Numerical Investigation of Helium Cooled Channel for First Wall Application

Seong Dae Park[a], Dong Won Lee[a], Eo Hwak Lee[a], Jae-Sung Yoon[a],
Suk-Kwon Kim[a], Hyung Gon Jin[a], Sunghwan Yun[a], Dong Jun Kim[b], Seungyon Cho[c]
[a]*Korea Atomic Energy Research Institute, Daejeon, Republic of Korea*
[b]*Korea Univ., Mechanical Engineering Dept., Seoul, Republic of Korea*
[c]*National Fusion Research Institute, Daejeon, Republic of Korea*
[*]*Corresponding author: sdpark@kaeri.re.kr*

1. Introduction

High pressure helium gas is considered as the favorite coolant of the first wall (FW) in several blanket concepts for DEMO and the ITER test blanket modules (TBMs) due to the chemically inert, no chemical corrosion, and the wide operation temperature etc. [1, 2]

There are some heat transfer characteristics in the first wall (FW) application. The heated surface is limited as the plasma facing surface. The heated helium is concentrate near the heated surface. There are some research by attaching the designed structure like the ribs and the mixing devices to lower the wall surface and improve the heat transfer. These increase the pressure drop while increasing the turbulence of the helium coolant. [3, 4, 5]

In this work, heat transfer characteristics of the FW was studied to enhance the heat transfer while minimizing the pressure drop. Thermal-hydraulic analysis was performed with a conventional CFD code, ANSYS-CFX.

2. Design Criteria for Structural Integrity

For structural material (KO RAFM steel, ARAA) of the FW, the design values are between 300 ºC and 550 ºC considering the DBTT (Ductile Brittle Transition Temperature) and the irradiation embrittlement. The inlet temperature and the velocity of the helium coolant was determined to maintain the structure integrity.

3. Heat transfer in BZ

Heat transfer in the FW could be described in Fig. 1. The major heat related in the FW heat transfer was generated from the plasma facing surface. The heated FW structure was cooled by the helium coolant.

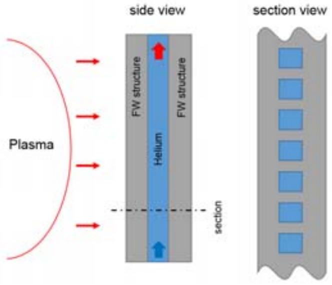
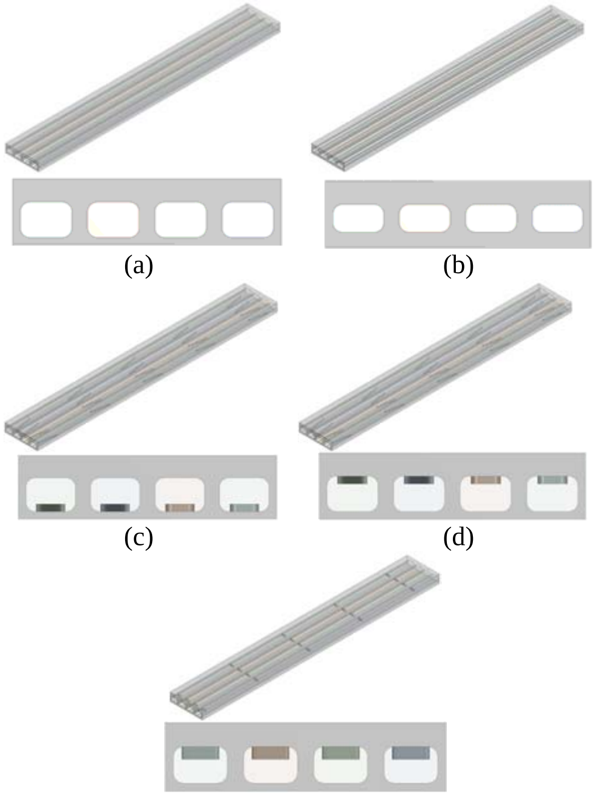


Fig. 1. Heat transfer in the FW

3. Thermal Hydraulic Analysis

3.1 Geometry model

The geometry models was described in Fig. 2. The reference model in Fig. 2 (a) is the smooth surface channel. The area of the flow channel in Fig. 2 (b) was reduced to improve the heat transfer. The size of the channel is 9 mm and 13.1 mm for the width and the length, relatively. The flow length of the helium channel is 500 mm. The mixing devices was attached on the inner surface of the channels in Fig. 2 (c), (d), and (e).



(a) (b) (c) (d) (e)

Fig. 2. Channel geometry model

3.2 Boundary condition

The mass flow of a helium coolant channel is 0.0114 kg/s. The inlet temperature of the helium is 350 ºC. The plasma facing surface heat is 0.3 MW/m^2. The turbulence model is shear stress transport model. The symmetry surface condition was applied on the both side of the FW surface to simulate the continuous channel geometry.

