Karlsruhe Institute of Technology

Institute for Neutron Physics and Reactor Technology (INR), Karlsruhe Institute of Technology (KIT), 76344 Eggenstein-Leopoldshafen, Germany
Guangming.Zhou@kit.edu

P2-031

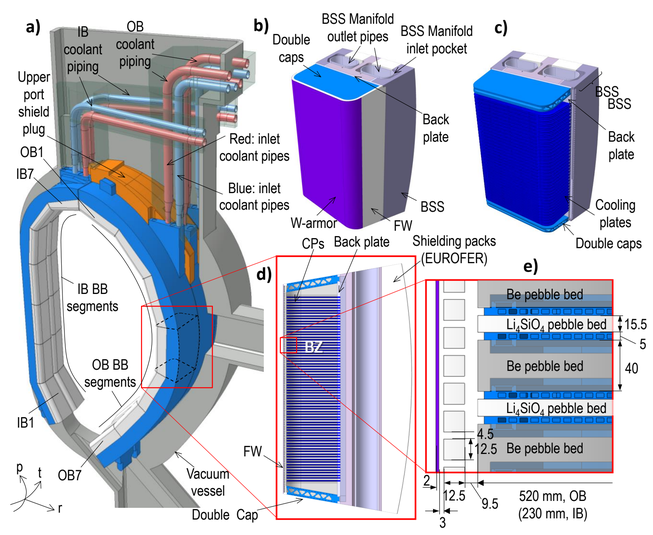
Transient thermal analysis and structural assessment of an ex-vessel LOCA event on the EU DEMO HCPB breeding blanket and the attachment system

Guangming Zhou*, Francisco A. Hernández, Christian Zeile, Ivan A. Maione

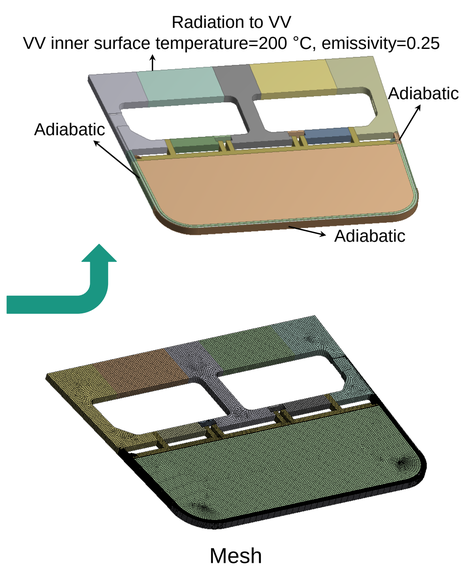
Introduction

- A 3D slice unit model of EU DEMO HCPB blanket has been developed for transient thermal analysis under an ex-vessel LOCA.
- The radial temperature profile has been re-constructed to the HCPB blanket segments, together with mechanical, gravity and electro-magnetic loads, to conduct structural assessment of the blanket segments and the attachment system.
- The results have been assessed with respect to the French design and construction rules for nuclear mechanical components RCC-MRx 2012.

