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Sensitivity of First Wall thermal-mechanical performance on cooling channel geometry and thermal conductivity

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Background and Objective

The First Wall has to withstand the thermal and erosive loads (radiation, neutrons and particles) originating from the plasma, and at the same time contribute to the balance of plant by delivering high temperature heat and consume only limited pumping power.

At the example of a helium cooled First Wall with smooth channels loaded with average heat loads, the impact of tolerances from manufacturing and materials is studied.

Simulation methodology

A first wall segment with 5 channels is simulated. The dimensions and relative position of the central channel are variated (param. e_i)

1.) The mass flow rate through each channel is calculated with a **hydraulic network model**

2.) Based on the individial mass flow rate, **local heat transfer** coefficients and pressures are computed

3.) The temperature field is simulated with ANSYS (static thermal)

4.) The stress field is simulated with ANSYS (static mechanical)

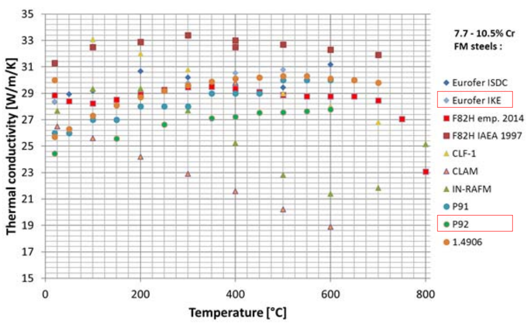
Validation and verification

The analytical thermohydraulic model ("SimFW v2" VBA) is **validated vs. HETRA experimental data** and compared to CFD

- Good conformity of $\Delta p(\dot{m})$ vs. HETRA experiment (+/-4%)
- Overestimation of heat transfer
  - of 0-5% by analytical "SimFW" vs. HETRA
  - of 8-12% by k-ε CFD model @y^+=20 (CFX) vs. HETRA

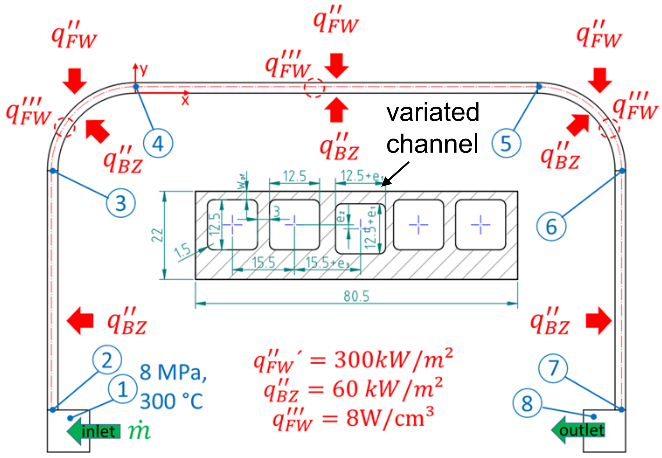
9%-Cr steels thermal conductivity

- Thermal conductivity λ directly influences thermal stresses
- It varies from **20-33 W/m/K** @500°C in the family of 9%Cr steels
- Two measurements for Eurofer differ by 5% @ 500°C
- The neural network tool "Thermal10" (calibrated with 9%Cr steel database) predicts +/-2% for Eurofer within alloy tolerances

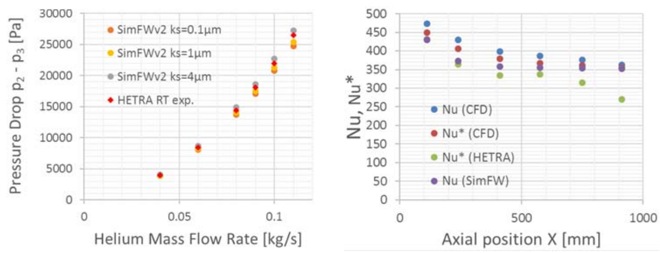


Comparison of 9% Cr steels therm. cond. ,

New own measurements for Eurofer and P92



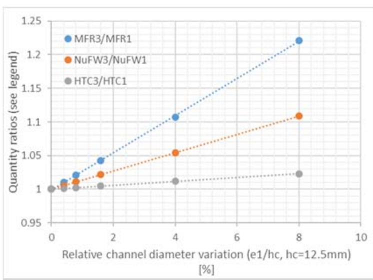
FW slab (5 channels) measures and variated parameters



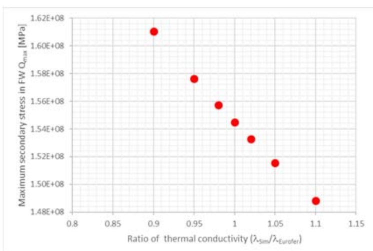
Validation/verifiication of thermal-hydraulic tool "SimFW v2"

Selected results

- Variation of channel width&height (e1=e2)
- Variation of thermal conductivity



Channel size variation impacts strongy on mass flow rate distribution, but much less on heat transfer coefficient.



In trhe expacted range, 10% less thermal conductivity results in 12% higher secondary stresses (at 300kW/m² - linear scaling with heat flux expected)

➔ In Short: (1) A model for FW thermohydraulics was validated (2) Thermal conductivities in RAFM steels vary by +/-20% and impact on stresses.(3) Channel dimension variations impact strongly on massflow, but less on HTC distribution.

EUROfusion
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