Status of the design optimization, analysis and R&D activities of Indian HCSB blanket program

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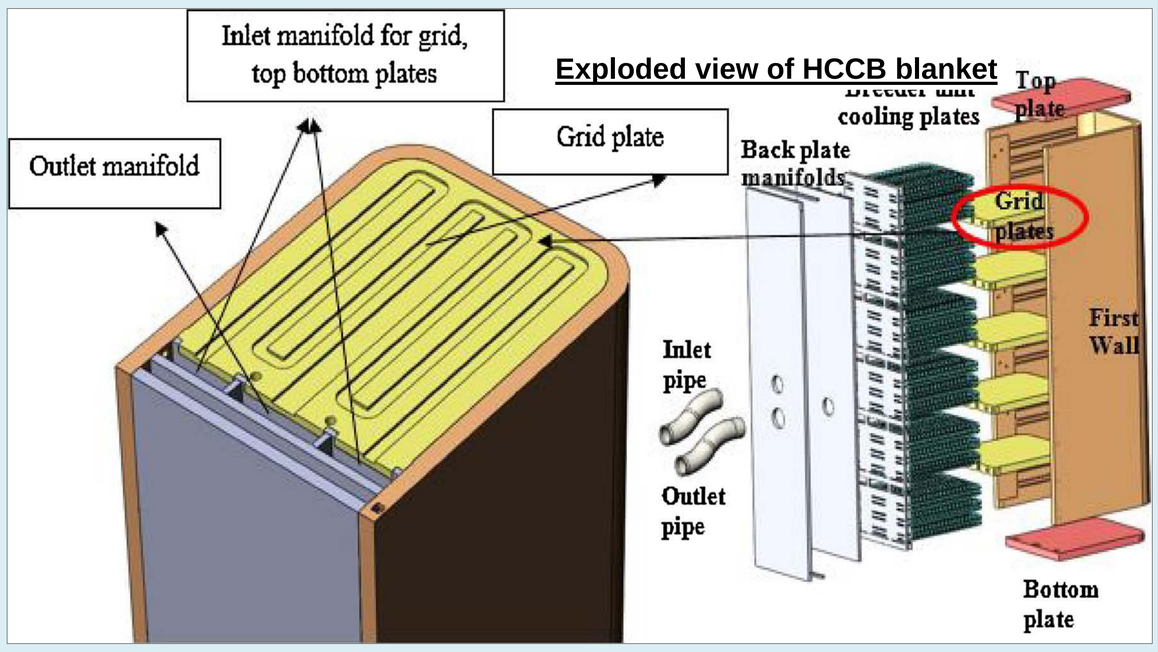
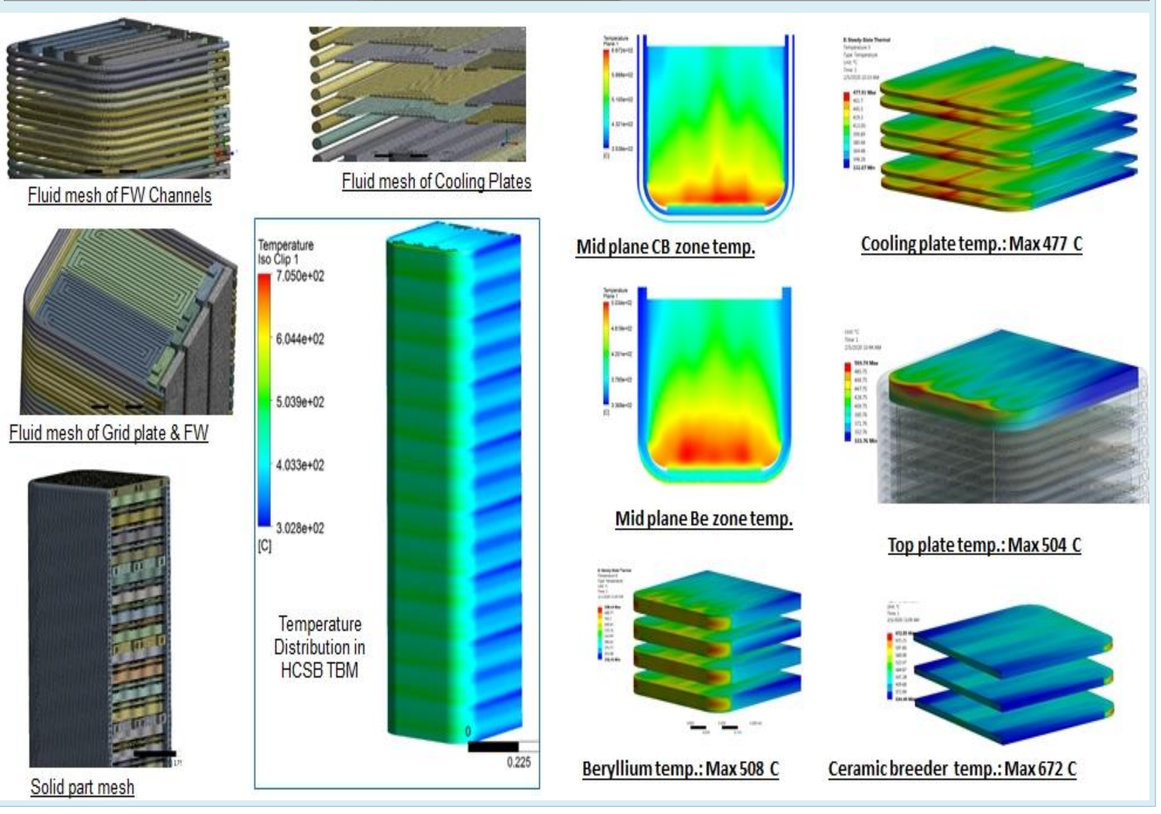
INTRODUCTION

