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

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ABSTRACT: Test blanket module (TBM) using helium cooling has been designed to install in ITER and verify the tritium production and the heat extraction. 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. 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. The structure integrity of the HCS model was confirmed.

Introduction

- Helium cooling system (HCS)
  - Helium coolant of some test blanket modules (EU, **KO**, CN)
  - Location: Tokamak building B11 floor L1 level
  - Key components: helium circulator, recuperator, Isolation valve

Installation of the isolation valve is required to protect the ITER machine from high pressure / temperature helium during accidents with the break our of the pipe or other components.

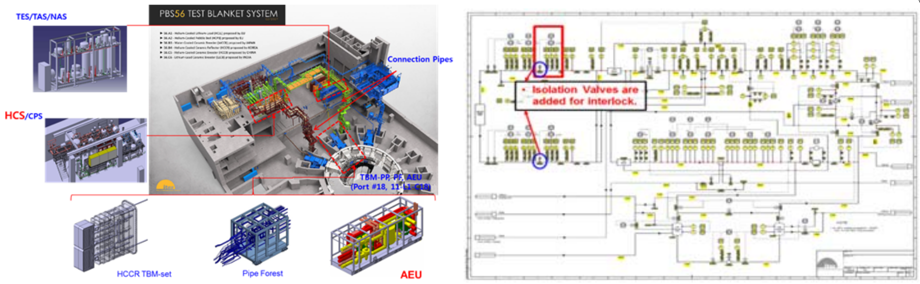
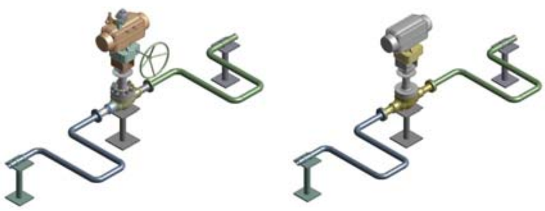


Fig.1 Overall configuration of the HCCR-TBS (left) and PnID of the HCS with Isolation Valves (right)

FEM analysis

Geometry & mesh

- The valve is being developed with a company, KOVAL Co. in Busan, and KAERI.
  - KOVAL: design, manufacturing, and testing of the valves
  - KAERI: thermal-hydraulic analysis, structure analysis
- Material: A4-70, A36, SS304, A36, etc. -> SS316 (valve), SS316 (pipe)



(a) Detailed model (b) Simplified model

Fig.2 Geometry model of HCS and isolation valve

- Mesh
  - Mesh element: Tetra
  - Total number of mesh: 79,270
  - Minimum / average mesh quality: 0.22 / 0.63

Fig.2 Mesh model of HCS and isolation valve

Thermal analysis

- Boundary condition
  - Insulation (pipe cover), helium flow (500°C), natural convection (exposed surface)
- Results
  - Insulated pipe: ~500°C
  - Isolation valve is maintained below ~50°C
  - Temperature mapping for thermal load of structure analysis

Fig.3 Boundary condition

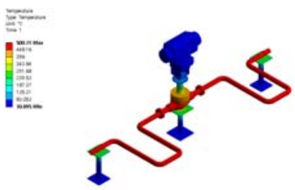


Fig.4 Temperature distribution

Structure analysis

- Constraint condition
  - The lower part of the support is fixed to the floor
  - The upper part is physically connected to the HCS pipe.

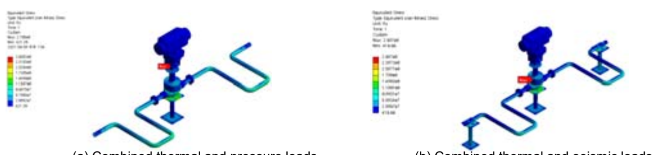
Fig.5 Constraint condition

- Analysis with single load
  - Thermal loads from heated helium
  - Pressure loads from helium in a pressurized state with 10MPa
  - Seismic loads among the accident situations
  - The maximum stress is lower than the allowable stress of the SS316. (RCC-MRx 2015)

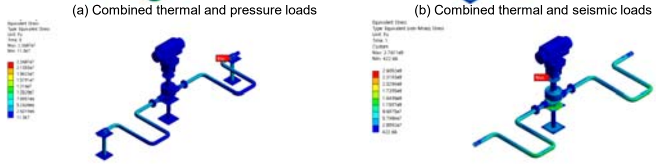
(a) Thermal load (b) Pressure load (c) Seismic load

Fig.6 Stress distribution with single load

- Analysis with load combinations
  - Various load combinations are considered for thermal, pressure and seismic load.
  - The maximum stress is lower than the allowable stress of the SS316. (RCC-MRx 2015)



(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.7 Stress distribution with load combinations

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.
- The structure integrity of the HCS model was confirmed.

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