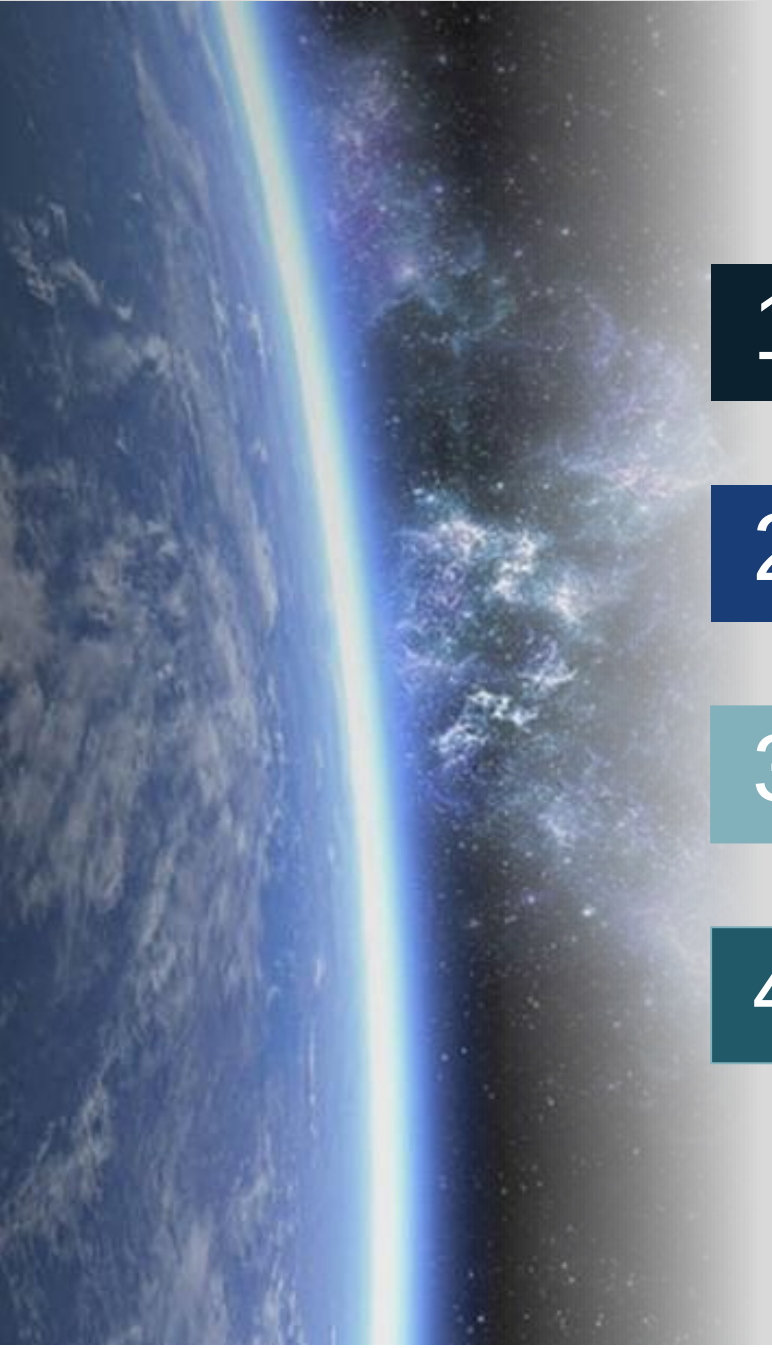
14. WOST

TMF panel design optimization

Weimar, 1st of June 2017
Marcus Lehmann // JOLE43

AIRBUS SAFRAN LAUNCHERS



1 Motivation and background

2 Optimization approach

3 Sensitivities and best design

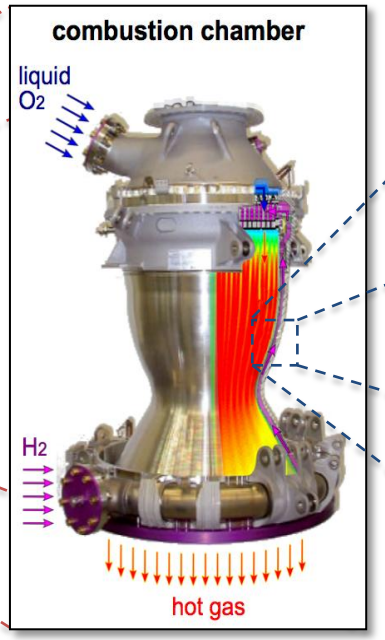
4 Summary

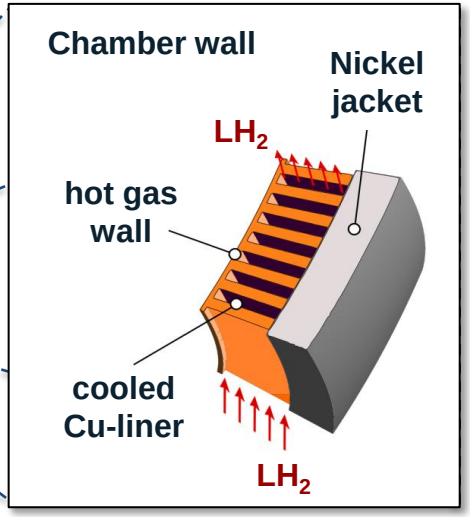
1 Motivation and Background

Title: TMF panel design optimization

Goal: Life time prediction of the chamber hot gas wall (HGW) under thermo-mechanical fatigue (TMF) load conditions.

