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Structural assessment of a whole toroidal sector of the HELIAS 5-B breeding blanket

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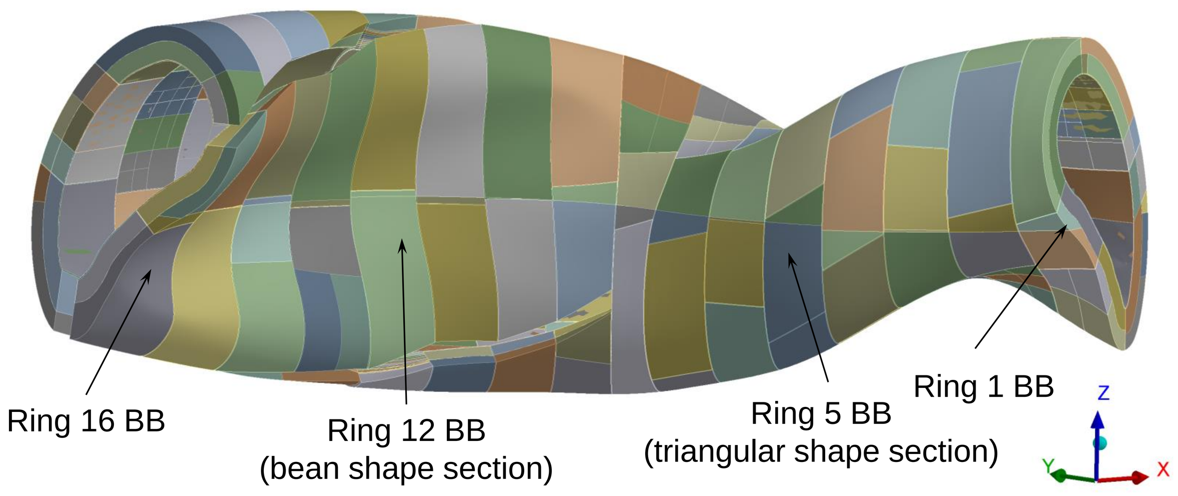
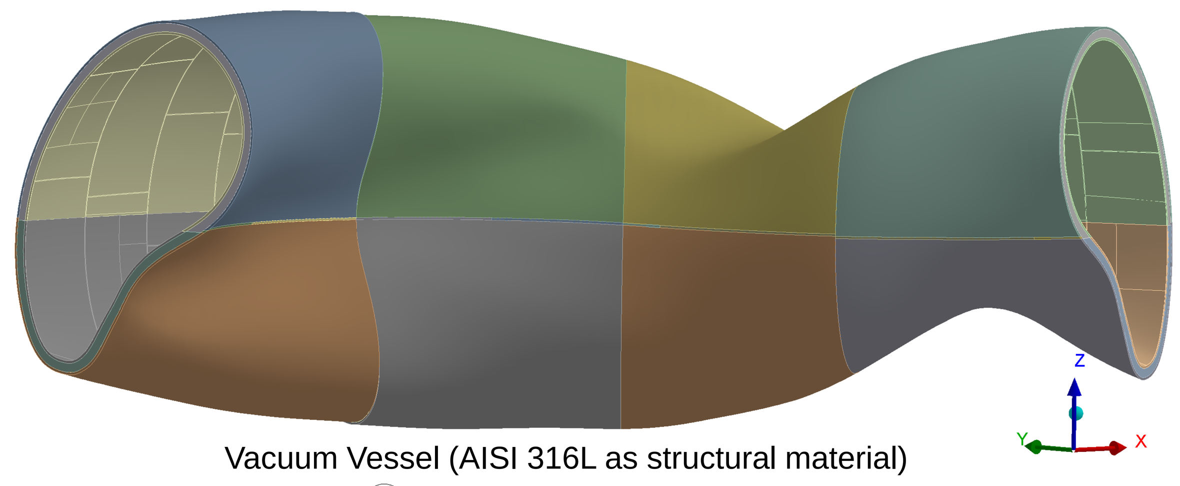
The European roadmap for the realization of fusion energy considers the stellarator line as a possible long-term alternative to a tokamak DEMO. Presently, the most promising option is a five-field period power plant called HELIcal-axis Advanced Stellarator (HELIAS) 5-B. It is a direct extrapolation of the Wendelstein 7-X, the largest stellarator reactor currently in operation. In order to allow the electricity production, the HELIAS 5-B reactor must be endowed with a breeding blanket (BB). Hence, in this paper, the advancements in the HELIAS 5-B BB design are reported.

