Preliminary Study on the ITER Neutral Beam Duct Liner Mockup for High Heat Flux Test

D. W. Lee[1*], S. K. Kim[1], E. H. Lee[1], J. S. Yoon[1], C. K. Park[2], J. W. Sa[2]
[1]*Korea Atomic Energy Research Institute, Republic of Korea*
[2]*National Fusion Research Institute, Republic of Korea*
[*]*E-mail: dwlee@kaeri.re.kr*

1. Introduction

An ITER Neutral Beam Duct Liner (NBDL) is located inside the NB port structure of a vacuum vessel (VV). The main functions are to protect the port wall from the high-power neutral beam, to limit the beam dimension, to contribute to the radiation shielding of the TF coil, and in particular, to provide a higher cooling performance [1]. The NB liner consists of two main components, the neutron shield of the double wall structures with cooling paths, and the cooling module utilizing copper alloy as a heat-sink material, as shown in Fig. 1. Figure 2 shows the typical configuration of the cooling module on the ITER NBDL.

In Korea, as a procurement country for NBDL, to verify the manufacturing processes of the cooling module of the ITER NB duct liner, simplified full-scale mock-ups with 6 holes have been fabricated, as shown in Fig. 3. Moreover, the mock-up will be tested using a high heat flux test for verifying the cooling and instrumentation performance, in which 4 types of thermocouples will be installed and their measurement capability tested through a high heat flux test.

In the present study, to determine the optimized test conditions and thermocouple locations, a thermal-hydraulic analysis was conducted considering the neutron beam profile.

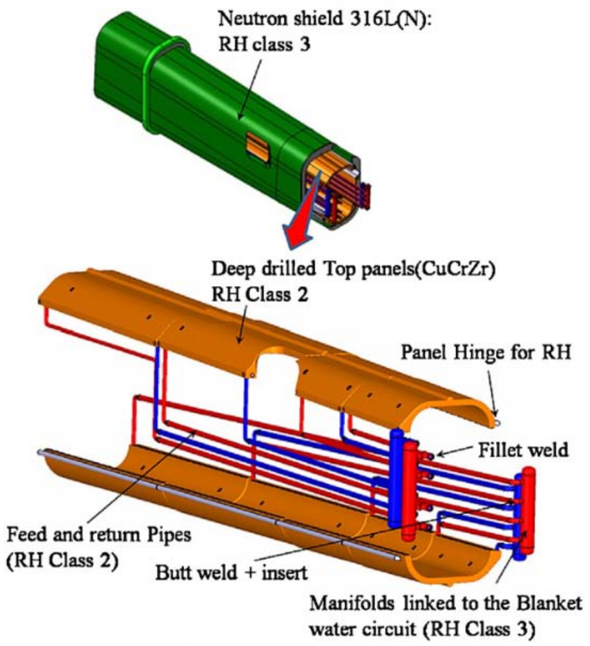

Fig. 1 Overall configuration of the ITER NBDL.

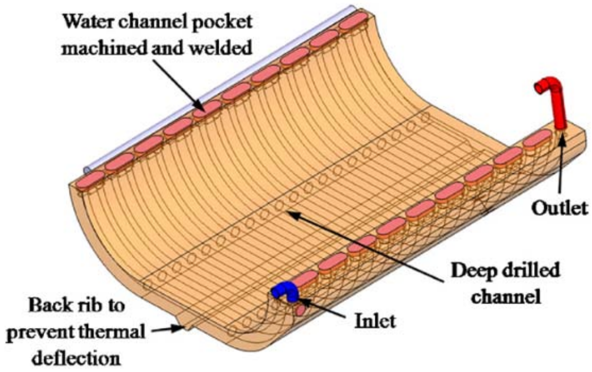

Fig. 2 Typical configuration of the ITER NBDL cooling module.

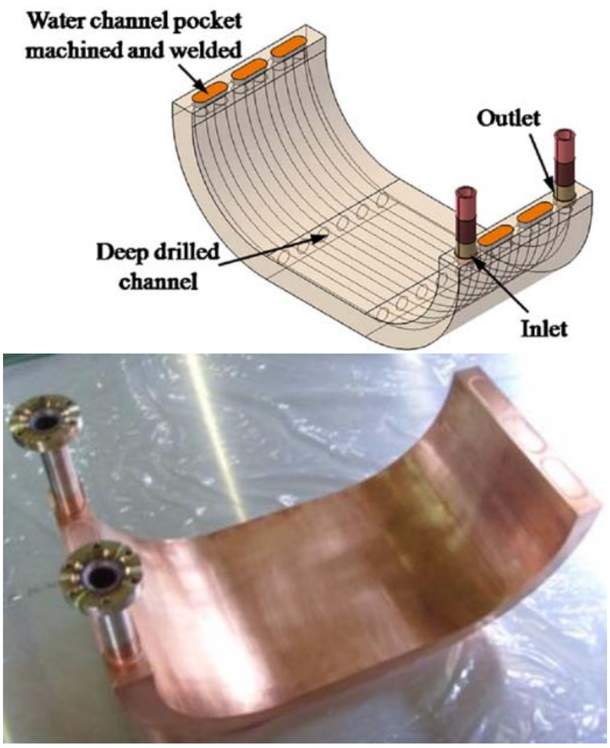

Fig. 3 Simplified configuration and fabricated photo of the ITER NBDL cooling module.