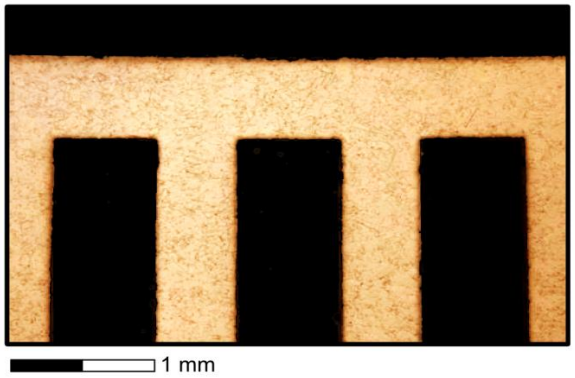
Source: airbusafran-launchers.com



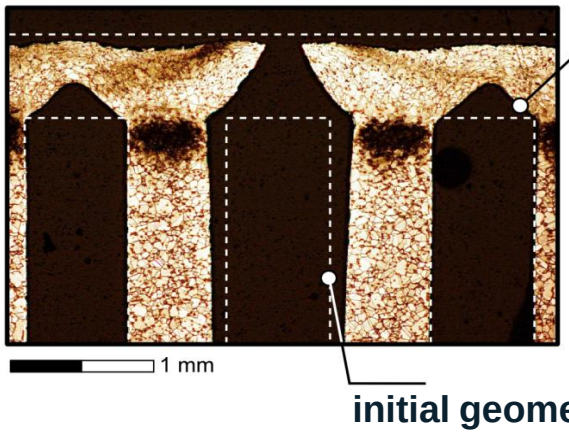


Failure mode: doghouse effect

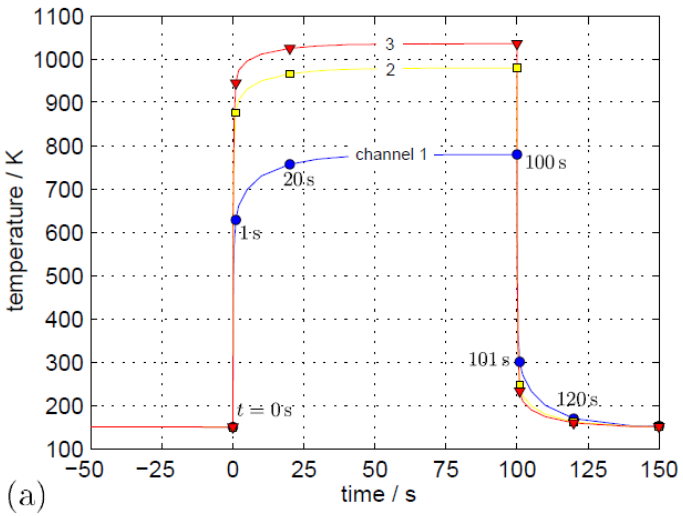
Cooling channels: initial state

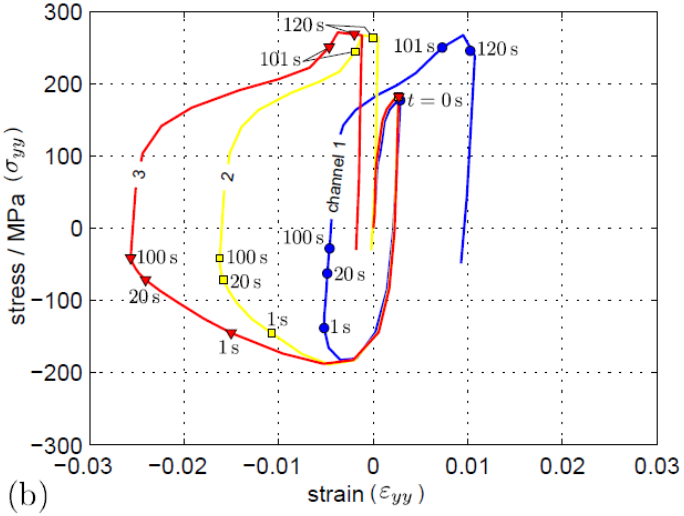


After hot firing campaign

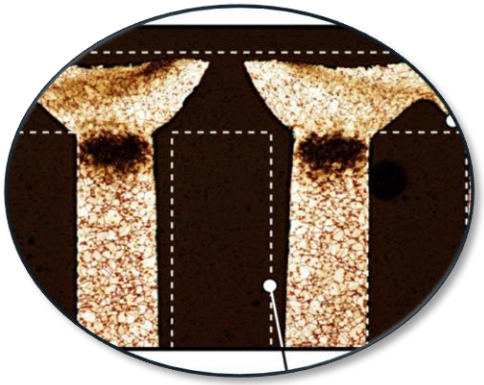


Loading cycle: thermal and mechanical course





Failure mode:
doghouse effect



Failure mode:
doghouse effect

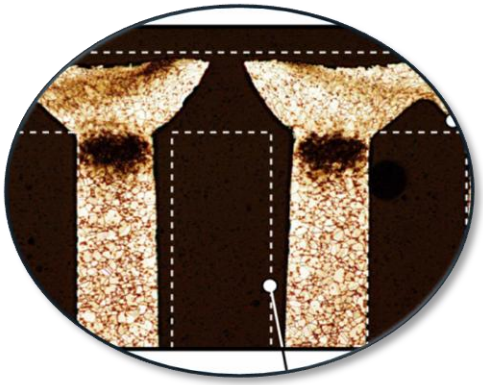
Hardware test: full scale

- Expensive
- No material investigation possible

Source: DLR

1 / Background

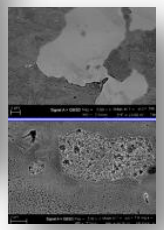
Failure mode:
doghouse effect

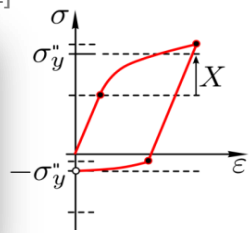


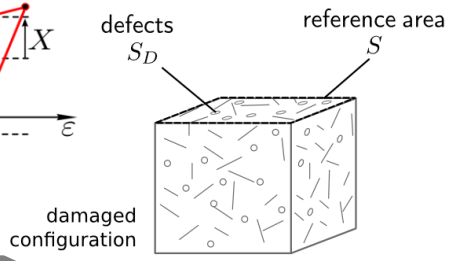
Hardware test:
full scale

1 / Background

[Schwub, 2012]





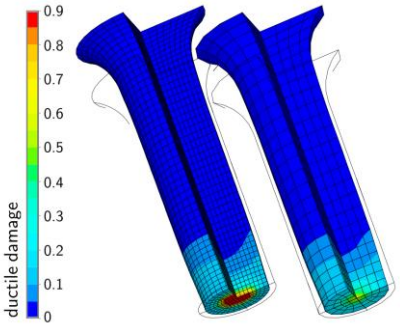


Microstructure and mechanical properties

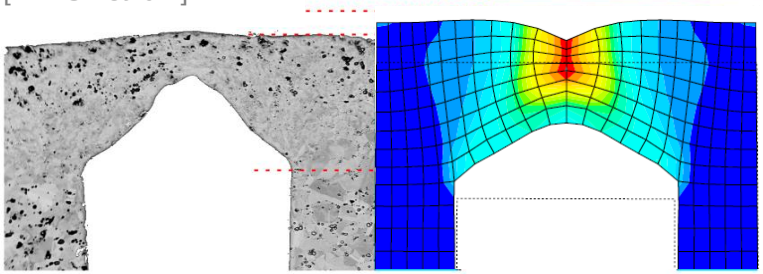
model

FEM-implementation

application



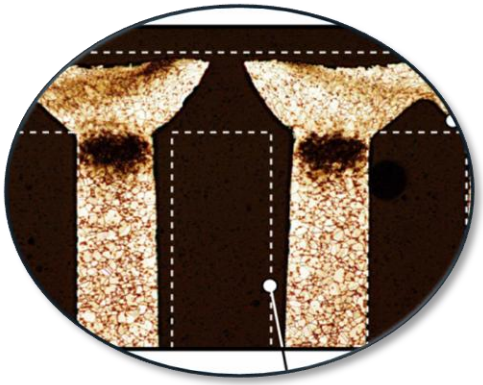
[EADS Astrium]



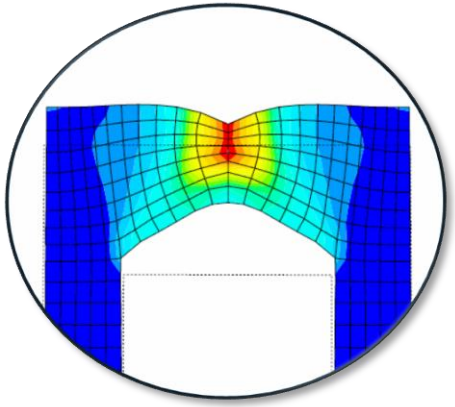
Damage analysis: life prediction

- Material model taking into account:
  - Viscoplasticity
  - Ageing effects
- Damage calculation
- Life prediction of hardware components