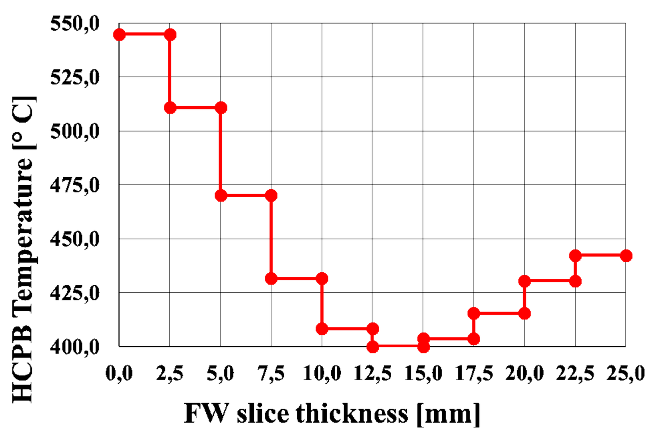
Displacement assessment of a whole toroidal sector of the HELIAS 5-B BB – HCPB and WCLL BB concepts

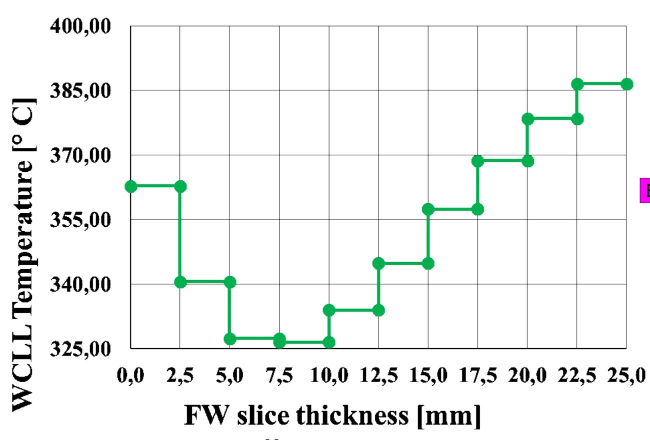



Vacuum Vessel (AISI 316L as structural material)

