Tue-Af-Po2 [236]

MT25

Measurements of the Effective Thermal Conductivity of the ITER TF Coil Case Cooling System

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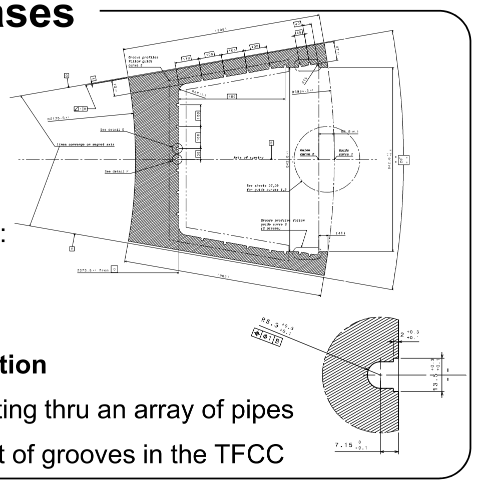
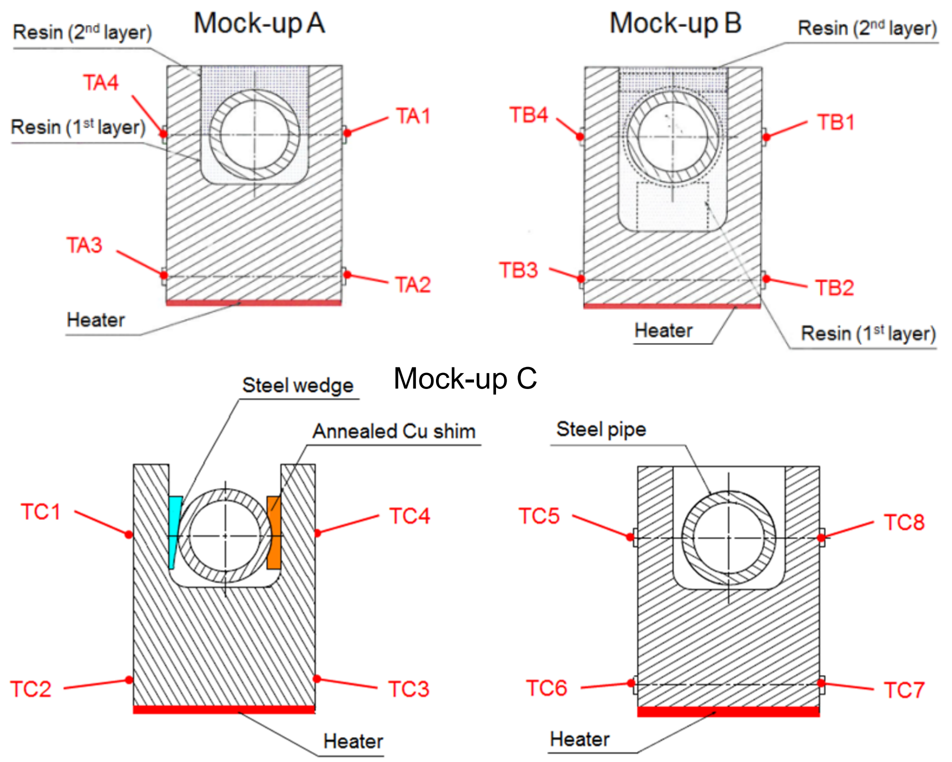
ITER Toroidal Field Coil Cases

- Each ITER TF winding pack is enclosed in a thick stainless steel case:
  - Provides **mechanical support**
  - Also acts as a **thermal screen**
- During operation, the coil case is subjected to:
  - **Eddy current heating**
  - **Nuclear heating**
  - Static heat loads: **conduction and radiation**
- The TFCCs are cooled by **He at 4.5 K** circulating thru an array of pipes
- The **cooling pipes** are **resin-bonded** to a set of grooves in the TFCC