Failure mode:
doghouse effect

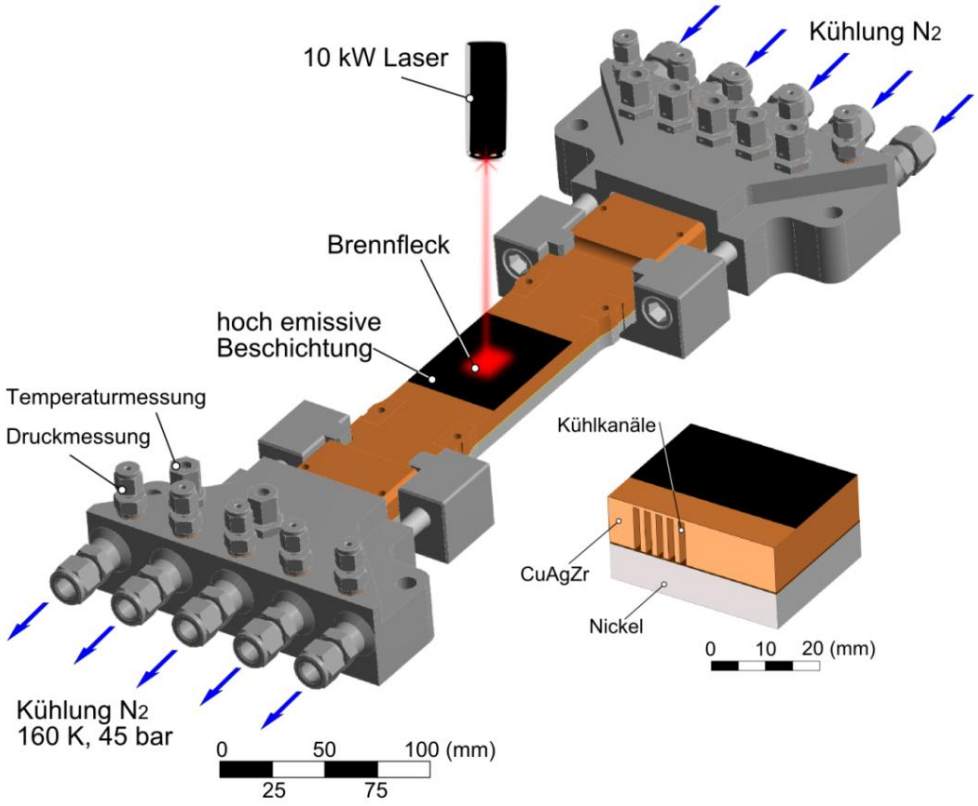


Hardware test:
full scale

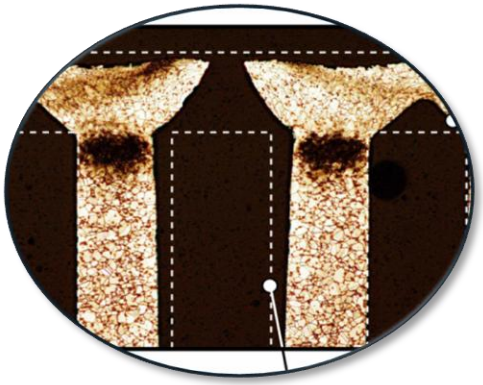


Damage analysis:
life prediction

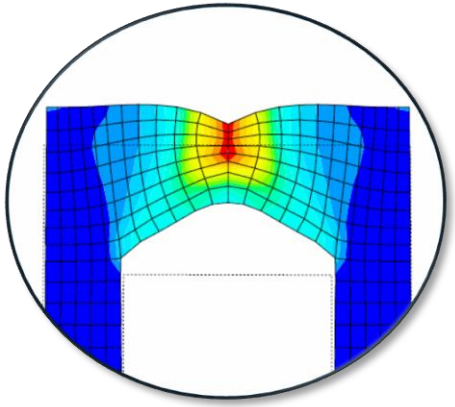
Hardware test: panel based