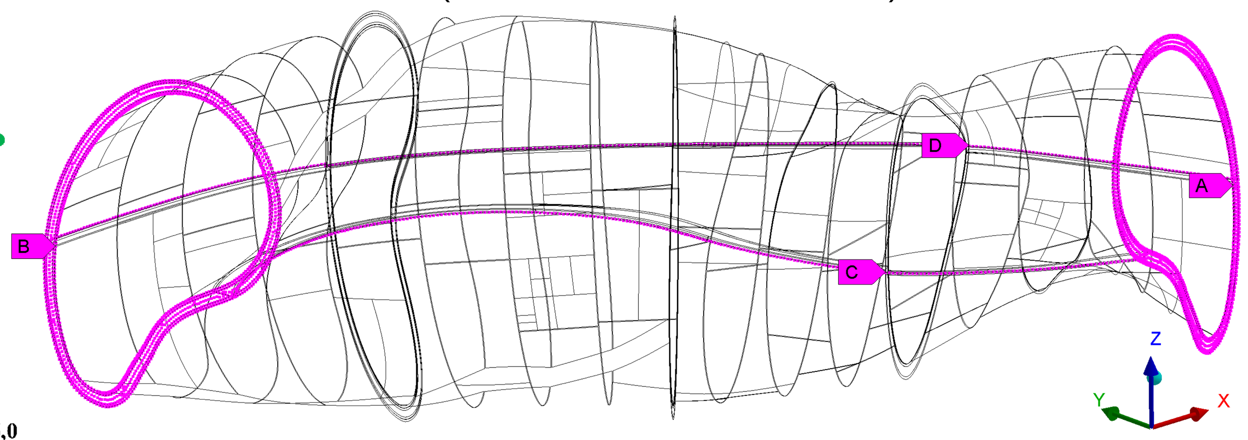
Assessed loading scenarios

- Less Conservative (LC) + Hot VV (E=10%, VV between 180 and 230 °C)
- More Conservative (MC) + Hot VV (E=100%, VV between 180 and 230 °C)
- Less Conservative (LC) + Cold VV (E=10%, VV between 40 and 90 °C)
- More Conservative (MC) + Cold VV (E=100%, VV between 40 and 90 °C)





- Temperatures inferred from DEMO BB. 3D discrete temperature profiles imposed to Ring 5 and 12. Spatially averaged temperatures to the other Rings.



Mechanical restraints

- **A** and **B**: displacement prevented along the local toroidal direction.
- **C** and **D**: displacement prevented along the vertical (Z) direction.

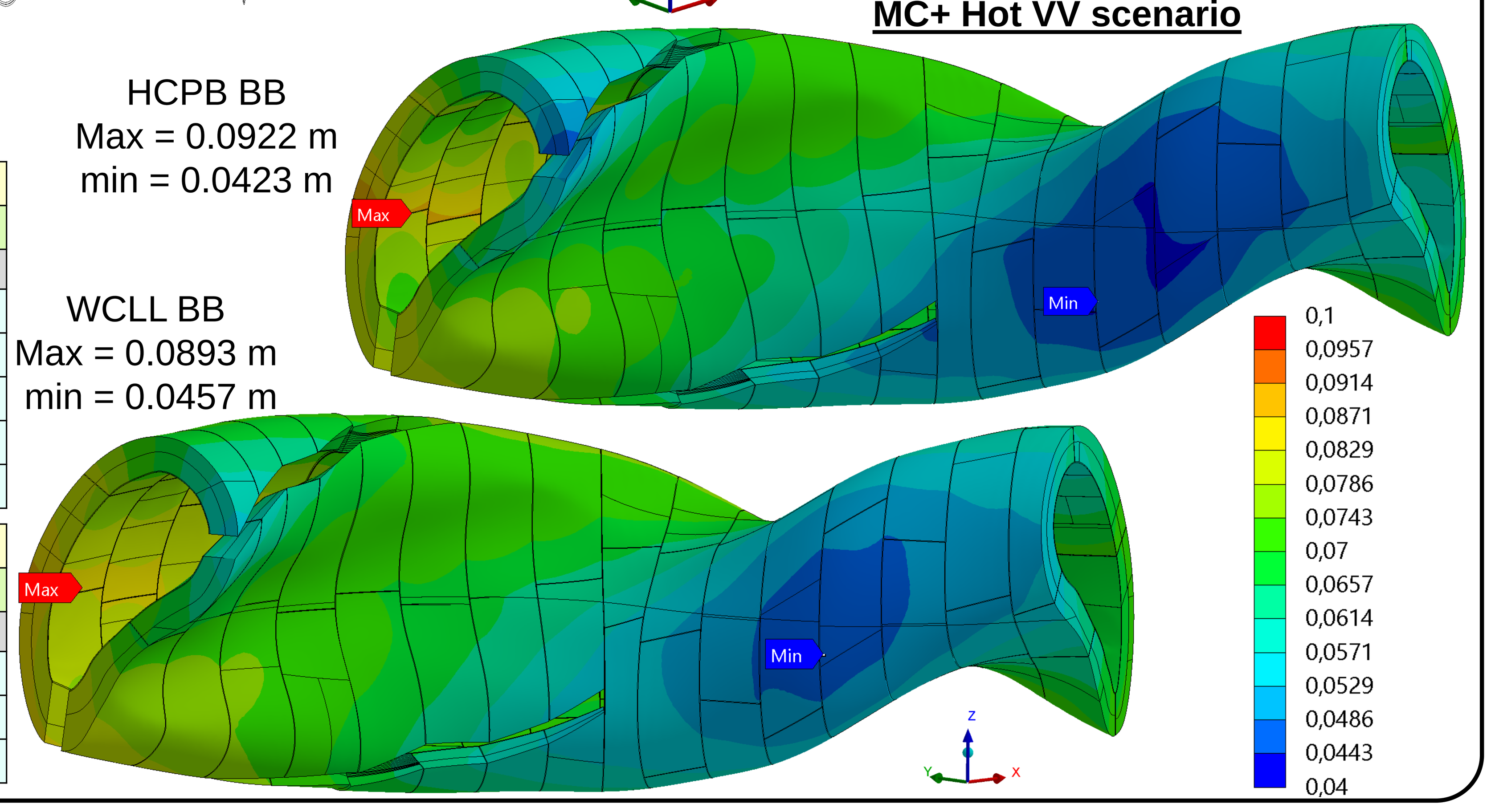
Ring 5 – minimum residual poloidal gaps [mm] (initial value 20 mm)

