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An attempt to incorporate experimental data in the Breeding Blanket First Wall design and safety analysis

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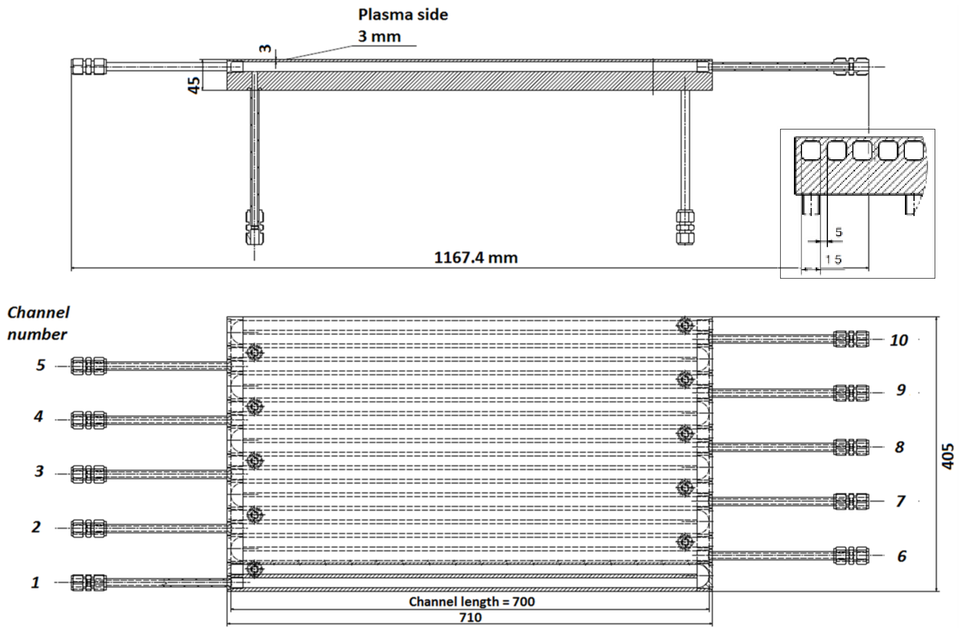
Goal

Incorporate the results of an experimental campaign and the lesson learnt from it in the Breeding Blanket First Wall design and safety analysis. The campaign investigated the behavior of a Helium Cooled Pebble Bed (HCPB) First Wall (FW) mock-up under Loss of Flow Accident (LOFA) conditions.

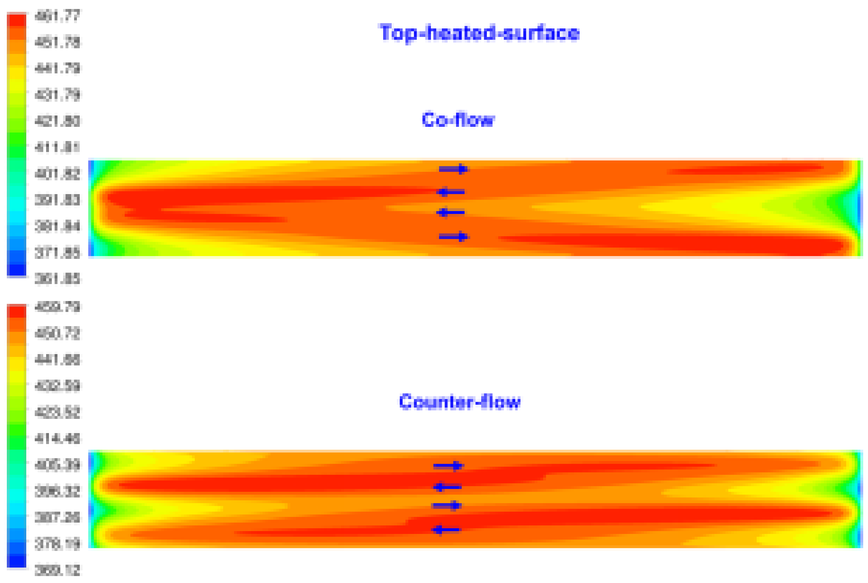
First Wall mock-up and preliminary experimental setup

The First Wall (FW) mock-up is a P92 steel plate crossed by 10 channels characterized by a 180° bend. It was developed as part of a study concerning various fabrication path for a blanket FW. The mock-up was installed in the KIT HELOKA-HP facility and heated-up by means of an electron beam gun on an area of 0.58x0.16 m^2 placed in the middle of the plate. Because of its single-loop nature, the mock-up had to be installed to two distinct distribution manifolds (both at the inlet and at the outlet). The LOFA condition have been reproduced closing a valve in one of the outlet manifolds. The cooling strategy (co-current or counter-current) was initially left as an open issue as well as the geometry and the layout of the pipes connecting the mock-up and the manifolds.



Preliminary numerical analysis

ANSYS calculations suggested the adoption of counter-current flow to have a more homogeneous distribution of the temperature (see figure below). RELAP5-3D calculations cleared the control strategy of the valves reproducing the LOFA and the duration of the tests to avoid damages to the mock-up itself.

