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Advancements in the HELIAS 5-B breeding blanket structural analysis

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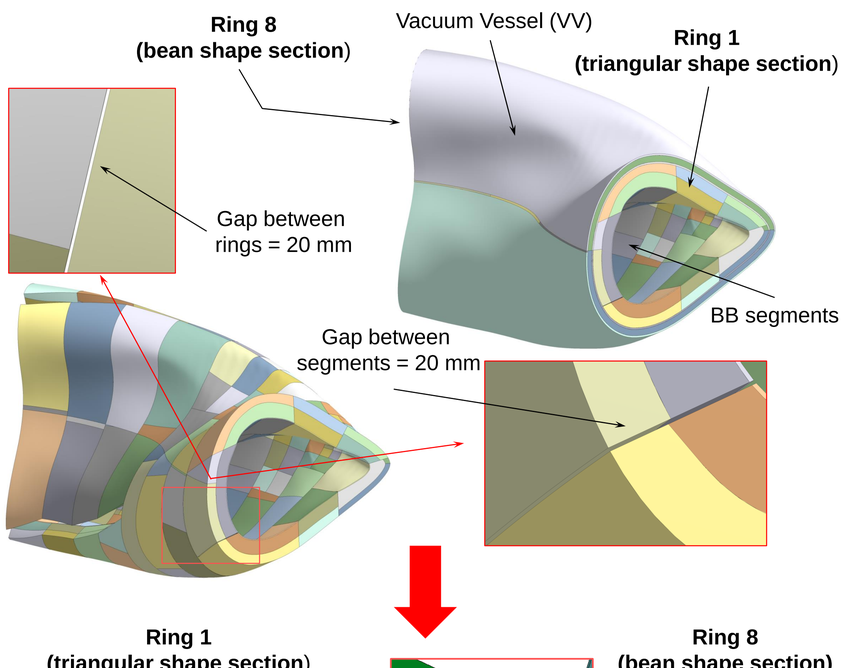
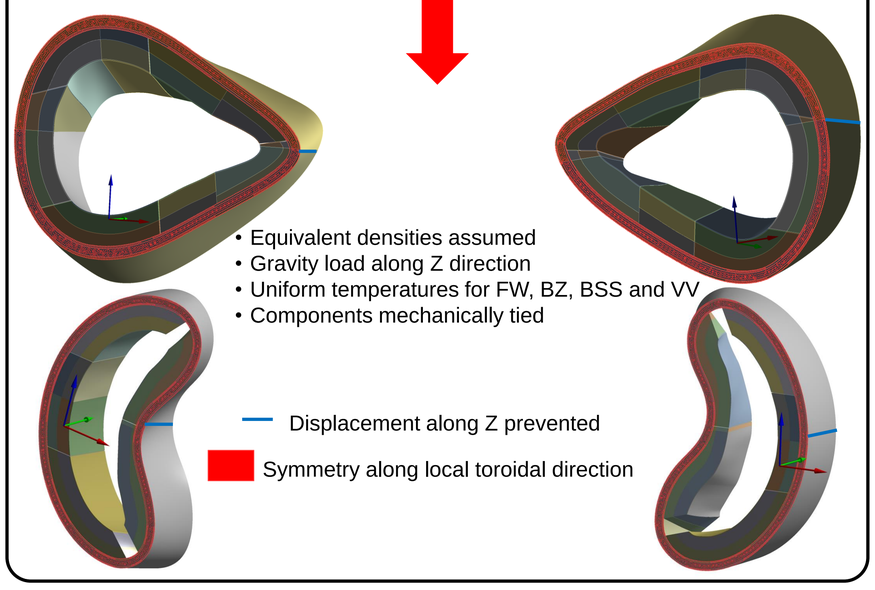
Within the framework of EUROfusion consortium, the work package S2 aims at developing the HELIcal-axis Advanced Stellarator (HELIAS) as a possible long-term alternative to a tokamak DEMO. Researches are currently ongoing at KIT in order to attain a preliminary design of the HELIAS 5-B breeding blanket (BB), taking into account as initial input the design experience acquired in the pre-conceptual design phase of the tokamak DEMO BB. To this end, the Helium-Cooled Pebble Bed (HCPB) and the Water Cooled Lithium Lead (WCLL) BB concepts have been considered, focusing on the investigation of the suitability of their main structural features to the stellarator geometry. In this regard, possible design constraints coming from the Remote Maintenance have to be fulfilled in order to better orient the blanket segmentation. In the present work, a more sophisticated assessment of the BB modules structural behavior has been performed. Attention has been also paid to the refinement of the numerical models so far adopted, investigating the impact of the major assumptions, such as Vacuum Vessel temperature and equivalent Young's Modulus, on the obtained results. To this purpose, dedicated parametric assessment has been carried out and discussed in this work.