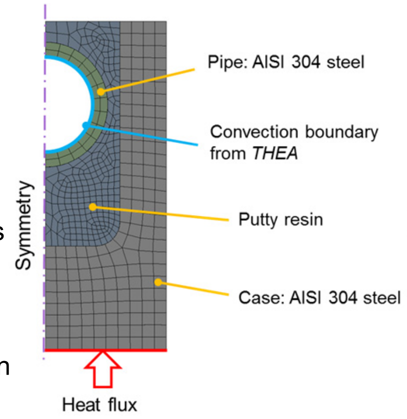
TFCC Mock-up samples

- **Mock-ups A** and **B** explore the effective thermal conductivity in the **baseline design**: thermal contact given by **wollastonite-charged putty**
- In **mock-up C** the thermal path is provided by 6 pairs of **stainless steel** and **copper shims**
- A **heater** is installed in each **mock-up**
- **Cernox sensors** (range 4 to 325 K) are used to measure the temperature
- **Mock-up B** was also tested after a four point bending at room temperature

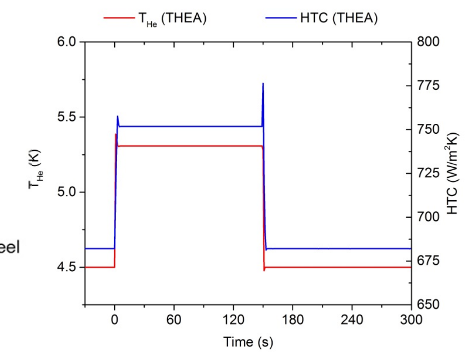


Finite Element Model

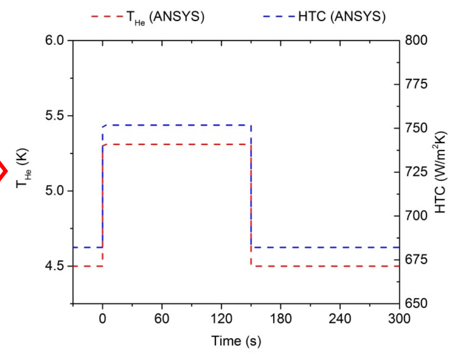
- **Heat load** applied at the bottom
- Boundary condition in the pipe imported from a **1D thermal-hydraulic model** in **THEA**
  - Dittus-Bölter correlation for computing HTC
- All **other boundaries** are assumed **adiabatic**
- **Thermal properties** of the **putty**: 3 assumptions
  1. "Epoxy-like" putty
  2. "Stainless-steel" putty
  3. Measurements of wollastonite-charged resin from KIT



- ***Output from THEA 1D model***



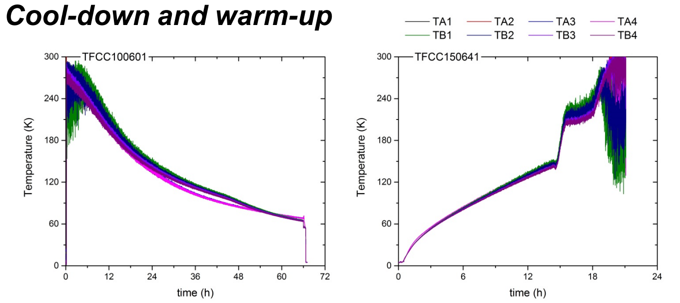
- ***Convection boundary in 2D FEM***



Experimental measurements

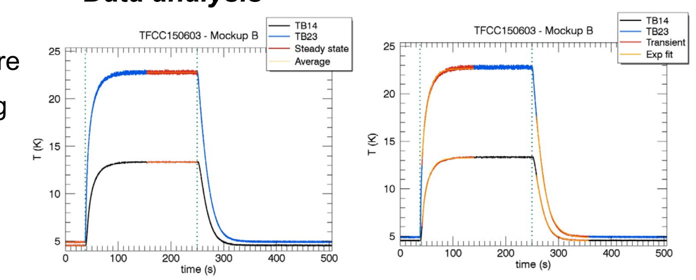
- ***Cool-down and warm-up***

- Care to **avoid thermal shock** to the samples
- **No signs of cracks or delamination** affecting the contact conductivity