FEM Models

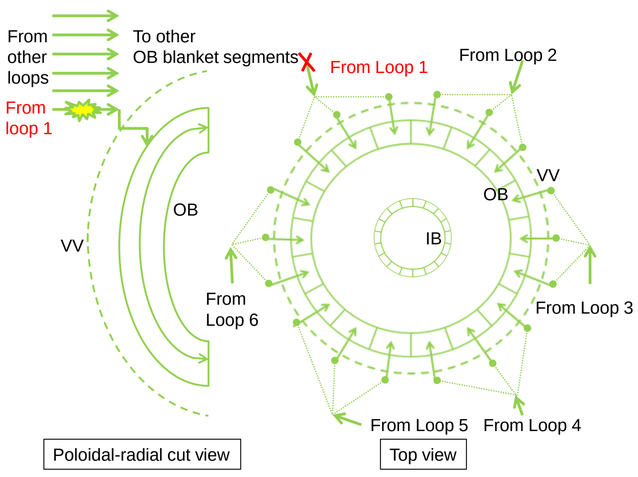


Current HCPB Design

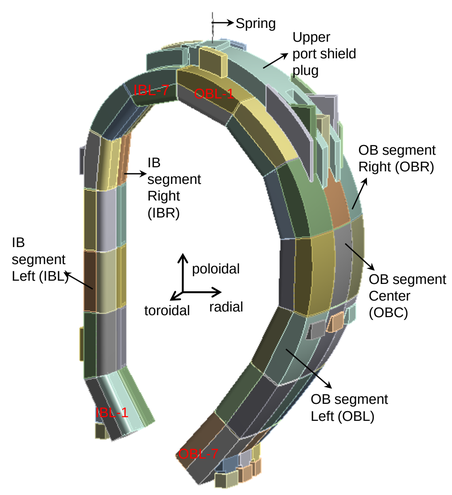


Mesh

Mesh statics: 1.1e6 elements, 6.5e5 nodes

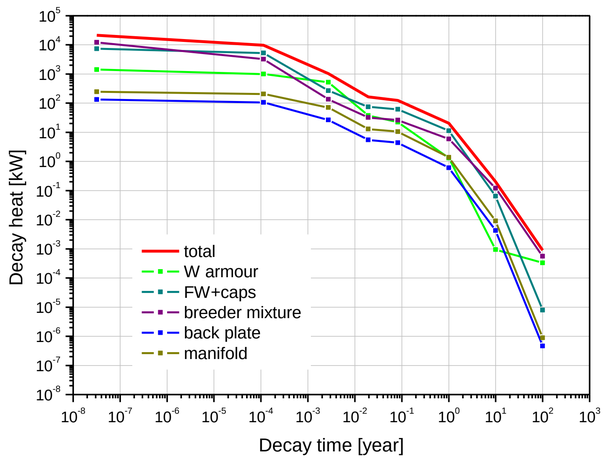


Schematic of ex-vessel LOCA in OB blanket segments

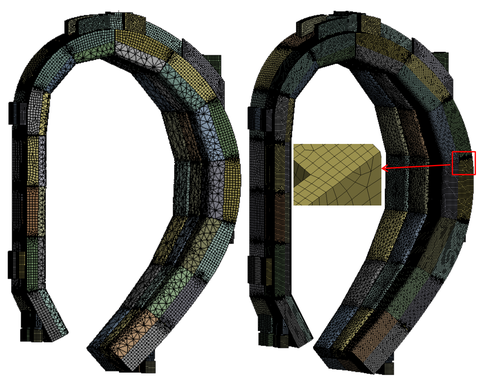


Global model for structural analysis

- 9 independent cooling loops are used for blankets:
  6 loops for OB blanket sectors;
  3 loops for IB blanket sectors.
- Only 1 loop for OB segment suffers ex-VV LOCA.
- Helium is assumed lost immediately.



Decay heat in EU HCPB-DEMO reactor

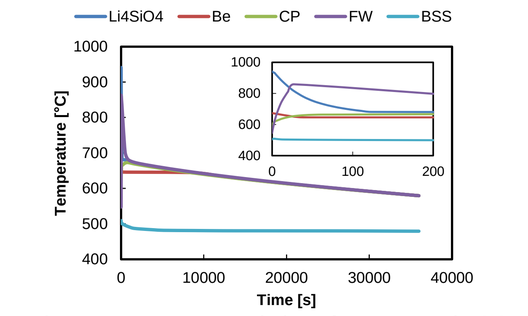


Coarse mesh and refined mesh

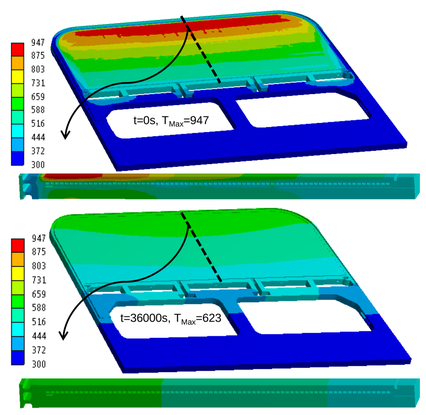
Coarse mesh: 2.8e5 elements, 9.1e5 nodes
Refined mesh: 6.5e5 elements, 2.2e6 nodes

Loads:
- Thermal field
- 8 MPa pressure
- Gravity
- Electro-magnetic

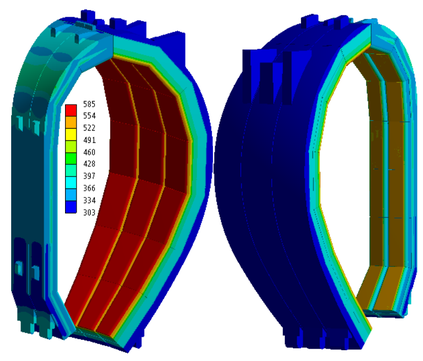
Results and Analysis



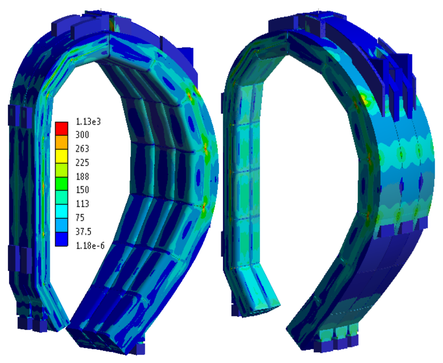
Maximum temperature evolution after ex-vessel LOCA



