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Preliminary Engineering Analysis For CN HCCB TBM Regarding ITER New Baseline Scenario

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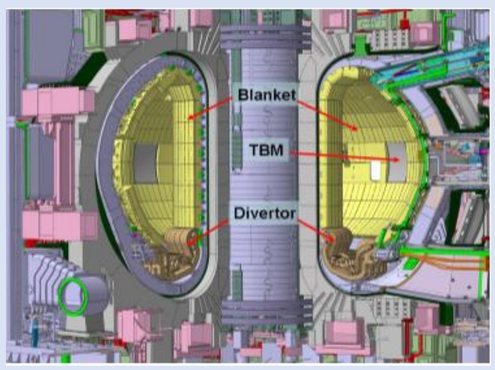
ABSTRACT

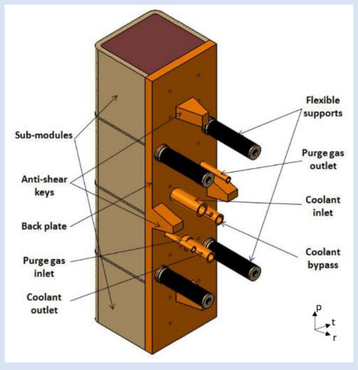
- Among the different TBM concepts proposed for DEMO design of different countries, China finally determined to develop the Helium Coolant Ceramic Breeder (HCCB) TBM.
- During preliminary design phase, some design update for CN HCCB TBM has been carried out, considering engineering performance and manufacturing feasibility.
- Regarding ITER 2024 new baseline scenario, further design optimization and engineering analysis was performed for CN HCCB TBM., including thermo-hydraulic analysis, system-level tritium transport analysis, structural analysis, etc.
- The current results showed that through design optimization by adding electrical heaters, the general design requirement can be met.

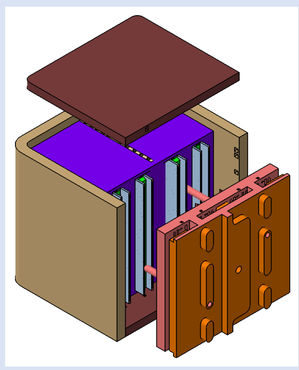
BACKGROUND

- According to the ITER project objectives, some DEMO blanket relevant technologies will be demonstrated by testing of ITER Test Blanket Modules (TBMs) in dedicated equatorial ports.
- The conceptual design of HCCB TBM has been completed since 2015. During preliminary design phase, some design update for CN HCCB TBM has been carried out, considering engineering performance and manufacturing feasibility.
- Considering some engineering and technical issues, a new ITER Baseline has been under development since the beginning of February 2023, which addressed a new ITER operation strategy allowing to start the nuclear phase as soon as possible.
- Further design optimization and engineering analysis was performed for CN HCCB TBM, including neutronics, thermo-hydraulic, tritium transport, and structural analysis, and the main results for each aspect are all included in this paper..



Schematic view of TBM port in ITER



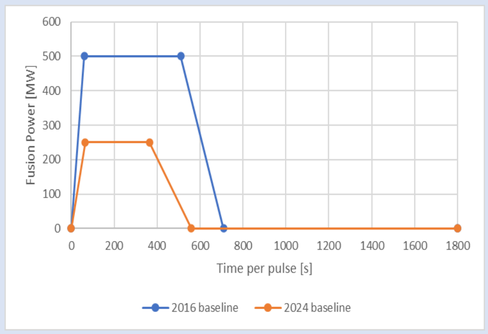


Preliminary design of CN HCCB TBM

Comparison of ITER 2016 baseline and 2024 baseline

- There are 4 operational stages for previous 2016 baseline, while there are only 3 operational stages for new 2024 baseline, including SRO, DT-1, DT-2.
- For new DT-1 operation stage, the target is to achieve Q=10 with fusion power ~500 MW for 300-500 s with a reduced neutron fluence and to demonstrate the integrated tokamak engineering system.

- The fusion power evolution of each pulse in different baseline is shown below. It can be seen that:
  - the fusion power us reduced from 500MW to 250MW.
  - the ramp up time and ramp down time are almost the same, while the flat-top time is reduced from 450s to 300s.