Failure mode:
doghouse effect



Hardware test:
full scale



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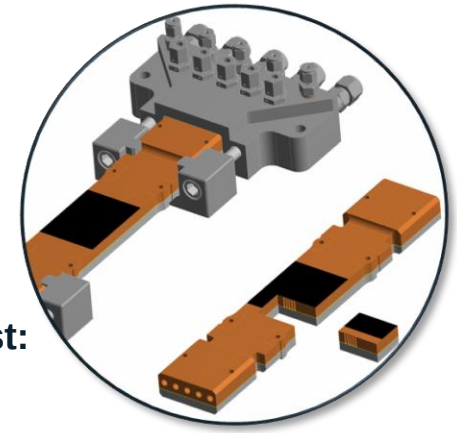
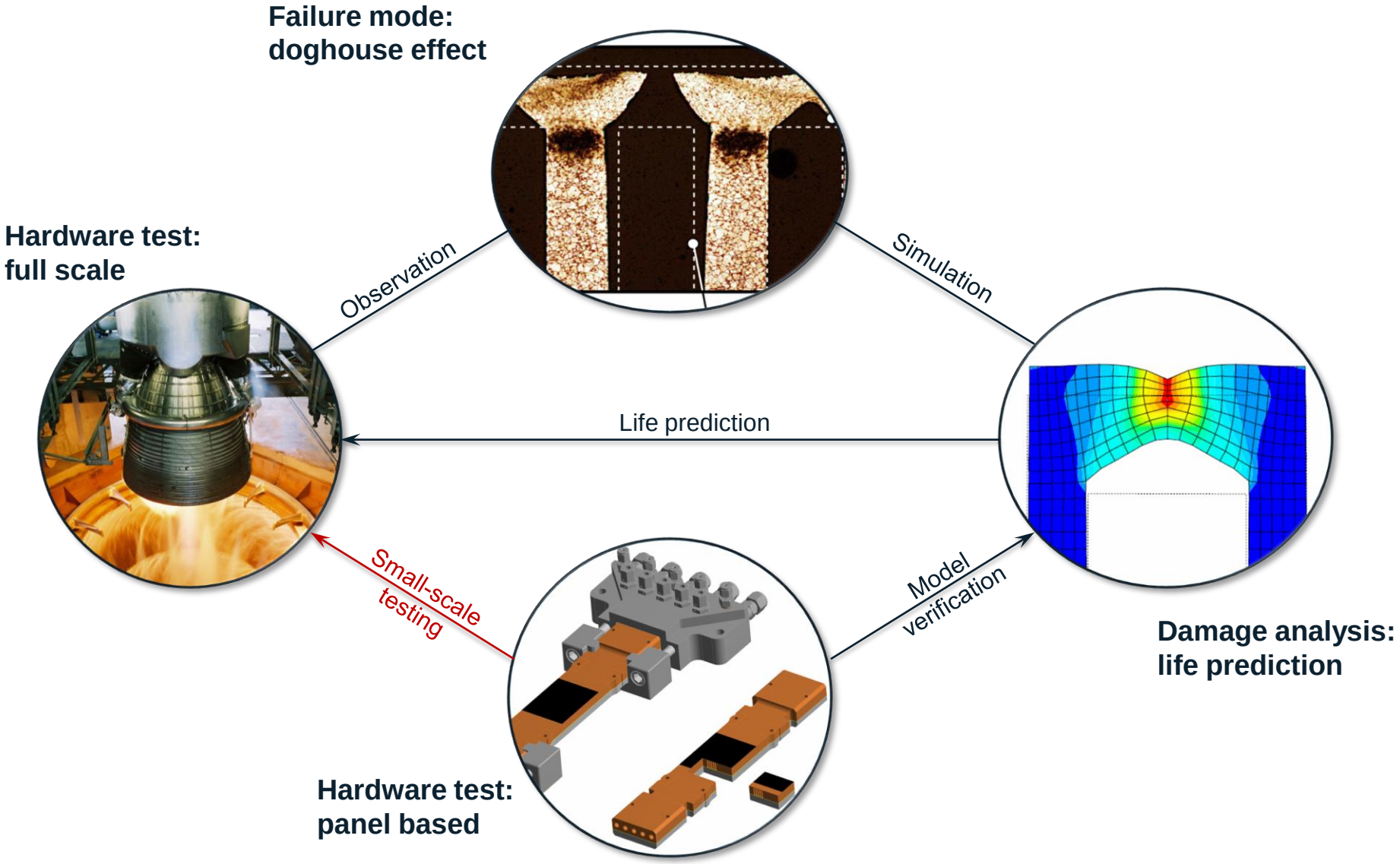
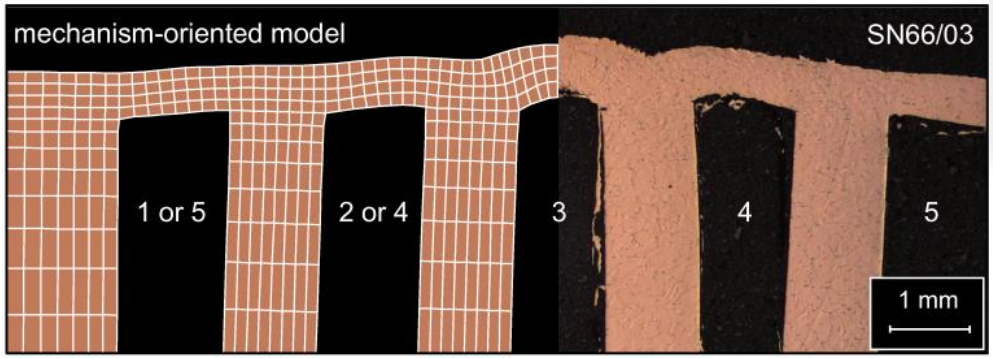
life prediction