- India has developed two concepts of breeding blanket for the future fusion reactor: one is Lead Lithium Ceramic Breeder (LLCB), and the other one is Helium-cooled Ceramic Breeder (HCCB) concept.
- Indian blanket related R&D program is focused on the development and characterization of different functional (Li_2TiO_3, Be, PbLi etc.) and structural materials, tritium technologies and fabrication technologies for the blanket module.
- IN- HCCB concept is having edge on configuration of helium-cooled solid breeder with RAFMS structure.
- Different R&D activities provide a roadmap for the future fusion blanket program.

ENGINEERING DESIGN ACTIVITIES

- The thermo-mechanical design and analysis has also been performed using ANSYS for different structural and thermal loads including the accident scenario of 8MPa helium coolant leak inside the box.
- Thermal-hydraulic analysis of full helium flow path using ANSYS CFX has been performed to estimate the flow distribution from manifolds, velocities and pressure drop and heat transfer coefficients in different circuits.





FUNCTIONAL & STRUCTURAL MATERIALS

- Li_2TiO_3 powder was prepared by solid state reaction using $LiCO_3$ and TiO_2 followed by ball-milling and calcinations.

- Li_2TiO_3 pellets and pebbles are prepared from this powder followed by high temp. sintering. At every stage of preparation, extensive characterizations are being carried out to meet the desired properties.
- Thermal conductivity of pebble beds has been measured experimentally by both steady state axial and transient hot wire methods under different experimental conditions (gas: He, Ar, and Air, different pebble dia etc.)

- India specific RAFM steels (IN-RAFMS) has been produced for the structural material of HCSB blanket.
- The final composition of IN-RAFM steel has been decided with varying tungsten and tantalum content.
- The 9Cr-1.4W-0.06Ta wt% RAFMS is found to show better impact properties than other RAFM steel heats.
- Thermo-physical and thermo-mechanical properties of IN-RAFMS material have been studied for the generation of material qualification database as per ITER requirement.

- A scaled down 10 channels First Wall (FW) mock-up successfully has been fabricated using gun drilling, wire cut EDM and machining followed by hot bending into U shape.

- The mock-up was tested in HELOKA test facility at KIT, Germany. Both normal and operating conditions were investigated under ITER-like surface heat fluxes.
- The performance (experimental and simulated results) of the mock-up is within the desired margin of 2% which is within the uncertainty margin except for some local hotspots and thus fulfils the expected requirements. The estimated max. temp. value for LOFA condition for 25% flow and for NO flow condition is also within the allowable margin of deviation.

CONCLUSION

- The thermo-mechanical design and optimization of cooling helium manifolds has been performed for pressure and relevant thermal loads. The stresses are within limits for design conditions as well as for normal operating conditions as per the level A criteria of RCC-MR for p type and s type damages including fatigue.
- Further R&D needs to be done for the material properties database up to the radiation damage expected in ITER (> 1 dpa)

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