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Thermal-mechanical analysis and design optimizations of the IFMIF-DONES HFTM

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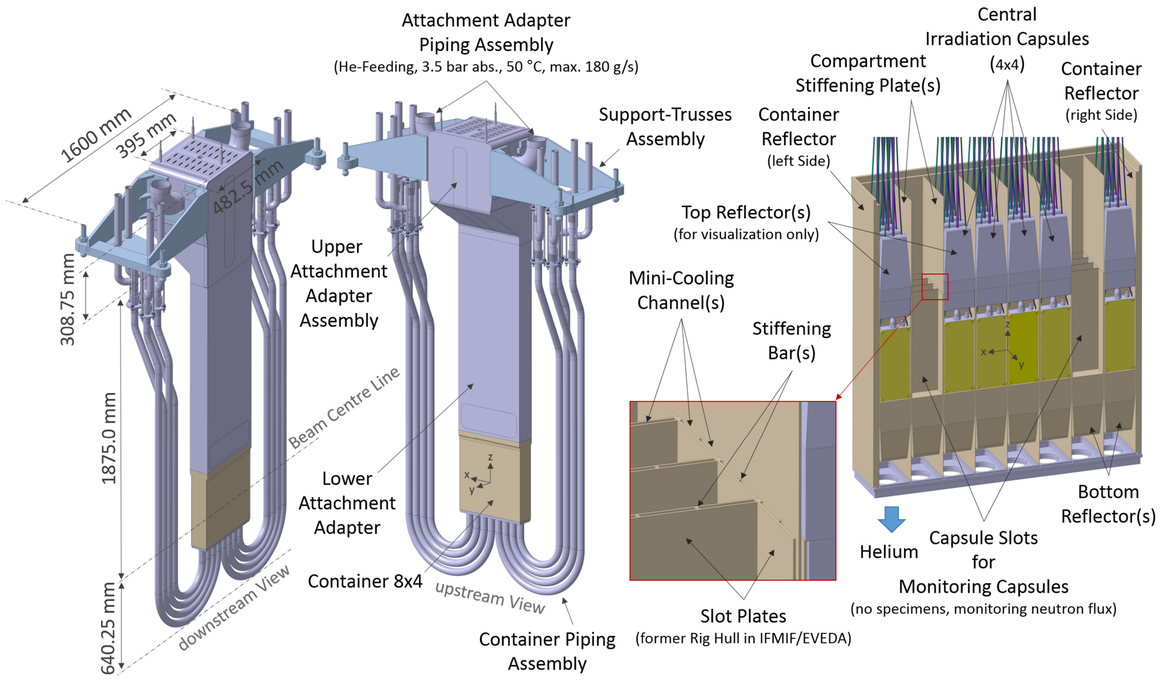
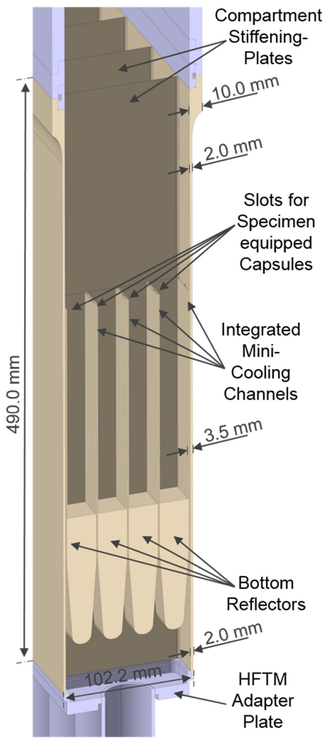
International Fusion Materials Irradiation Facility (IFMIF) High Flux Test (HFTM)

➔ Device to enable the irradiation of Small Scale Testing Technique (SSTT) specimens with a fusion relevant neutron flux of up to $5 \cdot 10^{16}$ neutrons/s.

➔ Generation of irradiated material data for design, licensing, construction and safe operation of future fusion reactors.

