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Manufacturing of the IFMIF HFTM double compartment prototype

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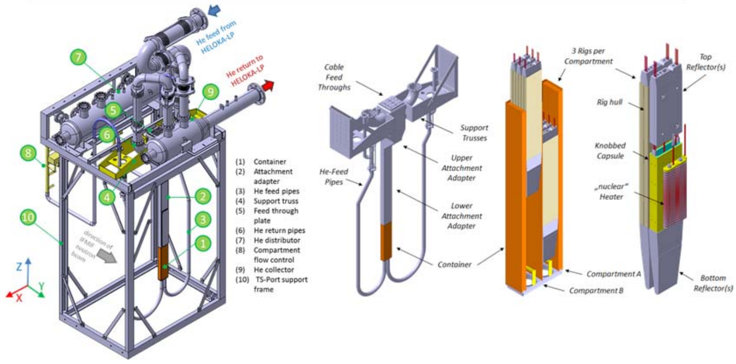
International Fusion Materials Irradiation Facility (IFMIF) High Flux Test (HFTM)

➔ device to enable irradiation of Small Scale Testing Technique (SSTT) specimens by neutrons up to a structural damage of 50 displacements per atom (dpa) in an irradiation campaign of one year. ➔ Design database for DEMO.

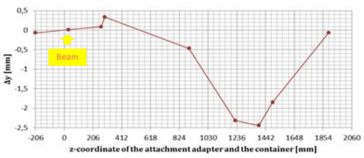


Container:

- 2.0 mm (+0.05/-0.07 mm) thin wall, divided by a 1.0 mm thin stiffening plate into two compartments (A, B).
- Manufactured by wire-EDM out of solution annealed round bar AISI 316Ti. The material was heat treated before wire-EDM to relieve residual stresses.
- Misaligning in clamping, 2.0 mm walls thinner than demanded and a "belly" on stiffening plate.
- Deflection detection by ten dial gauges and deformation detection by 22 resistance strain gauges in combination with temperature sensors.

Attachment Adapter:

- Consist of two partly welded parts (upper and lower attachment adapter).
- manufactured by milling out of round steel bars of AISI 316Ti.
- After welding, detected deflection of 10.0 mm in beam direction (y-axes).
- Aligning by partial heating after welding
- Machining reference plane is upstream side of lower attachment adapter.
- Deflection detection by two dial gauges and deformation detection by four resistance strain gauges and temperature sensors respectively.

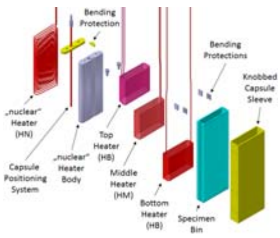


Measured deflection of welded assembly of attachment adapter and container after partial heating.

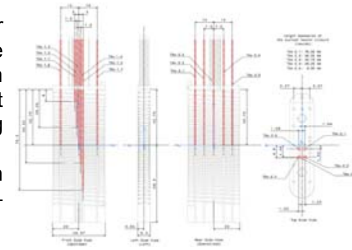
Capsule:

- Consist mainly of P92, a martensitic stainless steel with similar properties and composition to Eurofer, planned to be use in IFMIF.
- AISI 321 shielded, MgO isolated single core heaters with two true „cold ends" of copper, "hot part" material is NiCr 80/20 alloy.
- Instrumented with type-K thermocouples (TC):

  seven upstream TC to detect the longitudinal temperature field, five downstream TC for measuring the lateral temperature field and six central TC to control the power supply of top (HT), middle (HM) and bottom (HB) heater by a logic control unit, to stabilize the specimen temperature in a range between 250 and 650 °C during test- and foreseen irradiation campaign.



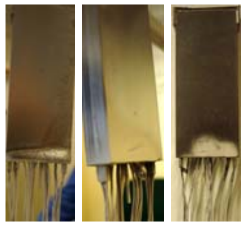
- „nuclear" heater grooves and heater wire (NH) respectively approximate the upper part of a Gaussian distribution to surrogate the heat generation of the SSTT during irradiation.
- Raw capsule sleeve and specimen bin were manufactured by sinker- and wire-EDM.



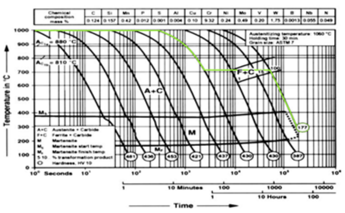
Position of thermocouples in the "nuclear" heater of a full instrumented HFTM-DC dummy capsule.

Brazing:

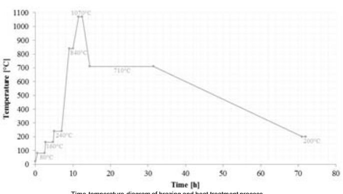
- B-Ni76CrP-890 in accordance to EN ISO 3677.
- Basic functional principle of brazing is the capillary effect. But because of the capsule height and the "into-each-other" assembling, it is not possible to use this effect only. Gravity should be used for brazing, too. Presently the capsule is stored upside-down in a framework
- At two of three capsules, braze had oozed out massively and brazed the heater- and thermocouple-wires together. However, after replacing the wires, the capsules were tested and fit for operation.
- After brazing, a "belly" on the width sides of each capsule was detected – this effect was known beforehand. For a precise orientation of the capsule assembly in the milling machine for performing the knops after brazing, all capsule corners of one width side must be arranged in the same (horizontal) plane.
- During manufacturing of previous capsules, knops often tear off. Responsible on the one hand it is the resulting thin rest wall thickness (at 550 °C, 0.350 mm) in combination with potential brazing cavities. On the other hand, it's the martensitic microstructure (480 – 380 HV10) and thus induced specific high cutting forces.
- An additional heat treatment directly following the brazing, changes the normally occurring martensite of P92 to a less hard microstructure of austenite and carbide (181 HV10).



Full instrumented HFTM-DC dummy capsule



Source: Presentation of Dr. Herbert Heuser of Böhler Welding on the Cluster-Forum, 20. Oct. 2010 at the SLV München.



Time-temperature-diagram of brazing and heat treatment process

Conclusions:

- Feasible fabrication of all parts of the HFTM–DC.
- Shortcomings in fabrication are identified, like brazing of the capsules or fabrication of container and attachment adapter.
- Functionality is tested successfully.

Outlook (aspects that will be further investigated):

- Improvement of brazing.
- Combination of the functionality of container and rig-hull.
- Fixing point for container (HFTM) at back plate support structure of neutron source, to prohibit large deflection.
- Replacing feed-through on attachment adapter head through manageable remote handling plugs.
- Attachment adapter design with less longitudinal or asymmetric welds, respectively.