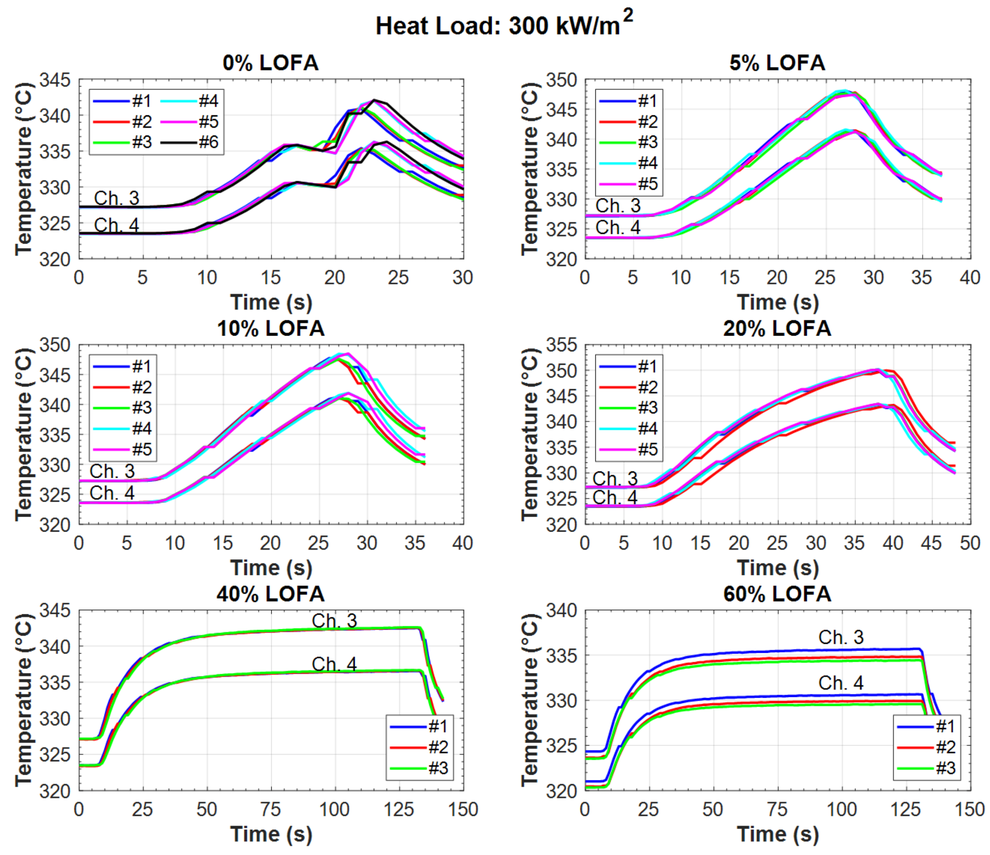


The experimental campaign

The experimental campaign was performed investigating two different heat loads: 300 and 330 kW/m^2. For each heat load 6 LOFA scenarios were investigated: 60% of the flow area of the outlet valve left open, 40%, 20%, 10%, 5%, and 0% (valve fully closed – also called full LOFA).

Outcomes of the experimental campaign

The experimental campaign provided a robust set of experimental data that is currently used to validate system codes RELAP5-3D and MELCOR 1.8.6 for fusion. The different tests also demonstrate the quick temperature rise in case of demanding LOFAs (0% and 5% scenarios) that might hamper the integrity of the system. In the full LOFA scenario, flows in reverse direction through some channels were established (plateau between 16 and 20 s in the 0% LOFA graph below). The figure below shows the outlet coolant temperature from channels 3 and 4 (both under heat load and LOFA) for several repetitions (tests) of the different scenarios at 300 kW/m^2.



Incorporation of data in design and safety analysis

One of the aims of the experimental campaign was to provide data and create practical experience to support the design and safety analyses. Although, during the development (design of the campaign, execution, and post-test analysis) the design of the HCPB FW changed and the 180° bend in the channels was removed and straight channels with artificial roughness are used instead. The bend has a direct influence on the flow field, which is no more representative of the current FW design. Hence, these data can't be directly used in support of the design and safety analysis, but these remarks can be made:

- A quick temperature rise on the FW surface is established in case of full LOFA. A quick reaction of the plasma shutdown system is needed to avoid damages that might hamper the integrity of the blanket.
- Even if due to the experimental set-up, the establishment of reverse flows in some channels in the actual FW design can't be excluded *a priori*. Localized thermal stresses can be then created that might cause local damaging.
- The practical experience gained through the campaign remains relevant for the planned experimental activities.
- The execution of pre-test numerical analysis in support of experimental campaigns is a successful strategy. The execution of post-test analysis open also room for the validation of numerical codes.

Q&A session

Q&A session will be held on Skype on Monday 21st Sept. at 17:00. You can find the corresponding author on Skype under the name: "Bruno Gonfiotti (KIT-INR)" or through the following link: https://join.skype.com/invite/o9lTs2M0nfOg