1. Design Improvements



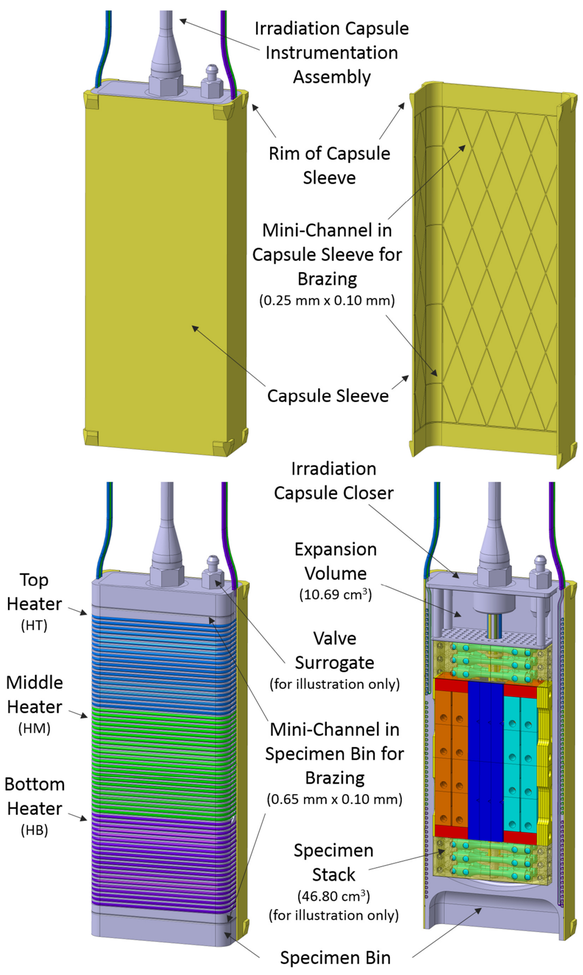


IFMIF-DONES HFTM Container 8x4:

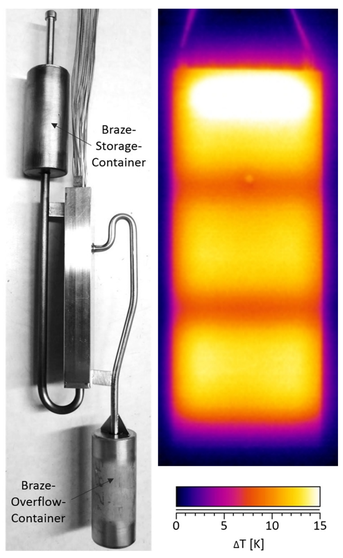
- HFTM **Container twice as thick** as in IFMIF/EVEDA: 102.2 mm (possible due to 50% nuclear heating and no other modules in Test Cell).
- **New container structure** (Slots with integrated Mini-Cooling Channels) effects higher structural stiffness: better pressure resistance and less deflection.
- Capsules directly inserted in Slots (without rig hull), surrounded by Helium Mini-Cooling Channels
- **32 Slots** per Container, 4 Slots per Container Compartment in beam-direction.
- **Helium coolant flow direction reversal** causes less deflection of Attachment Adapter Assembly.
- 2.0 mm thick external walls on up- and downstream side and 10.0 mm thick reflectors on left and right side, like in IFMIF/EVEDA.

IFMIF-DONES HFTM Irradiation Capsule Assembly:

- **Specimen Bin is combined with its bottom closure** to a new part, manufactured by sinker-EDM: Avoids the failure-prone welding of bottom closure.
- **Increase heater-wire lifetime by increasing heater-wire bending radius** from 2.0 mm to 3.0 mm.
- heater-wire bending radius increase **doubles** the capsule thickness and the **theoretical specimen payload volume** to roughly 46.8 cm^3.
- **New inlet and outlet design of heater-wire** groove on Specimen Bin (no empty grooves anymore, increase of heater-wire lifetime).
- **NaK is replaced by Sodium (Na)**, because NaK produces Argon (Ar) isotopes under neutron irradiation.



- Tool for alkali metal injection is installed only during filling and replaced by Irradiation Capsule Instrumentation Assembly, before irradiation. This prevents Sodium leaking during operation even if internal capsule pressure will rise.
- **Knobs on Capsule Sleeve are not needed any more** because of updated container design.
- **Brazing process is re-designed** as well, the capsules will be filled up now from bottom to top, supported by mini-channels in Specimen Bin and Capsule Sleeve.