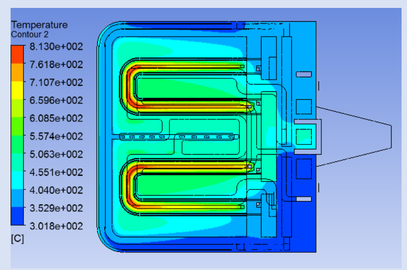


Fusion power pulse in different ITER baseline

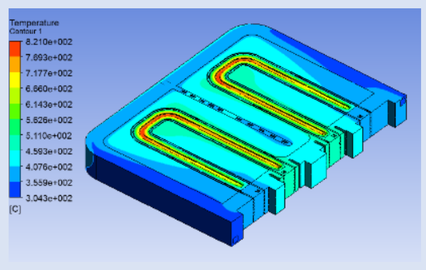
UPDATE ENGINEERING ANALYSIS RESULTS OF CN HCCB TBM

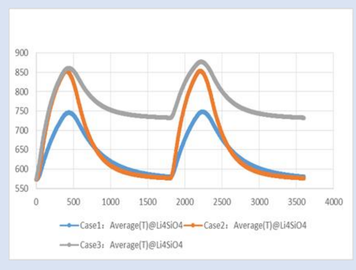
THERMO-HYDRAULIC ANALYSIS:

- Steady-state thermo-hydraulic analysis was performed for one typical sub-module. It's found that: the maximum temperature of functional materials have been largely reduced for the 2024 baseline, through adding internal electrical heater, the temperature of Li4SiO4 pebble bed can be increased.
- Transient thermo-hydraulic analysis was performed for sliced model. The results showed that through adjustment of mass flow rate of the bypass loop and adding electrical heater inside tritium breeder zone, the maximum temperature of Li4SiO4 could increase to 821℃



Static temperature of sub-module with internal heater

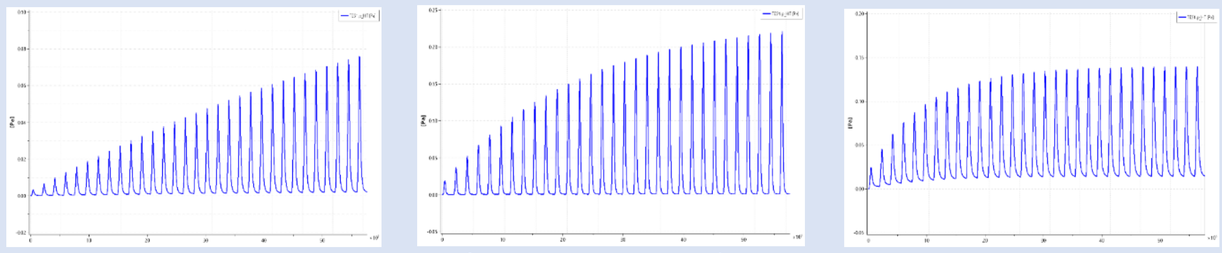




Temperature variation of sliced model with internal heater continuous working

TRITIUM TRANSPORT ANALYSIS:

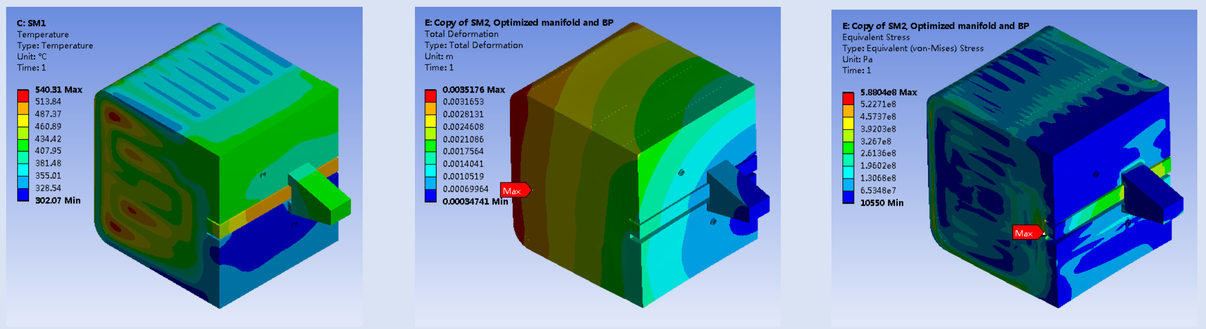
- System-level transient tritium transport analysis was performed according to calculated temperature distribution for three operational conditions. The results showed that : for the condition with electrical heater under continuous heating, the tritium partial pressure could achieve steady-state after ~15 pulses, but the overall tritium concentration was slightly lower than the 2nd condition.



Tritium partial pressure inside CN HCCB TBS

STRUCTURAL ANALYSIS:

- Since there was no major change for overall temperature distribution of CN HCCB TBM after adjusting the bypass flow rate and adding internal electrical heater, especially for the FW region and breeding zone, the structural performance was generally the same with previous baseline, only with slight difference on TBM back plate and pipes inside TBM shield.



Thermal load,deformation and equivalent stress of CN HCCB TBM

CONCLUSION

- Regarding update of ITER baseline scenario in 2024, further design optimization and engineering analysis was performed for CN HCCB TBM, including neutronics, thermo-hydraulic, tritium transport, and structural analysis.
- The current results showed that through design optimization by adding electrical heaters, the general design requirement can be met.
- In the future, detailed analysis will be performed for CN HCCB TBM-set, considering the update design of internal electrical heater