Effect of Grooved Wall in TBM to Reduce the Maximum Temperature of the Breeder Pebbles

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ABSTRACT: The HCCR TBM is composed of four sub-modules and a common back manifold (BM). The main components of the sub-module are a first wall (FW) and a breeding zone (BZ). The breeder and the multiplier material are located in the BZ in continuous layer structure. To cool the BZ, the cooling channels were formed inside the wall in contact with the breeder and the multiplier material to remove heat from the BZ. The BZ was maintained with high temperature due to the nuclear heating of material. It is necessary to improve the cooling performance to meet the temperature requirement of the breeder material. The grooved wall concept was considered to reduce the maximum temperature of breeder layer. The heat of the breeder layer is quickly removed through the tip of the grooved wall. This concept design were analyzed by CFD analysis. The grooved wall in TBM was designed with the parametric study, and the maximum temperature of the breeder pebble bed is 735 ºC in the optimized design. The maximum temperature of the original design is 916 ºC. It was confirmed that the temperature requirement which is 800 ºC for the breeder pebble bed was satisfied.

Introduction

- The HCCR TBM-set consists of TBM and TBM-shield
  - The TBM is composed of four sub-modules and a common Back Manifold (BM).
- Main design parameters and materials were as follows
  - Each sub-module consists of FW, BZ, and SW
  - BZ consists of 7 layers considering efficient tritium breeding and temperature requirement; 3 breeder layers, 3 multiplier layers and one reflector layer
  - HCCR-TBM has an unique concept of graphite reflector to be located at the last laye considering the maximized nuclear efficiency.

✓ Breeder material: Li_2TiO_3, ~80kg, 70% enrichment Li-6
✓ **Temperature requirement: 920 ºC -> 800 ºC**

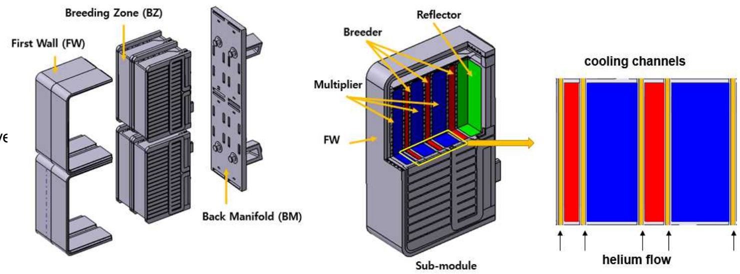


Fig.1 HCCR TBM-set configuration at PD-3 phase

Concept of the grooved wall

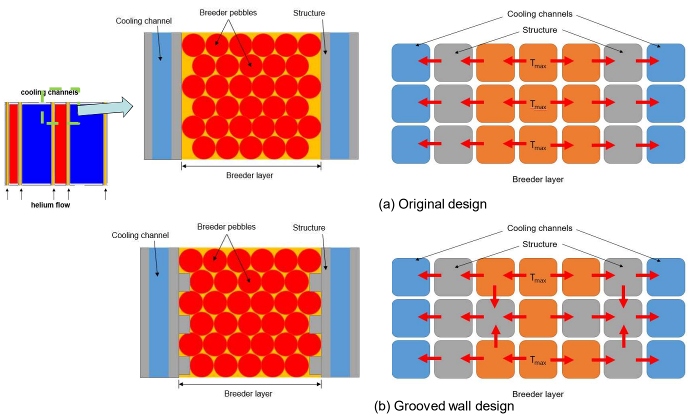


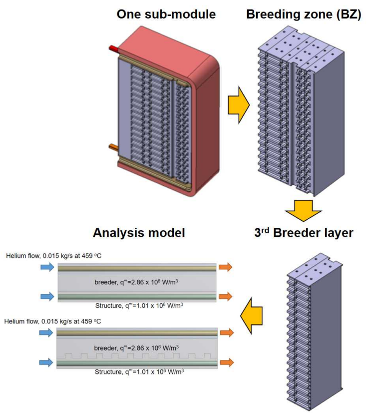
Fig.2 Configuration and heat flow

- To reduce the maximum temperature of the breeder
  - Improve the thermal property of the breeder material
    - Research of the material itself is required.
  - Increase the mass flow of the coolant
    - Increase of the pressure drop and the pumping power occurs.
    - The reduction of the maximum temperature for the breeder is not sufficient compared to the increase of the mass flow..
  - Reduce the thickness of the pebble bed for the breeder
    - The neutron characteristics are changed.

➢ **The grooved wall design is adopted to bring the effect of reducing the thickness.**
➢ **The amount of the breeder is remained.**

Thermal-hydraulic analysis

- Modeling & boundary condition



- Geometry: TBM module -> partial breeder layer and two channel (representative part)
- Nucleating heat source: breeder, structure
- Helium flow condition: 0.015 kg/s at 459 ºC

- Result of grooved wall structure

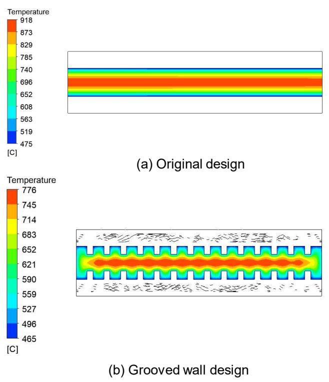


Fig.3 Temperature distribution in breeder layer

- Maximum temperature of breeder: 918 ºC -> 776 ºC
- Maximum temperature of structure: 475 ºC -> 540 ºC

❖breeder limit temperature: 800 ºC
❖Structure limit temperature: 550 ºC

- Parametric study

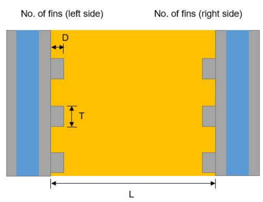


Fig.4 Design parameter

	L	D	T	No. of fins (right side)	No. of fins (left side)	Max. Temp. of breeder
ref.	20	-	-	-	-	916
case 1	22	4.2	8.6	10	0	870
case 2	24	4.2	8.6	10	10	835
case 3	24	4.5	8	10	10	845
case 4	24	6	6	10	10	809
case 5	24	7	5.2	10	10	792
case 6	24	7	4.3	12	12	765
case 7	24	7	3.7	14	14	753
case 8	24	7	3.2	16	16	741
case 9	24	7	2.9	18	18	740
case 10	24	6	4.3	14	14	776
case 11	24	6	3.8	16	16	763
case 12	24	4.5	5.8	14	14	828
case13	24	4.5	5	16	16	821
case14	24	7	3.2	16	16	735

- Parameter: thickness, length, number of tips
- The parametric study for lowering the maximum temperature of the breeder
  - Installing grooved walls on both sides of the breather layer are more effective to reduce the maximum temperature of the breeder.
  - A longer tip is easy to access in the middle of the layer to decrease the maximum temperature of the breeder.
  - A thicker tip lowers the maximum temperature of the breeder making the heat transfer better.
  - A thin tip is recommended to avoid increasing the thickness of the breeder layer to maintain the amount of the breeder.
  - The case 14 is the best condition to meet the requirement of the materials.

Conclusions

- Without change or reduction of the breeder amount, grooved wall concept was investigated in KO HCCR TBM as a heat transfer enhancing method.
- The effectiveness of the grooved wall in lowering the maximum temperature of the breeder was confirmed.
- The various shapes as a parametric study were analyzed by CFD analysis. The maximum breeder temperature is reduced from 916 ºC to 735 ºC.

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