	HCPB BB				WCLL BB			
Segment	LC+ColdVV	LC+HotVV	MC+ColdVV	MC+HotVV	LC+ColdVV	LC+HotVV	MC+ColdVV	MC+HotVV
1-2	2.6	9.9	5.6	10.1	9.7	16.0	12.5	16.6
2-3	-4.7	5.7	-3.2	4.7	3.4	13.9	5.9	13.9
3-4	7.3	12.6	9.1	12.9	10.7	16.0	12.7	16.3
4-5	-5.1	4.9	-3.5	4.1	3.5	13.6	6.0	13.7
5-1	4.7	11.1	7.3	11.5	10.3	16.4	12.6	16.6

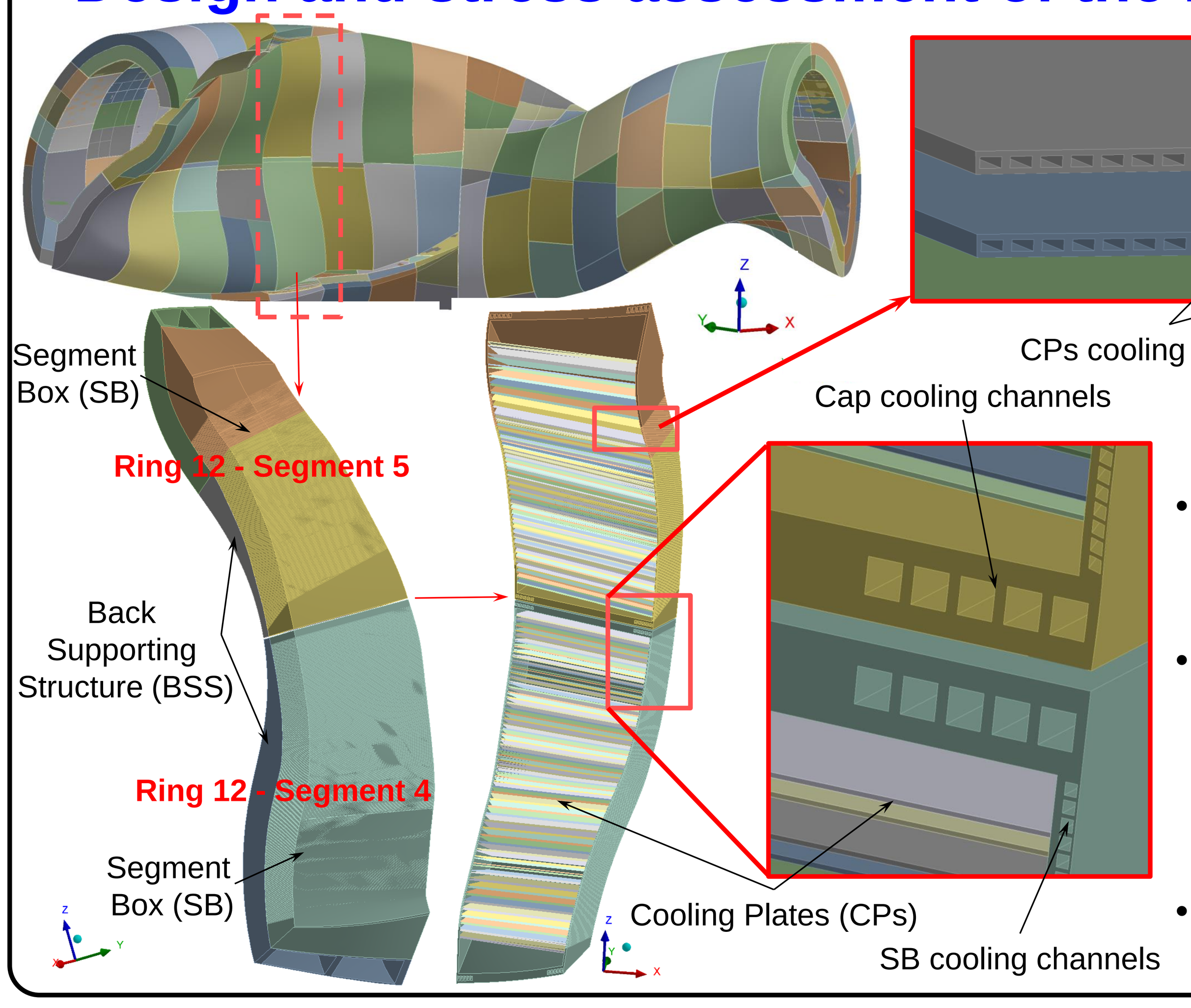
Ring 12 – minimum residual poloidal gaps [mm] (initial value 20 mm)

