermal load on the plasma-facing surface of FW from the plasma is assumed to disappear right after the LOOP accident. Decay heat for each structure was used as the heat source from the neutronics analysis.

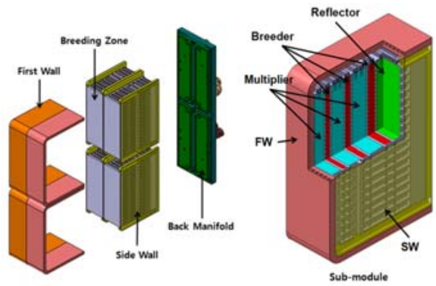
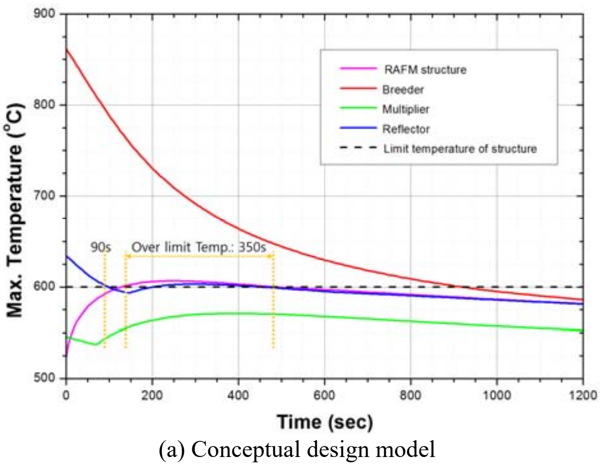


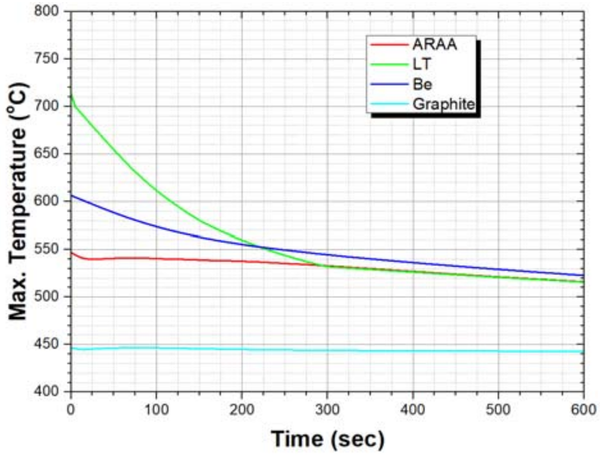
Fig.1. Exploded and internal view of the conceptual design of HCCR-TBM

3. Analysis results

Figure 2 shows the maximum temperature evolution at each component after LOOP accident. The maximum temperature for the PD model is 545 °C which is same at the steady-state condition. The major difference in Fig. 2 is the trend of the temperature for the structure. In CD model, the temperature of the structure increases and then decreases. On the other hand, the structure temperature for PD model keeps decreasing. It is caused by the initial temperature of the breeder material. Due to the thermal equilibrium state between the lower and higher temperature regions, breeder and multiplier temperatures decrease. The amount of heat from these material is difference between the CD and PD models. A relatively small amount of heat is transferred at PD model.



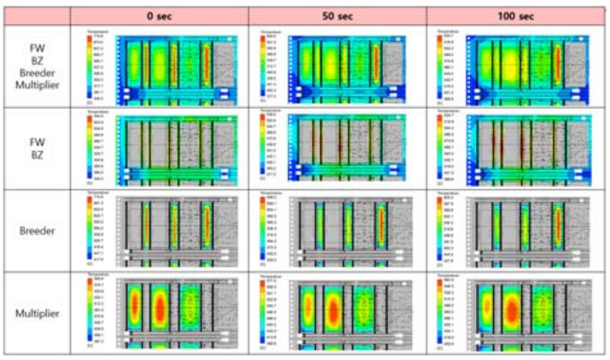
(a) Conceptual design model



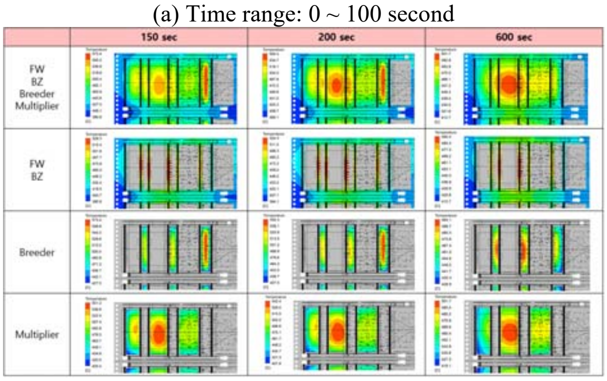
(b) Preliminary design model

Fig. 2. Temperature evolution at each TBM component

Figure 3 shows where the maximum temperature region of each material occurs in 100 second increments on the cross section of TBM. The breeder is the component with the highest temperature in its initial state. Breeder continues to transfer its heat with the multiplier and the RAFM steel in contact with each other. At the 300 second point, the maximum temperature of the structure (ARAA) and the breeder material (LT) becomes equal.



(a) Time range: 0 ~ 100 second



(b) Time range: 150 ~ 600 second

Fig. 3. Time-temperature history of TBM components

4. Conclusions

Transient thermal analysis of HCCR-TBM was performed for the LOFA induced by LOOP accident for the preliminary design TBM model. The maximum temperature of the RAFM steel is kept below 550 °C. The structural material temperature does not exceed 550 °C, while the previous result shows that the temperature of the structural material increases up to 595 °C at 90 s.

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