Structure Analysis of Helium Cooling System including Isolation valve for Test Blanket Module

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1. Introduction

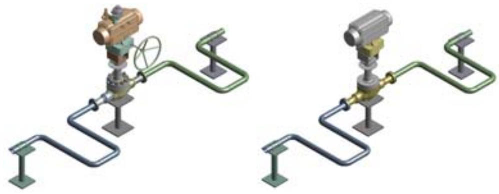
Test blanket module (TBM) using helium cooling has been designed to install in ITER and verify the tritium production and the heat extraction [1, 2]. The helium cooling system removes the heat generated in TBM. There is heat coming from the surface facing the plasma and heat generated during nuclear reaction between functional materials such as breeders and multipliers located inside the TBM. The helium temperature and flow rate of helium cooling system (HCS) are designed in order to satisfy the requirement of the structure design temperature. Therefore, the HCS must be operated according to the conditions of normal and accident situations.

The development and analysis results of HCS with isolation valve are shown in this work. Isolation valve plays the role of urgently blocking or opening the flow of helium according to the set logic in the accident situations. Structure integrity was confirmed by applying various loads to partial HCS models including isolation valve with ANSYS [3].

2. Geometry & mesh

The valve is being developed with a valve specialized company, KOVAL Co. in Busan, and KAERI. KOVAL is in charge of design, manufacturing, and testing of the valves, while KAERI was conduct thermal-hydraulic analysis, structure analysis on developed valves by KOVAL. Figure 1(a) is a CAD model including detailed valve shape and HCS part. For the convenience of analysis, the model as shown in Fig. 1 (b) was completed through removal and simplification of parts that do not affect the results, and the analysis was performed. The material of the valve and connected HCS pipe is SS316. Although A4-70, A36, SS304, A36, etc. were used for the material of the parts constituting the valve, it is a part that is not in direct contact with helium and does not significantly affect the structure integrity. The material of the valve and connected HCS pipe is SS316.

Figure 2 shows a meshing model. The mesh element is composed of tetra, and the total number of mesh is 79,270. The minimum mesh quality is 0.22, and the average mesh quality is 0.63.



(a) Detailed model (b) Simplified model
Fig. 1. Geometry model of HCS and isolation valve

Fig. 2. Mesh model of HCS and isolation valve

3. Thermal analysis

In order to confirm the structure integrity of the model against thermal load, thermal analysis was performed to obtain the temperature distribution of the entire model. The pipe is covered with insulation. The pipe support and part of the valve are exposed to the outside. Helium at 500°C is flowing into the pipe. The conditions for convective heat transfer only on the surface exposed to the outside were set as shown in Figure 3. Figure 4 shows the temperature distribution analysis result. It can be seen that the pipe was maintained at 500 °C by the insulating material. Various temperature distributions occur in the support and the isolation valve.

Fig. 3. Boundary condition

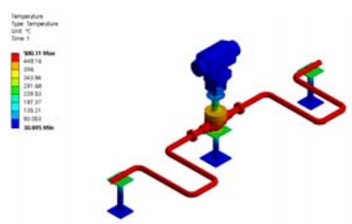


Fig. 4. Temperature distribution

4. Structure analysis

The HCS connected to the isolation value is subjected to various loads. Basically, thermal loads from heated helium, pressure loads from helium in a pressurized state with 10MPa which is design pressure, and various loads that can occur in an accident situation can be considered. In this analysis, structure analysis was carried out only for thermal loads, pressure loads, and seismic loads among accident analyses.

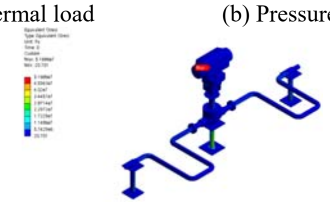
Figure 5 shows the constraint condition of structure analysis. The lower part of the support is fixed to the floor, and the upper part is physically connected to the HCS pipe.

Fig. 4. Constraint distribution

Figure 6 shows the structure analysis results under thermal load, pressure load, and seismic load. The maximum stress generated location of the thermal load and seismic load case occurred in the inner region of the valve. In the pressure load case, the maximum stress occurred at the support, and the maximum stress on the pipe is about 10 MPa. In three cases, it was confirmed that the maximum stress was lower than the allowable stress of the SS316 material calculated based on RCC-MRx [3].

(a) Thermal load

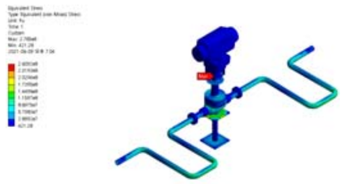
(b) Pressure load



(c) Seismic load

Fig. 5. Stress distribution with single load

Figure 6 shows the structure analysis results for load combinations. Various load combination can be considered for thermal load, pressure load and seismic load. As a result of structure analysis of these combinations, it was confirmed that the maximum stress was lower than the allowable stress of the SS316 material calculated based on RCC-MRx.



(a) Combined thermal and pressure loads

(b) Combined thermal and seismic loads

(c) Combined pressure and seismic loads

(d) Combined thermal, pressure and seismic loads

Fig. 6. Stress distribution with load combination

5. Conclusions

Isolation valve was designed by KOVAL and then the structure analysis (thermal, pressure, seismic, and load combination) was performed. the maximum stress was lower than the allowable stress of the SS316 material calculated based on RCC-MRx [4]. The structure integrity of the HCS model was confirmed.

Acknowledgments

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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. Cho et al, Design and R&D progress of Korea HCCR TBM, Fusion Engineering & Design, 89 (2014)

[3] ANSYS 17.0, 2016, User Manual, ANSYS

[4] RCC-MRx, Section III - Tome 1- Subsection B, AFCEN, 2015