3.3 Temperature results

Temperature distribution on the heated surface and the helium channel cross-section was described in Fig. 3. When the mixing devices were attached on the inner surface, the maximum temperature of the heated surface was decreased except for the (c) case. The parametric study is required to distinguish the effects and optimize the design.

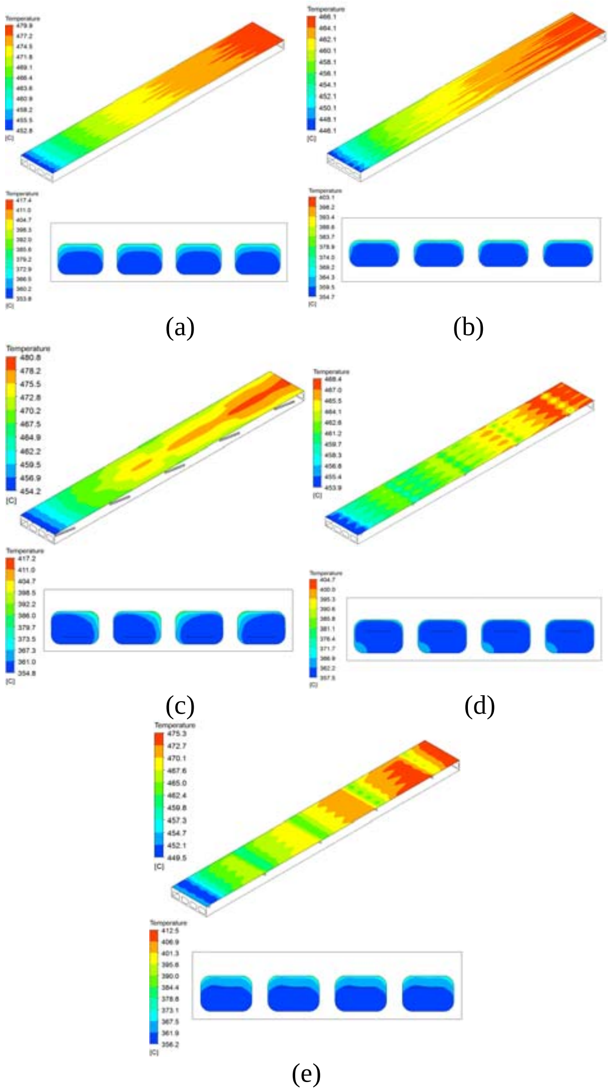


Fig. 3. Temperature distribution on the heated surface and the flow cross-section

3.4 Pressure drop

Table 1 shows the pressure drop of the helium flow channel. The pressure drop of the reference model is 15.1 kPa. The pressure drop of other cases are increased due the change of the flow channel. The flow channel is reduced in the (b) case. The mixing devices are inserted in the flow channels in other cases.

	Pressure drop (kPa)
(a)	15.1
(b)	29.5
(c)	25.2
(d)	25.2
(e)	57.0

4. Further Work

The thermal hydraulic analysis for the helium channels in the FW was performed. The maximum temperature and the pressure drop were changed according to the channel geometry. The parametric study is required to distinguish the effects and optimize the design. The mechanical analysis will be performed to check what temperature distribution on the plasma facing surface is beneficial to ensure the structure integrity.

Acknowledgment

This work was supported by the R&D Program through the National Fusion Research Institute (NFRI) funded by the Ministry of Science and ICT of the Republic of Korea (NFRI-IN1803).

REFERENCES

[1] G. Federici, R. Kemp, D. Ward, C. Bachmann, T. Franke, S. Gonzalez, C. Lowry,M. Gadomska, J. Harman, B. Meszaros, C. Morlock, F. Romanelli, R. Wenninger,Overview of EU DEMO design and R&D activities, Fusion Eng. Des. 89, 7–8, 882–889 (2014)

[2] S. Ruck, F. Arbeiter, Thermohydraulics of rib-roughened helium gas runningcooling channels for first wall applications, Fusion Eng. Des. 109–111, 1035–1040 (2016)

[3] F. Arbeiter, C. Bachmann, Y. Chen et al., Thermal-hydraulics of helium cooled First Wall channels and scoping investigations on performance improvement by application of ribs and mixing devices. Fusion Engineering and Design, 109, 1123-1129 (2016)

[4] S. Ruck, & F. Arbeiter, Thermohydraulics of rib-roughened helium gas running cooling channels for first wall applications. Fusion Engineering and Design, 109, 1035-1040 (2016)

[5] D. Cheng, W. Wang, H. Deng, B. Yang, B. Shi, & J. Yang, Numerical Investigation of Channel for Helium Cooled China HCCB-TBM First Wall by Application Enhance Heat Transfer Method. Journal of Fusion Energy, 35, 748-757 (2016)