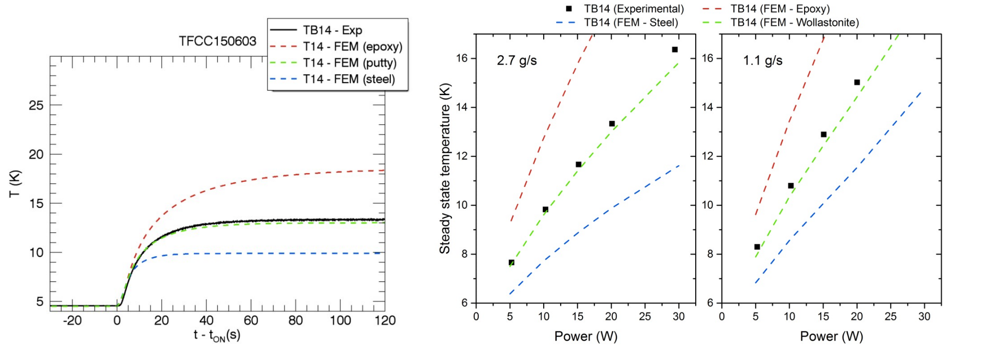
- ***Data analysis***

- Steady state temperature
- Time constants by fitting an exponential function to the transients



- ***Comparison with simulations***

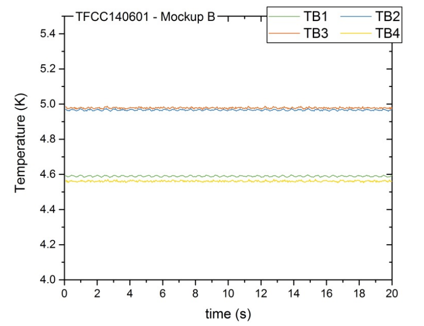
- The FEM assuming the prop of wollastonite-charged resin accurately predicts T



- ***Temperature gradient with no intentional heat input***

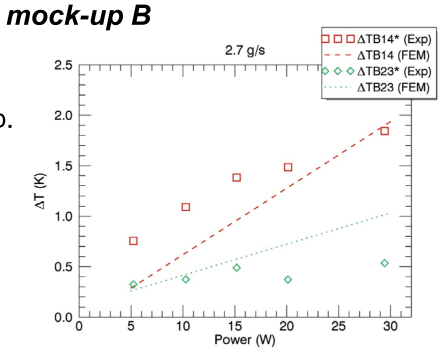
- A **small temperature gradient** observed even when **no** intentional **heat** is applied
- The **offset can be corrected** during post-processing:

$$T^{*} = T_{heat\ ON} - (T_{heat\ OFF} - T_{He\ IN})$$



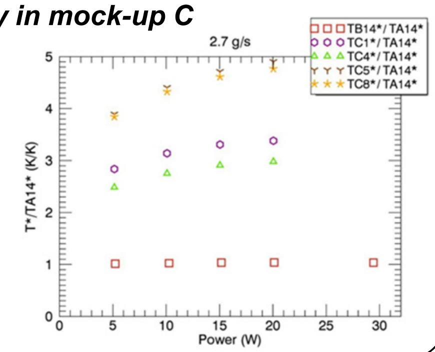
- ***Effect of bending mock-up B***

- A **small increase ΔT** observed **after a four point bending** process at room temp.
- ΔT is comparable to that observed if the **contact conduction** between resin and steel case is **limited to ~380 W/m²·K** in the FEM



- ***Effective conductivity in mock-up C***

- The conductivity in mock-up C is **dominated** by the **poor contact between** the metallic **shims** and the cooling **pipe**
- TC1* and TC4* are **~3× higher** than TA14*
- The time evolution is **15 to 50 times slower** compared to mock-ups A and B



Experimental set-up

- The samples were tested in **SULTAN** (hanging from the 100 kA trafo)
- A constant flow of **He** at **10 bar** and **4.5 K** circulates through the pipes (1.1 to 2.7 g/s)
- A **steady state heat load** is applied in the sample heater (5 to 30 W)
- The **effective thermal conductivity** is evaluated by comparing the **measured temperature distribution** with the **predictions** from a **finite element model**

Conclusions

- The model assuming the thermal conductivity of a **wollastonite-charged resin predicts quite well the temperature distribution**
- **No indication of cracks or delamination** decreasing significantly the overall heat conductivity of the mock-ups **after cool-down**
- A **four point bending process** introduces a small contact resistance, but it **does not compromise the overall heat conductivity**
- **An alternative design** relying exclusively in the **contact between metallic shims** and the cooling pipe is **not as effective as the baseline design**