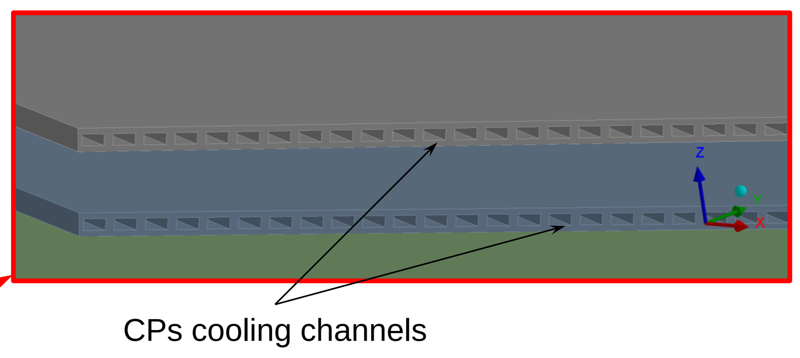
	HCPB BB				WCLL BB			
Segment	LC+ColdVV	LC+HotVV	MC+ColdVV	MC+HotVV	LC+ColdVV	LC+HotVV	MC+ColdVV	MC+HotVV
1-2	-4.9	5.5	-3.6	4.3	3.7	14.2	6.2	14.0
2-3	-6.2	4.7	-5.3	3.2	2.6	13.5	4.8	13.3
4-5	0.5	8.6	0.1	7.3	7.4	15.6	8.1	15.2

Displacement [m]
MC+ Hot VV scenario



Design and stress assessment of the inboard internal components of a bean-shape ring – HCPB BB concept