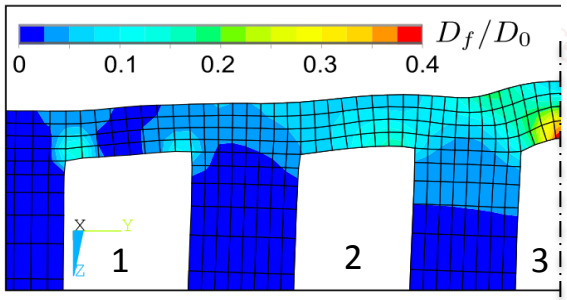
Hardware test:
panel based

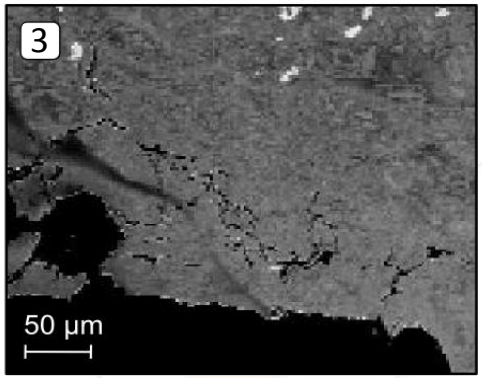


Micro cut investigation of the panel

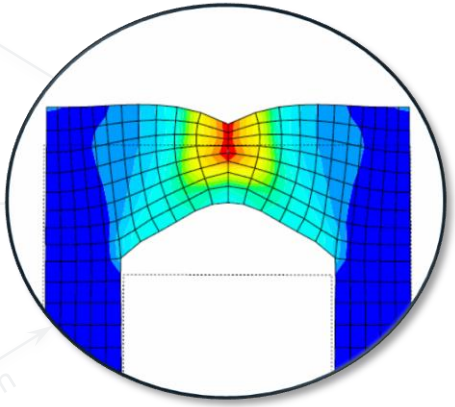


Comparison: simulation and test of panel

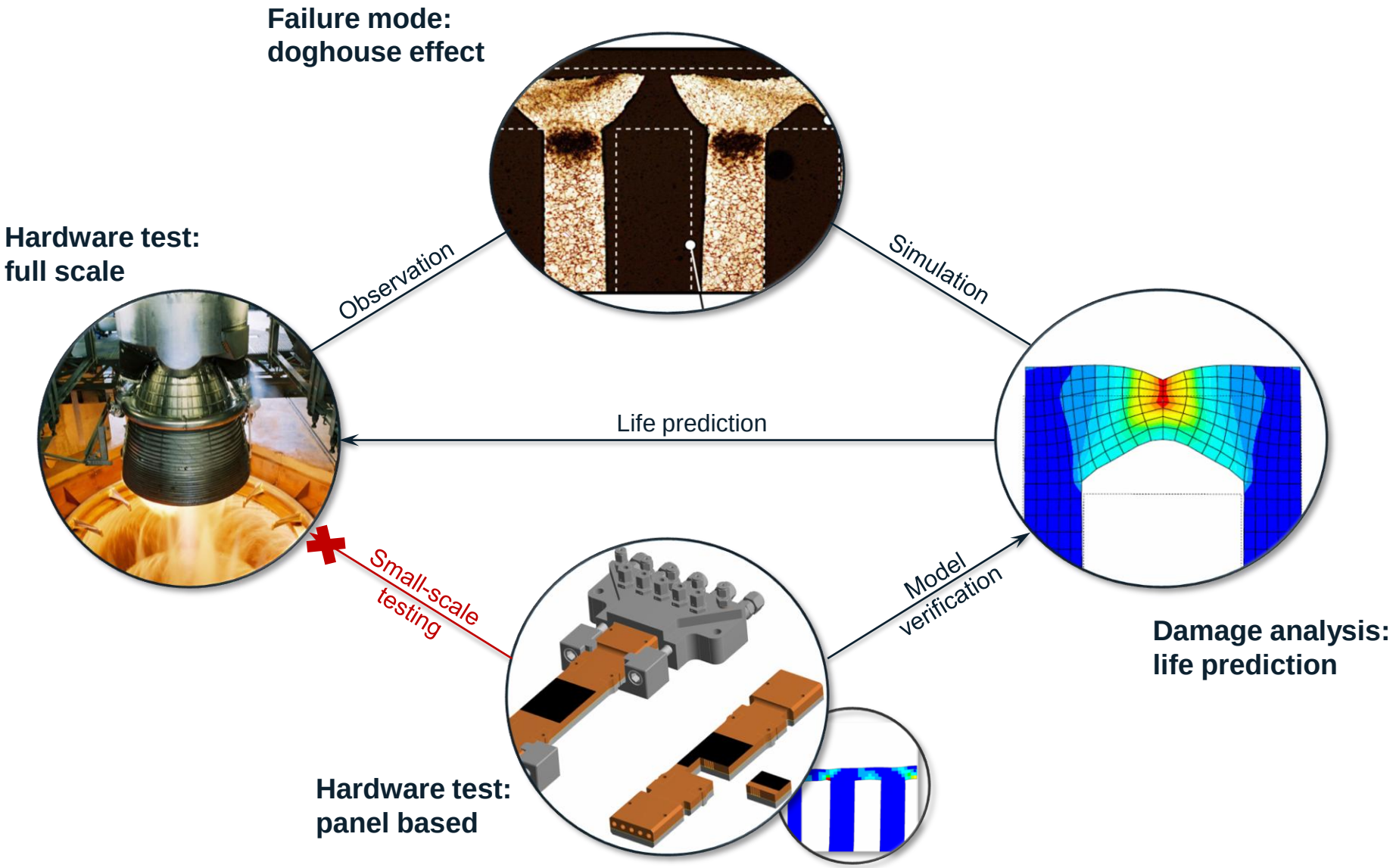




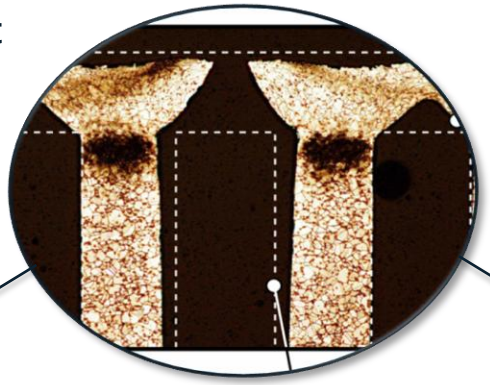
Chamber behavior



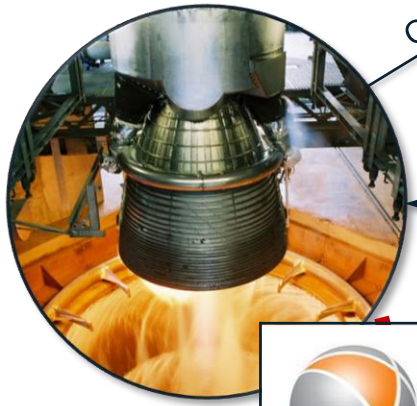
Damage analysis: life prediction



Failure mode:
doghouse effect

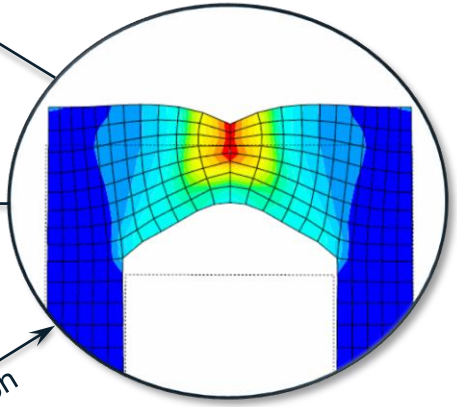


Hardware test:
full scale



Observation

Simulation

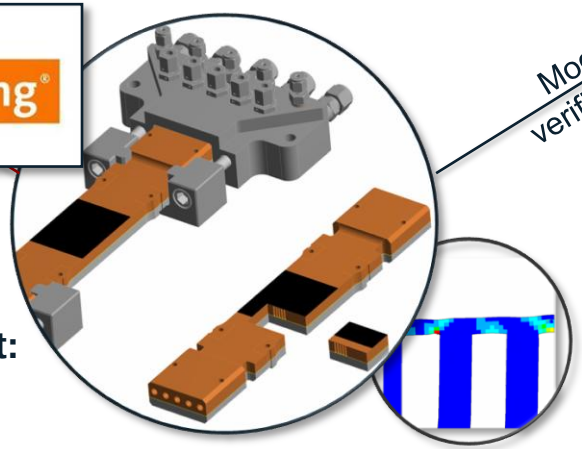


Life prediction

Panel design
optimization

dynardo optiSLang®

Model verification



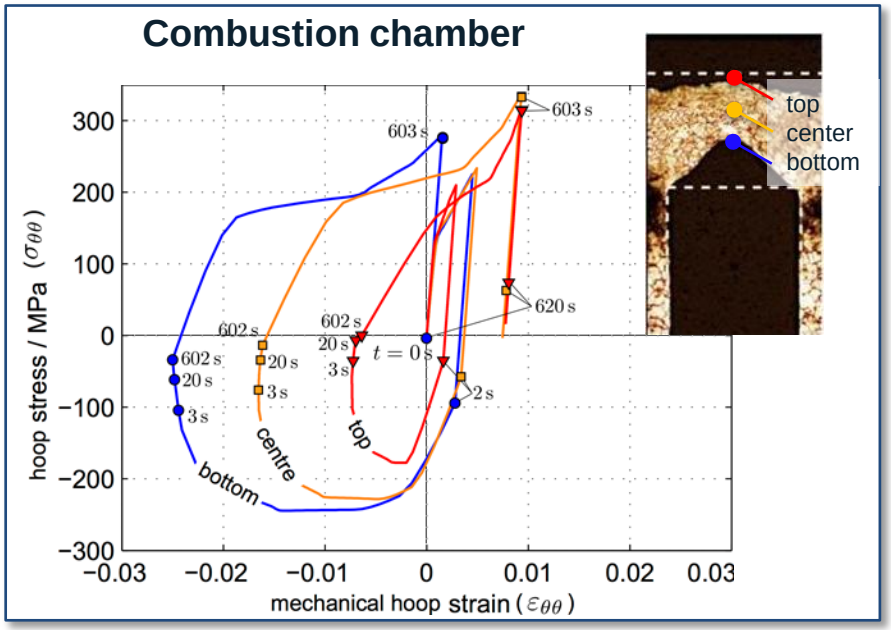
Damage analysis:
life prediction

Hardware test:
panel based