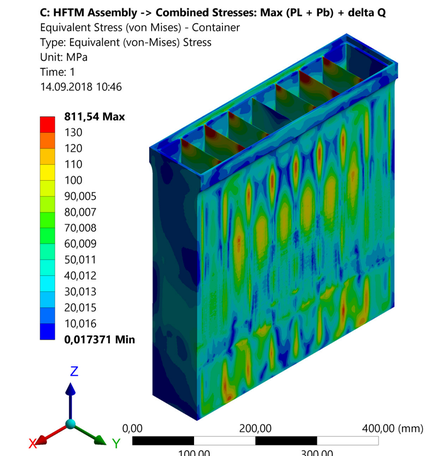


2. Thermal-mechanical analysis

Reflector on left Side in x-direction [mm]		Comp.-Stiff.-Plate No. 04 in x-direction [mm]		Reflector on right Side in x-direction [mm]	
upstream	downstream	upstream	downstream	upstream	downstream
-0.13	-0.21	-0.46	-0.45	-0.77	-0.69

Reflector on left Side in y-direction [mm]		Comp.-Stiff.-Plate No. 04 in y-direction [mm]		Reflector on right Side in y-direction [mm]	
upstream	downstream	upstream	downstream	upstream	downstream
-0.73	-0.86	-0.63	-0.77	-0.74	-0.86

Reflector on left Side in z-direction [mm]		Comp.-Stiff.-Plate No. 04 in z-direction [mm]		Reflector on right Side in z-direction [mm]	
upstream	downstream	upstream	downstream	upstream	downstream
-1.53	-1.40	-1.57	-1.43	-1.52	-1.39

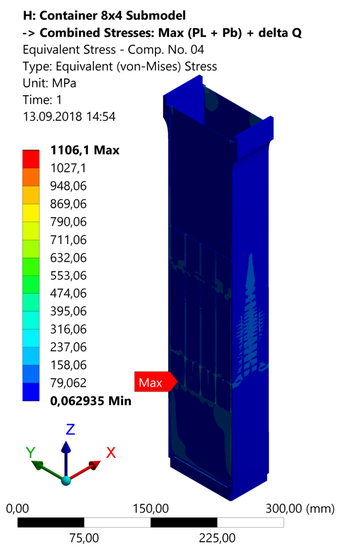


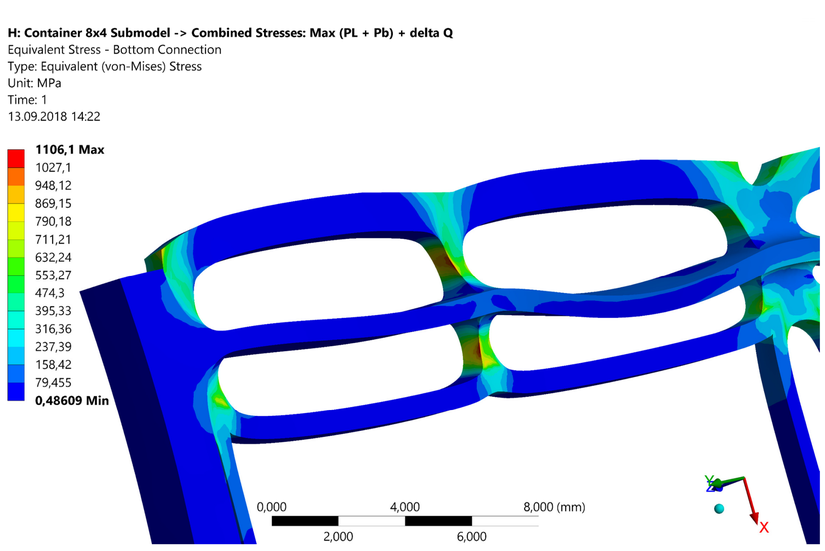
Sub-Model Mesh:

- Nodes: 8 791 873
- Elements : 2 645 114

Global Model Mesh:

- Nodes: 19 687 210
- Elements : 10 365 162





- Sub-Model shows localized high stresses in the transitions of the mini-cooling channels on top and at the bottom of the Slot Section, caused mainly by primary stresses.
- Maximum stress on pressure bearing wall of Container is 133 MPa. The averaged von Mises stress of Comp.-No. 04 is 76.62 MPa and of the whole Container it is 44.3 MPa. So, the stresses are on acceptable level.

Conclusions:

- Parametric CAD model of HFTM, including capsules is ready.
- FEM analysis show low deflection away from target.
- Brazing-process is working but with still some potential to improve.

Outlook (aspects that will be further investigated):

- Capsule manufacturing is ongoing with focus on brazing process improvement.
- Elastic-plastic simulation of HFTM Container 8x4 planned.
- Lowering the number of stiffening bars of the container mini-cooling channels.
- Na-filling tool and process under development.
- Development of Multi-Connector solution for HFTM and Test Cell (TC).
- FEM analysis for different operational cases and less stiffening bars.
- Full stress assessment in accordance with RCC-MRx.
- Development of Monitoring Capsules.

EUROfusion

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The views and opinions expressed herein do not necessarily reflect those of the European Commission.