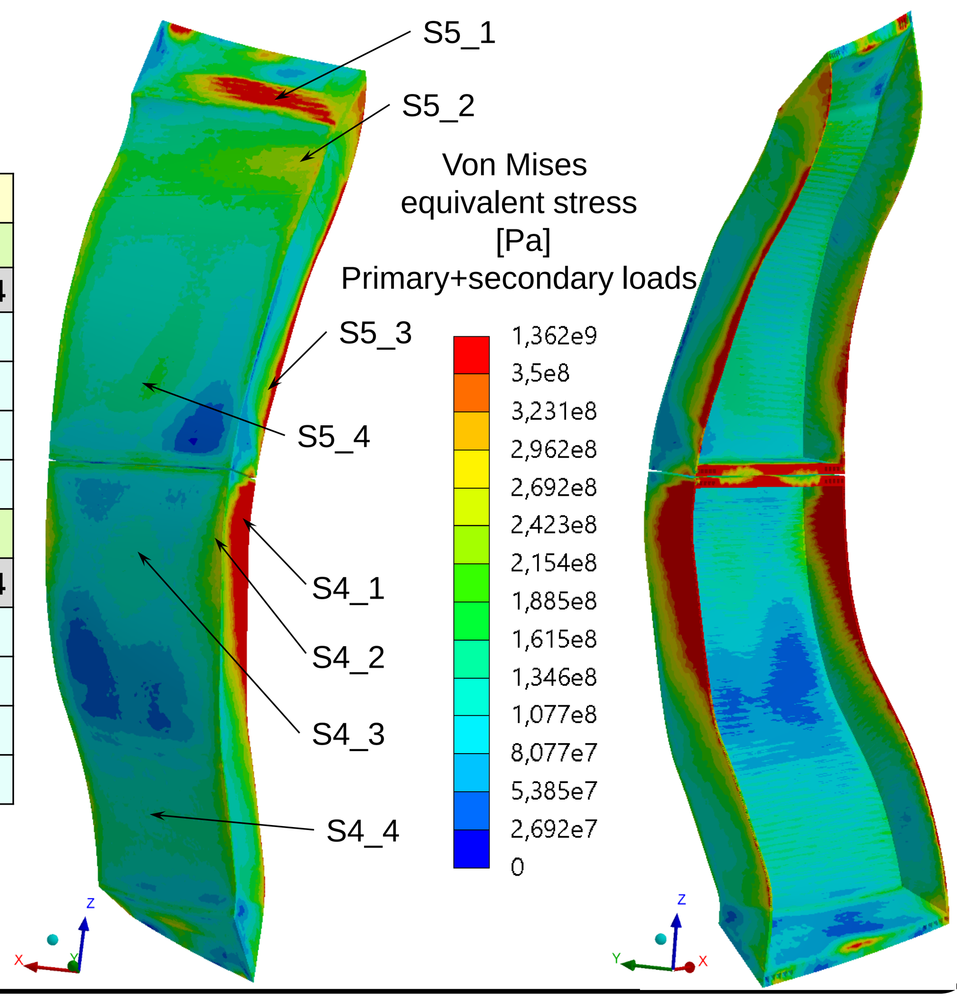




Over-Pressurization (OP) loading scenario

- Temperature: W armor @ 550 °C, SB, CPs and BSS @ 500 °C.
- Pressure: 9.2 MPa (cooling helium design pressure for DEMO HCPB BB) onto both breeder and coolant wetted surfaces.
- Mc+Hot VV conditions for the rest of the sector.

RCC-MRx Level D Criteria				
	Segment 4 Path			
Criterion	S4_1	S4_2	S4_3	S4_4
P_m/S_m	0.39	0.14	0.22	0.33
$(P_m+P_b)/(k_{eff} \cdot S_m)$	0.31	0.11	0.16	0.23
$(P_m+Q_m)/S_e$	1.51	0.41	0.23	0.22
$(P_m+P_b+Q+F)/S_{et}$	0.24	0.06	0.04	0.04
	Segment 5 Path			
Criterion	S5_1	S5_2	S5_3	S5_4
P_m/S_m	0.30	0.45	1.75	1.34
$(P_m+P_b)/(k_{eff} \cdot S_m)$	0.48	0.31	1.29	1.02
$(P_m+Q_m)/S_e$	0.18	0.36	0.87	0.29
$(P_m+P_b+Q+F)/S_{et}$	0.09	0.07	0.15	0.05



Firstly, a displacement assessment of a whole toroidal sector of the HELIAS 5-B BB has been performed considering both WCLL and HCPB BB concepts. Homogenized geometric models have been set-up, adopting dummy components (full blocks without internal details). Results allow concluding that the proposed BB segmentation strategy is viable for more detailed BB design. Then, focusing on the HCPB BB concept, a preliminary design of internal components in the inboard blanket segments of the Ring 12 has been carried out. Structural analysis under the reference over-pressurization accidental conditions have been performed. Comparing the calculated stress against the RCC-MRx structural design criteria, one allows concluding that the adopted design approach is promising. Nevertheless, a more detailed assessment is necessary to develop design modifications aimed at improving the blanket structural performances, especially in the most critical regions highlighted by the present work.

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