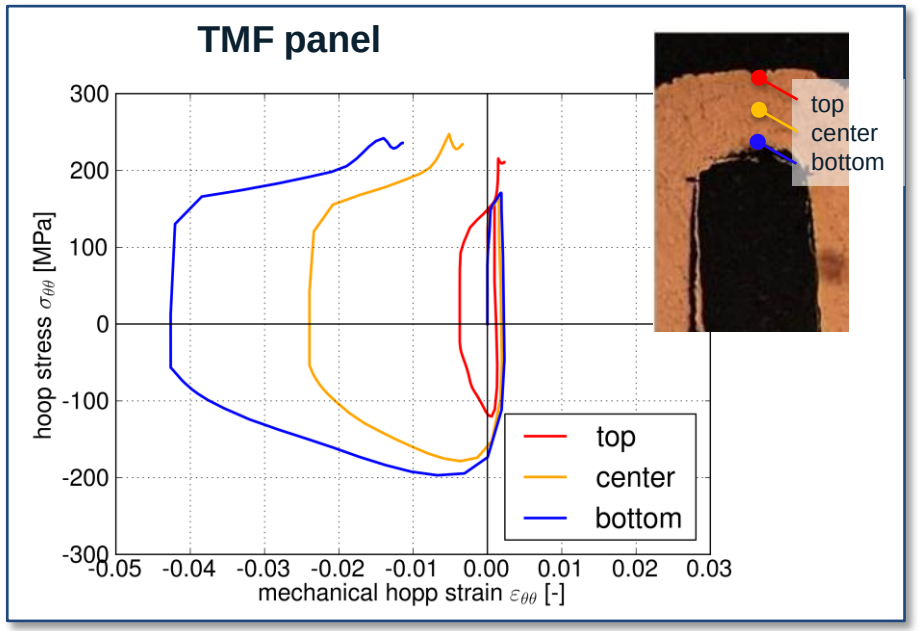
2 Optimization approach

Objective of the optimization:

- Increase the representativeness of the TMF panel test



- Damage mechanism based on cumulated **tensile** deformation in the hot wall ligament

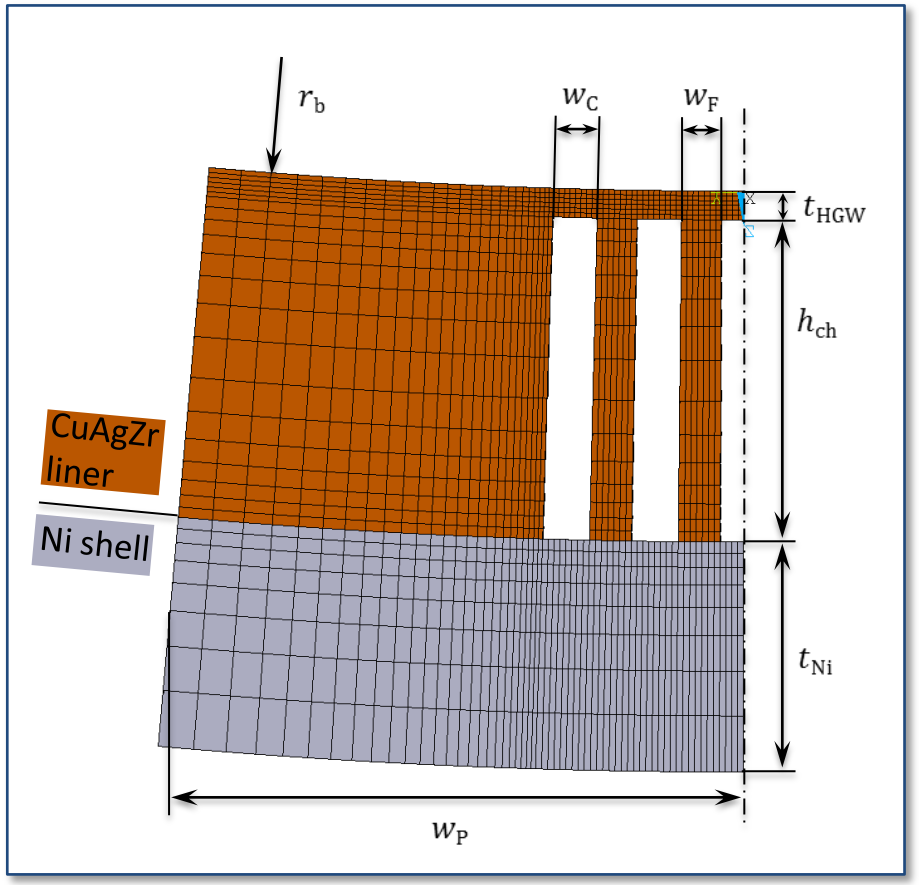


- Damage mechanism based on cumulated **compressive** deformation in the hot wall ligament

Model description

- Autonomous model generation based on 7 parameters
  - Panel width w_P
  - Channel width w_C
  - Fin width w_F
  - Ni thickness t_{Ni}
  - Channel height $h_{ch} = \text{const.}$
  - HGW thickness t_{HGW}
  - Bending radius r_b

- Simulation of transient thermal conditions
  - Max. temperature T_{max}



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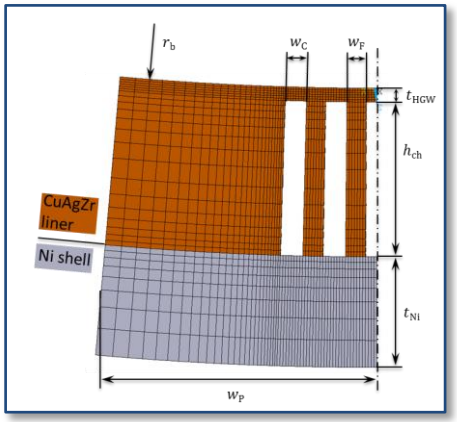