The HELIAS 5-B Breeding Blanket (BB)



Structural materials:
- AISI 316 for VV
- Eurofer for BB components
- W for FW armor (not considered in the E sensitivity study)

	Ring 1 [ton]		Ring 8 [ton]	
	HCPB	WCLL	HCPB	WCLL
Ring 1	17.4	39.8	27.0	54.7
Ring 2	18.6	43.8	25.2	56.0
Ring 3	19.9	45.7	30.4	63.3
Ring 4	18.8	50.0	17.8	47.4
Ring 5	17.4	38.9	16.9	43.9



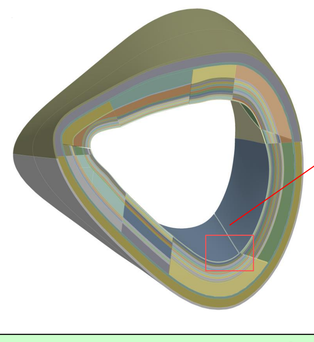
Parametric study of the assumed equivalent Young´s Modulus

Ring 1 minimum residual gaps [mm]					
E	1-2	2-3	3-4	4-5	5-1
10 %	3.097	8.916	4.757	6.003	5.503
25 %	3.095	8.539	3.983	5.968	5.792
50 %	3.005	8.105	3.209	5.992	5.396
75 %	2.899	7.816	2.658	6.043	4.962
100 %	2.799	7.609	2.222	6.103	4.584

Ring 8 minimum residual gaps [mm]					
E	1-2	2-3	3-4	4-5	5-1
10 %	6.917	0.209	-	18.13	-
25 %	6.901	-0.465	-	17.92	-
50 %	6.391	-1.190	-	17.67	-
75 %	5.943	-1.620	-	17.35	-
100 %	5.575	-1.903	-	17.05	-

Derived loading scenarios:
- Less conservative (LC): **E = 10 %**
- More conservative (MC): **E = 100 %**

