Consideration and Basic Direction of Pipe Design in KO TBM-set

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1. Introduction

Test blanket module TBM will be installed in the toroidal port of ITER to check the production and transport of tritium, heat removal in high-temperature environments, and structural integrity [1, 2]. TBM-set has a TBM box and a TBM-shield. The TBM-box is where tritium is generated in accordance with the purpose of installation, and is exposed to high temperature. The TBM-shield acts as a shielding block composed of water and structures to reduce the amount of radiation affecting in the place at the rear end of the port where the TBM-set is installed. Pipes are needed for coolant to cool the TBM box, transport of the generated tritium and I&C for measurement of TBM box main. Pipes should be designed to secure structural integrity without affecting the radiation shielding role of TBM-shield.

In this study, considered points and design direction for the pipe design of TBM-set are introduced.

2. Pipe Specification in TBM-set

The TBM-set consists of pipes for passing the TBM-shield for helium coolant and transportation of tritium, and pipes for cables connected to various instrumentation devices. These pipes come from the pipe forest and the pipes related to the coolant and tritium are connected to the back end of the TBM-box. It is not directly connected to the TBM-box with pipes related cables. Pipes welded to the back of the TBM-shield pass through the inside of the TBM-shield. Figure 1 show the arrangement of pipes located at the back of TBM-shield with the specifications [3].

Pipe Color	OD-ID [mm]	
	Standard	Value(OD-thickness)
HCS	DN80-80S	88.9OD-7.62t
TES	DN40-40S	48.3OD-3.68t
NAS	DN50-40S	60.3OD-3.91t
I&C	DN50-40S	60.3OD-3.91t
CW	DN32-10S	42.2OD-2.77t

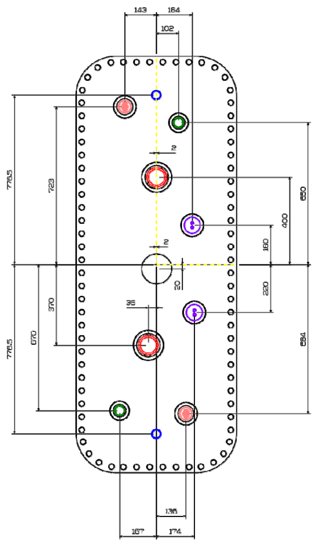

Fig. 1. Pipis arrangement and Spec. in TBM-set

3. FEM analysis

FEM analysis using ANSYS was performed to check the consideration in the pipe design related to TBM-set.

2.1 Geometry Model and material

Figure 2 shows the TBM-set model used for the analysis. The inside of TBM-box and TBM-shield is removed to focus on the design of the pipe. A complex geometry for the TBM-set is not required. In addition, there are a total of 8 pipes of 3 types passing through the TBM-shield, but in this analysis, a total of 3 pipes for each type were reflected in the design analysis. After confirming the effect of pipe design issues which are bending on the design and welding geometry type, all pipes are reflected in the design and the arrangement of pipes will be studied to avoid interference. The pipes are welded to the back of the TBM-shield and the TBM-box. Banding is located in the middle of TBM-shield. This banding is required to reduce the stress applied to the pipe and the amount of radiation measured at the rear end of the TBM-shield. It can lower the generated stress due to the expansion of the pipe in the axial direction and prevent radiation from escaping in a straight line.

TBM box and TBM-shield are made of RAFM steel and 316L(N)-IG, respectively [4, 5]. The material of the pipes is 316L.

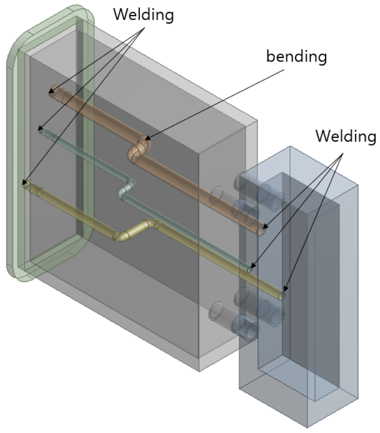

Fig. 2. Geometry model

2.2 Boundary & constraint condition

The temperature is the major factor influencing stress generated in the pipes. The analysis was carried out by reflecting the boundary conditions as shown in Fig. 3 for the temperature considering the normal operation state. The TBM-box rises up to 550 degrees. The temperature of the front end of TBM-shield is formed up to 240 degrees. The back of the TBM-shield is heated up to 130 degrees. Helium coolant and tritium transport pipes are heated up to 450 degrees. The flange area at the back of the TBM-shield is bolted to the TBM port. In this analysis, the TBM-shield flange area was selected as a fixed condition. The inside of the pipe with a pressurized helium coolant is exposed to 8 MPa. In order to consider the material weight, the gravitational acceleration is reflected. These constraint conditions are shown in Figure 4.