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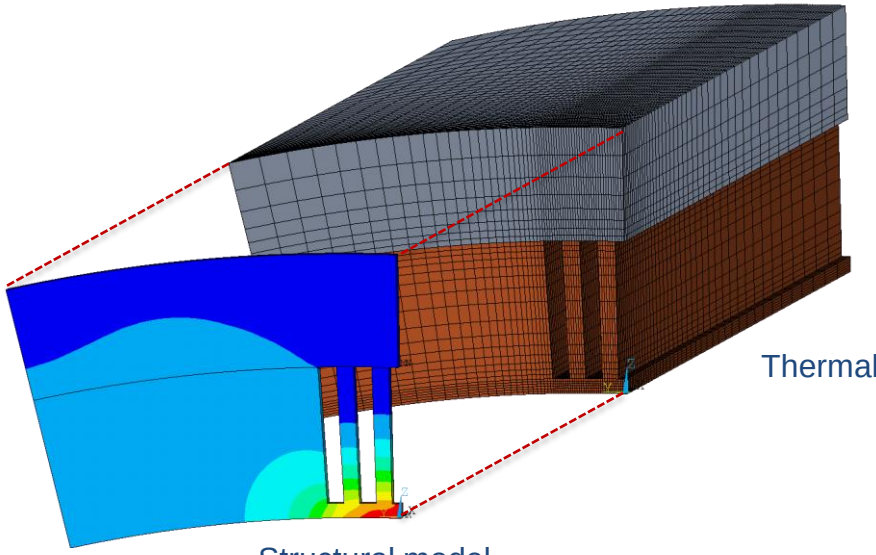
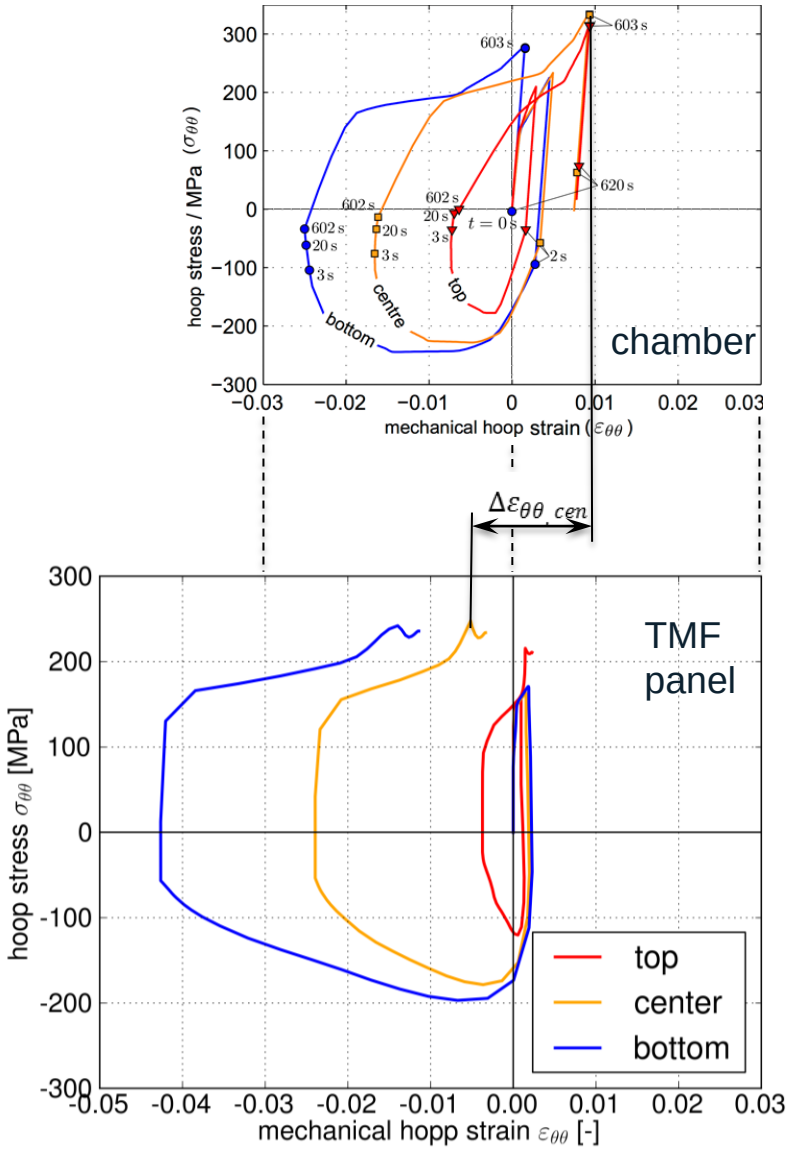


Thermal model

Structural model with thermal field

Preparation of sensitivity analysis

- Parameter variation +/- 20%
- Simulating 100 designs created by LHS (Latin Hypercube Sampling)
- Calculate strain error compared to chamber strains
  - $err = \sqrt{\frac{1}{3}\sum_{bottom}^{top}(\Delta\varepsilon_{\theta\theta})^2}$
  - Chamber strains (target values):
    - $\varepsilon_{\theta\theta,\,top} = 0.9\%$
    - $\varepsilon_{\theta\theta,\,center} = 0.9\%$
    - $\varepsilon_{\theta\theta,\,bottom} = 0.1\%$
- TMF panel – current situation:
  - $err = \left(\frac{1}{3}\begin{pmatrix}(-1.5\% - 0.9\%)^2 + \\ +(-0.5\% - 0.9\%)^2 + \\ +(0.1\% - 0.9\%)^2\end{pmatrix}\right)^{1/2} = 1.67$
- Optimization objective: error minimization

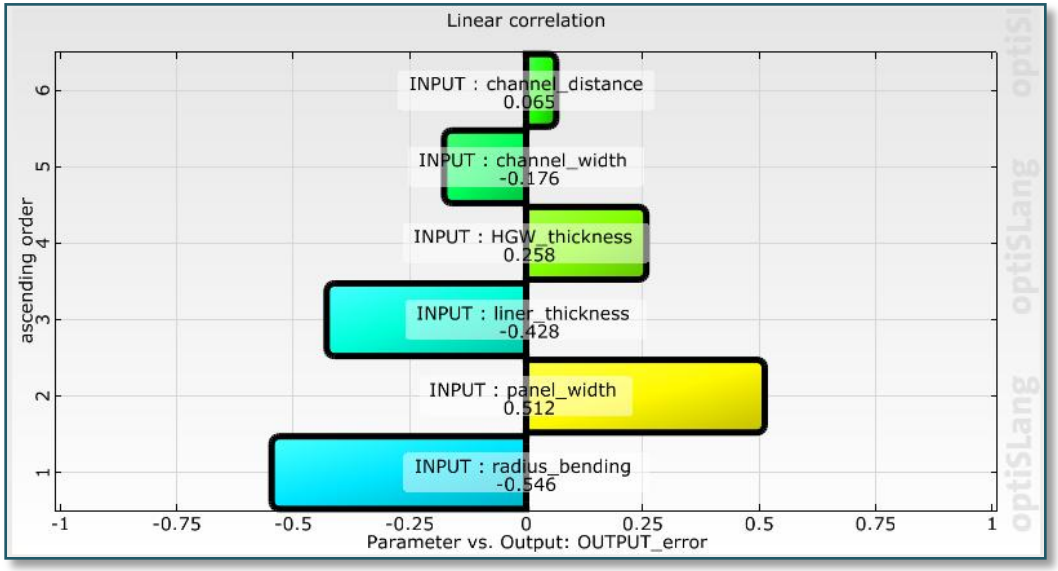


3 Sensitivities and best design

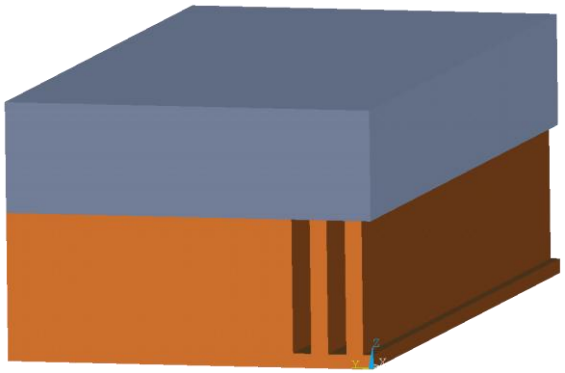
Sensitivity analysis - results

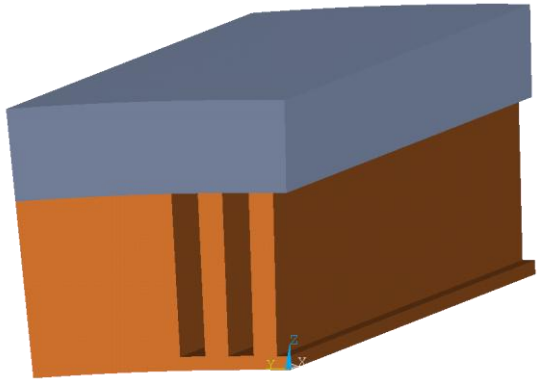
- Parameter variation +/- 20%
- Simulating 100 designs created by LHS (Latin Hypercube Sampling)
- Calculate strain error compared to chamber strains: $err = \sqrt{\frac{1}{3}\sum_{bottom}^{top}(\Delta\varepsilon_{\theta\theta})^2}$
- Sensitivities based on deviation from chamber strains