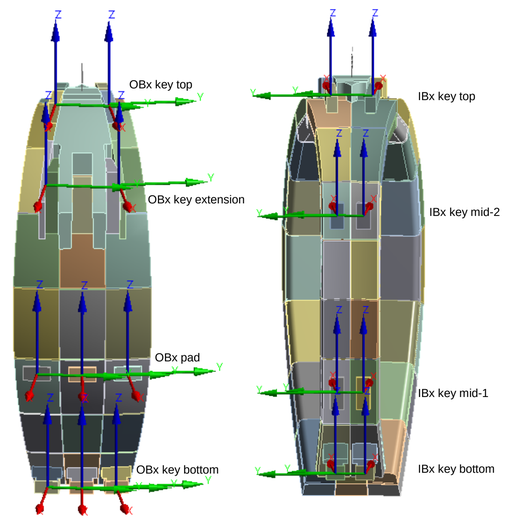
Temperature contours at t=0 s and t=10 h [°C]



Temperature contours on blanket segments [°C]



Von-Mises stress field on blanket segments [MPa]



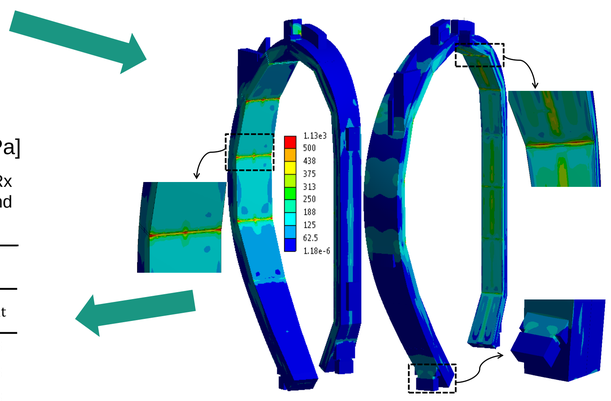
Local coordinates for reaction forces and moments

Table 2. Reaction forces and moments at attachments acting upon VV (F-force, M-moment)

	Fx	Fy	Fz	Mx	My	Mz
Units	MN	MN	MN	MN·m	MN·m	MN·m
OBR key bottom	3.2	-6.7e-2	5.7	-6.0e-2	1.3e-1	-7.6e-3
OBR pad	3.7e-4	-2.5e-8	5.2e-3	-5.6e-8	6.3e-6	-4.9e-8
OBC key bottom	3.1	-2.7e-2	5.6	1.8e-1	1.3e-1	3.4e-2
OBC pad	0	0	5.4e-3	-2.1e-8	-2.5e-6	2.3e-11
OBL key bottom	3.2	5.0e-2	5.8	-9.1e-2	1.3e-1	-4.2e-2
OBL pad	5e-4	-1.6e-8	5.2e-3	-5.5e-8	9.9e-6	1.0e-7
OBR key extens.	6.2e-1	-9.4	-2.6e-2	7.7e-1	4.7e-2	5.7e-1
OBR key top	2.8	-2.2e-1	-4.2	2.6e-1	-9.6e-1	2.3e-1
OBL key extens.	6.4e-1	9.6	-3.1e-2	-1.4	8.3e-2	-1.3
OBL key top	2.7	1.5e-2	-4.5	-3.3e-1	-9.3e-1	-2.0e-1
IBR key bottom	8.9e-1	2.8e-2	3.8	-1.4e-2	7.4e-3	1.5e-2
IBR key mid-1	2.3	1.5e-2	3.4e-2	-2.5e-3	-1.9e-1	2.8e-3
IBR key mid-2	5.7	-1.7e-1	-2.5e-1	2.0e-2	5.7e-1	-7.9e-3
IBR key top	-2.5e-1	1.4e-1	-2.8	3.7e-2	-2.2e-1	6.3e-2
IBL key bottom	7.8e-1	5.4e-2	4.7	1.9e-2	4.2e-3	-2.1e-2
IBL key mid-1	2.4	-1.5e-1	3.6e-2	-2.6e-3	-2.0e-1	-1.4e-2
IBL key mid-2	6.4	3.2e-1	-2.9e-1	-5.7e-2	7.0e-1	1.7e-2
IBL key_top	-3e-1	-2.1e-1	-3.6	-5.5e-2	-3.7e-1	-1.7e-1

Table 1. Stresses assessment with respect to RCC-MRx Level D criteria on the most critical path on OBL, IBL and attachments [MPa]

	IPC		IPI		IPFL	
	$\overline{P_m}$	Limit	$\overline{P_L+P_b}$	Limit	$\overline{P_m+Q_m}$	Limit
OBL	16	332	27	498	364	506
IBL	24	340	142	509	169	506
Attach.	98	361	220	541	102	506



Conclusions

- Transient thermal analysis of the current reference HCPB breeding blanket for EU DEMO baseline 2015 under an ex-vessel LOCA has been presented, showing a sufficient cooling down of decay heat by thermal radiation to VV after accident.
- The structural assessment of the HCPB BB segments under the selected accident has been conducted, showing large margins against selected damage modes with respect to the RCC-MRx Level D criteria.
- The reaction forces and moments at attachments acting on VV under the selected accident are obtained.

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