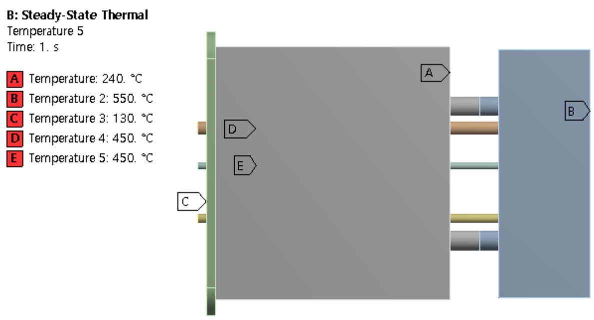

Fig. 3. Temperature boundary condition in TBM-set

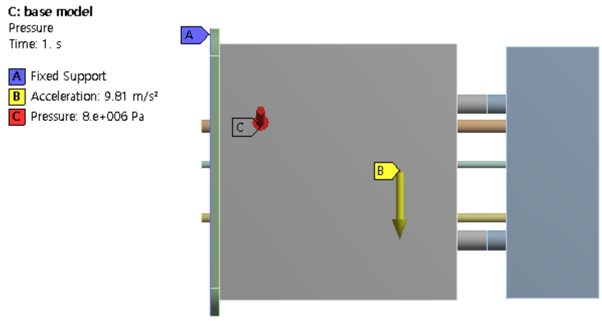

Fig. 4. Constraint condition in TBM-set

2.3 Results

Figure 5 shows the temperature distribution formed on the TBM-set. It can be seen that various temperature gradients are formed by reflecting the selected boundary conditions.

Figure 6 shows the stress distribution formed in the pipe. There are three concerned locations where the stress is concentrated. These are the TBM-shield welding area, TBM-box welding area and bending area. The stress formed in the TBM-shield welded area is caused by the difference between the temperature of the pipe and the TBM-shield. Since the TBM-shield and the pipe are made of similar materials, the effect of volumetric expansion on the stress is minor. The temperature of the pipe inside is relatively higher than that of the TBM-shield. The stress concentration on the back of TBM-shield occurs.

The stress concentration formed at the back of the TBM-box is due to the dissimilar welding. High stress is generated due to the different thermal expansion coefficient between RAFM and SS316. In order to relieve stress concentration, the position of the dissimilar weld zone should be adjusted and the weld shape should be changed. The stress concentration occurring in the bending region is related to the number of bending. Basically, in order to suppress the stress generation due to the expansion in the pipe axial direction, two bending are required. In the TBM-set pipe design, only one bending was reflected in the design due to spatial limitations. It should reflect the 2nd banding or the design that can expect the same effect.

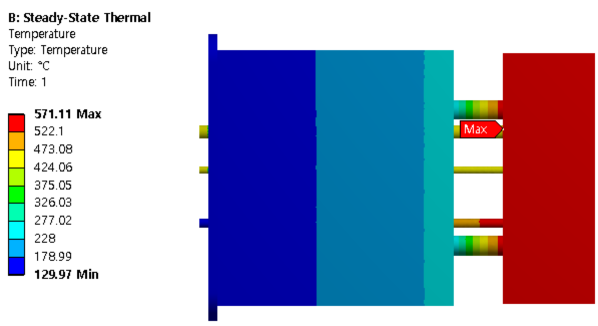

Fig. 5. Temperature distribution in TBM-set

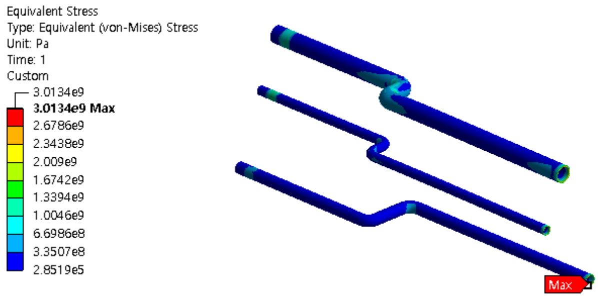

Fig. 4. Stress distribution in pipes

3. Summary

FEM analysis was performed for pipe analysis using a model in which the TBM-set geometry was simplified. Structural analysis was performed by applying dead weight, pressure load, and thermal load. The stress concentration formed in the pipe was confirmed, and the design direction to reduce the stress was described. It is planned to proceed with pipe design using the described design method to check the effect of stress relief, and to apply these contents to the entire pipe to conduct structural analysis and evaluation according to the arrangement.

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