2. Preliminary analysis for high heat flux test of the mockup

To determine and confirm the test conditions, a preliminary analysis with ANSYS-CFX was performed. The mockup has 6 holes for cooling with a 23 mm diameter and 40 mm pitch. The U-shaped mockup has a bending angle of 170 mm in the center and 270 mm in width. These dimensions were used for redrawing the CATIA model and draft, as shown in Fig. 4. Since there is one inlet and one outlet for the coolant, the coolant was also modeled in CATIA for thermal-hydraulic analysis with ANSYS-CFX. Using the developed CATIA model, hexa meshes were produced with ICEM-CFD as shown in Fig. 5, in which the numbers of elements were 253 and 401, and 457 and 488, for a solid and fluid, respectively.

In the ITER conditions, the inlet water flow rate is about 2.2 kg/sec with 3.0 MPa pressure and 100 °C wate temperature, as shown in Table 1. The surface heat flux has a Gaussian distribution, but the maximum value is about 1.5 MW/m^2 with 5.0 MW/m^3 of volumetric heating, and the expected maximum temperature in the Cu alloy panel is then about 250 °C. Under the same conditions, the mockup temperature is about 290 °C. In the high heat flux test, the temperature measurement and cooling is important. Therefore, the surface heat flux can show that the temperature was found to be 1.0 MW/m^2 considering the KAERI coolant system (0.5 kg/sec flow rate, 0.2 MPa pressure, and 100 °C temperature of water). Figure 6 shows the temperature distribution of the simulation, the maximum temperature of which is about 314 °C. The results are summarized and compared in Table 1.

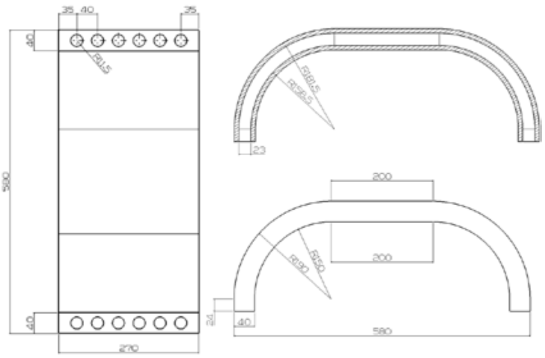

Fig. 4 Redrawn draft of the fabricated mockup.

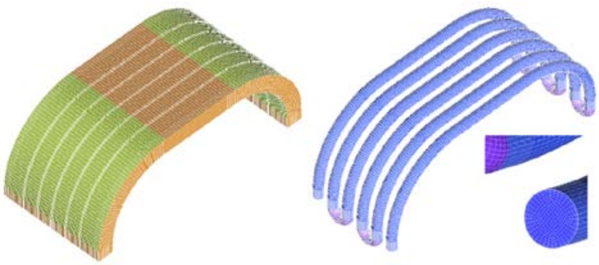

Fig. 5 Hexa meshes for simulation (solid and fluid).

Table 1 Test and simulation conditions of ITER NBDL mockup.

Items	ITER conditions	Test conditions
Surface heat flux	1.5 MW/m^2 with vol. heating 5.0 MW/m^3	1.0 MW/m^2
Inlet water conditions	2.2 kg/sec 3.0 MPa, 100 °C	0.5 kg/sec 0.2 MPa, 100 °C
Duration time	Transient	~100 sec

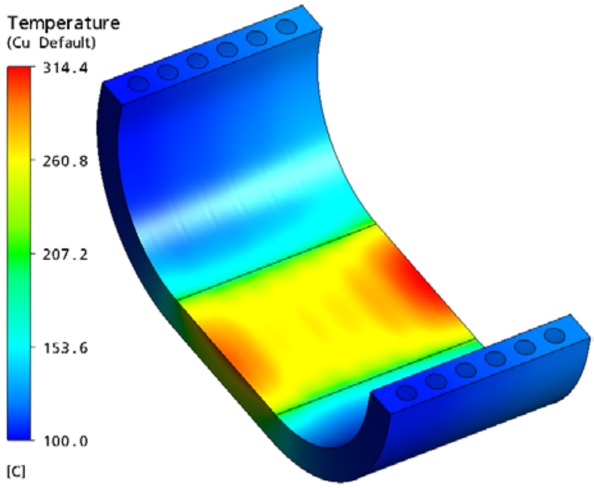

Fig. 6 Temperature distribution of the simulation.

3. Conclusion

The ITER NBDL is one of the procurement packages in Korea. Confirming the cooling performance and temperature measurement during the ITER operation is essential considering its important main functions. To verify them, a NBDL mockup was fabricated and has been prepared for testing in the high heat flux facility in KAREI. In the present study, the test conditions were found through a commercial CFD code, ANSYS-CFX, considering that they can produce a similar temperature distribution during ITER operation. For this, the mockup modeling was reviewed and reproduced with CATIA. The proposed test conditions are as follows: 1.0 MW/m^2 of surface heat flux using the current water supply system.

In KAERI, a new electron beam facility will be installed by the end of June 2012, including a trial operation, which can produce about a 10 MW/m^2 heat flux. In addition, an NBDL mockup will be tested in July 2012.

References

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