Ring 1 and Ring 8 structural performances – refined FEM models



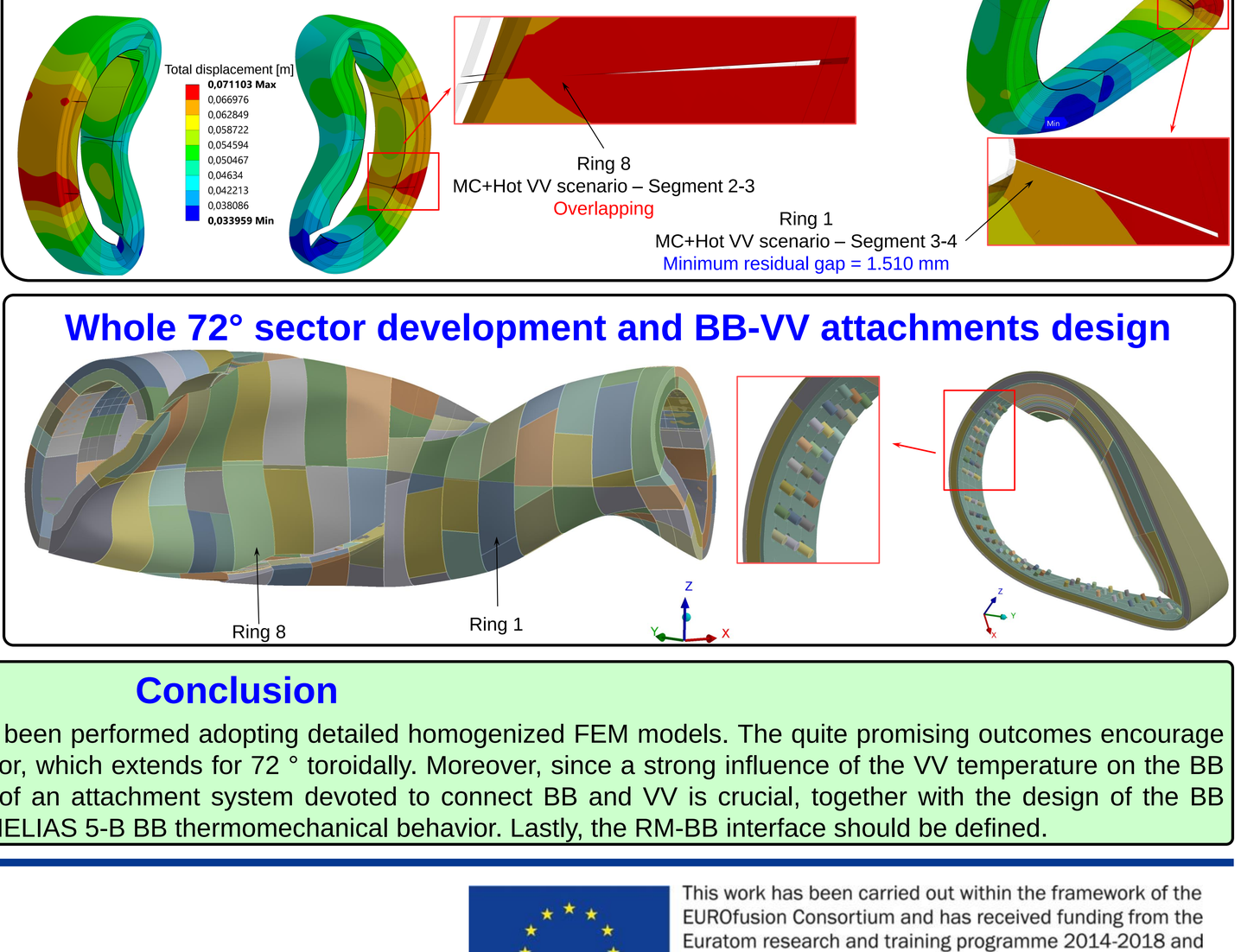
Sliced components to impose
a different temperature to each slide
(3D discrete temperature profile)

Assessed loading scenarios:
- LC+Hot VV (E=10%, VV between 180 and 230 °C)
- MC+Hot VV (E=100%, VV between 180 and 230 °C)
- LC+Cold VV (E=10%, VV between 40 and 90 °C)
- MC+Cold VV (E=100%, VV between 40 and 90 °C)

Model	Node	Element	Type
Ring 1	~1.1M	~4.0M	Linear tet
Ring 8	~1.4M	~5.0M	Linear tet

Ring 1 – minimum residual gaps [mm]							
Segment	LC+Cold VV	LC+Hot VV	Δ%	MC+Cold VV	MC+Hot VV	Δ%	Δ% Hot VV
1-2	-5.938	4.294	172.3%	-5.199	2.952	156.8%	-31.2%
2-3	-0.846	9.066	1171.4%	-2.069	6.791	428.2%	-25.1%
3-4	-10.363	4.303	141.5%	-11.192	1.510	113.5%	-64.9%
4-5	-3.715	8.031	316.2%	-4.703	6.340	234.8%	-21.1%
5-1	-2.598	2.249	186.6%	-1.390	2.203	258.5%	-2.0%

Ring 8 – minimum residual gaps [mm]							
Segment	LC+Cold VV	LC+Hot VV	Δ%	MC+Cold VV	MC+Hot VV	Δ%	Δ% Hot VV
1-2	-6.621	4.503	168.0%	-6.264	2.388	138.1%	-47.0%
2-3	-12.514	1.037	108.3%	-14.342	-2.976	79.2%	-387.0%
4-5	-1.168	7.635	753.4%	-1.631	6.081	472.8%	-20.3%



Whole 72° sector development and BB-VV attachments design

Conclusion

Structural calculations of the most representative BB rings have been performed adopting detailed homogenized FEM models. The quite promising outcomes encourage the follow-up of the activity aimed at assessing a whole BB sector, which extends for 72 ° toroidally. Moreover, since a strong influence of the VV temperature on the BB structural performances has been found out, the development of an attachment system devoted to connect BB and VV is crucial, together with the design of the BB segments internal components, to more realistically assess the HELIAS 5-B BB thermomechanical behavior. Lastly, the RM-BB interface should be defined.

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