  - Bending radius ≈ 160 mm shows minimal error
  - Smaller panel width reduces error
  - Higher Ni thickness reduces error

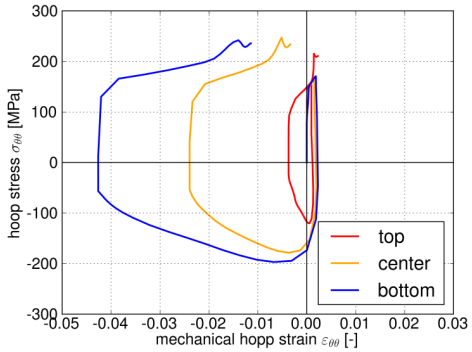


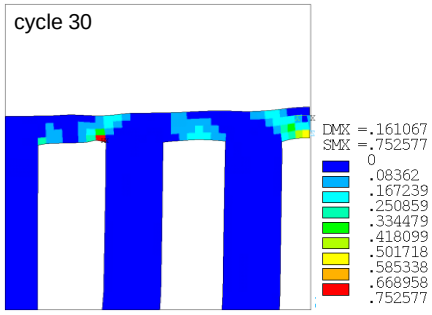
Panel Design evolution – optimization results





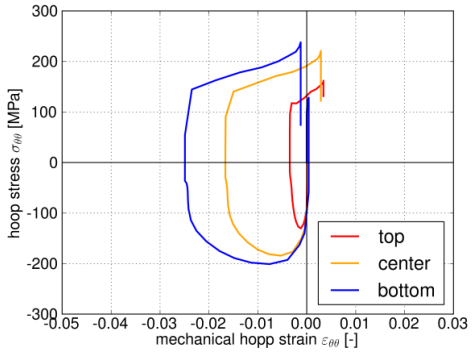
Initial Panel Design

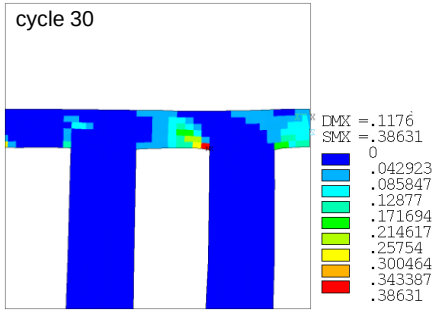




- Compressive damage accumulation in mid channel
- Max. damage on edge of side channel

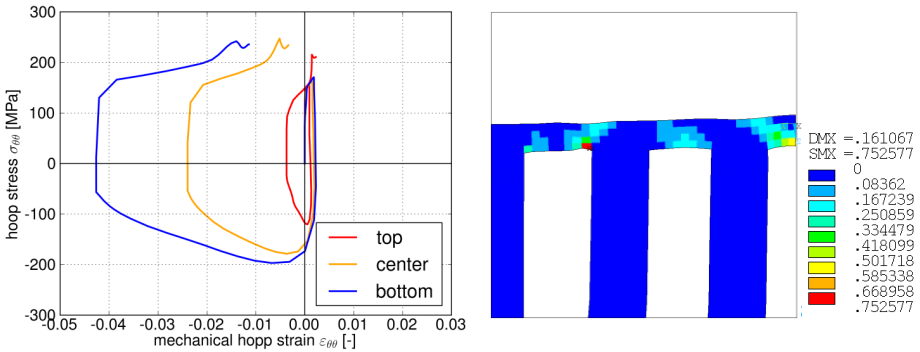
Optimized Panel





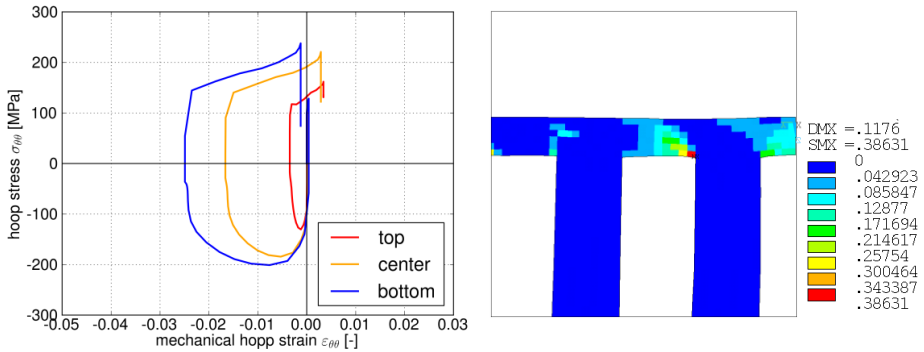
- Tensile damage accumulation in central ligament
- Max. damage still occurs on side channel edge

Initial Panel Design



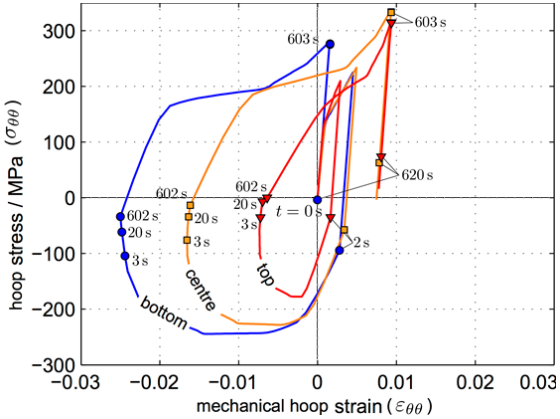
- Compressive damage accumulation
- Max. damage on edge of side channel

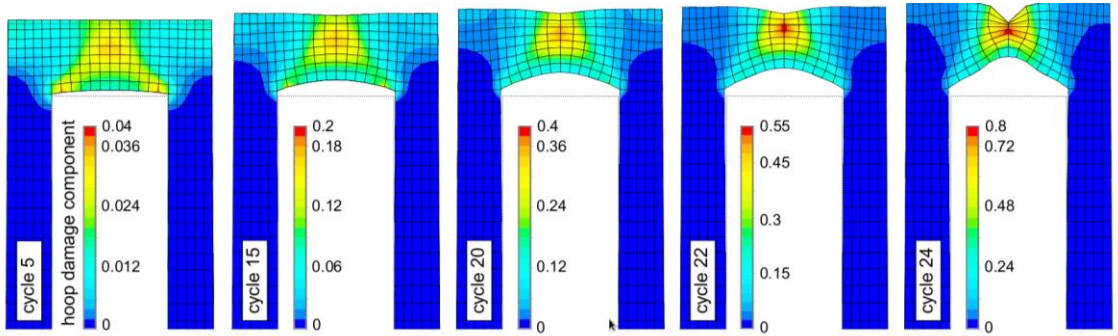
Optimized Panel



- Tensile damage accumulation
- Max. damage still occurs on side channel edge

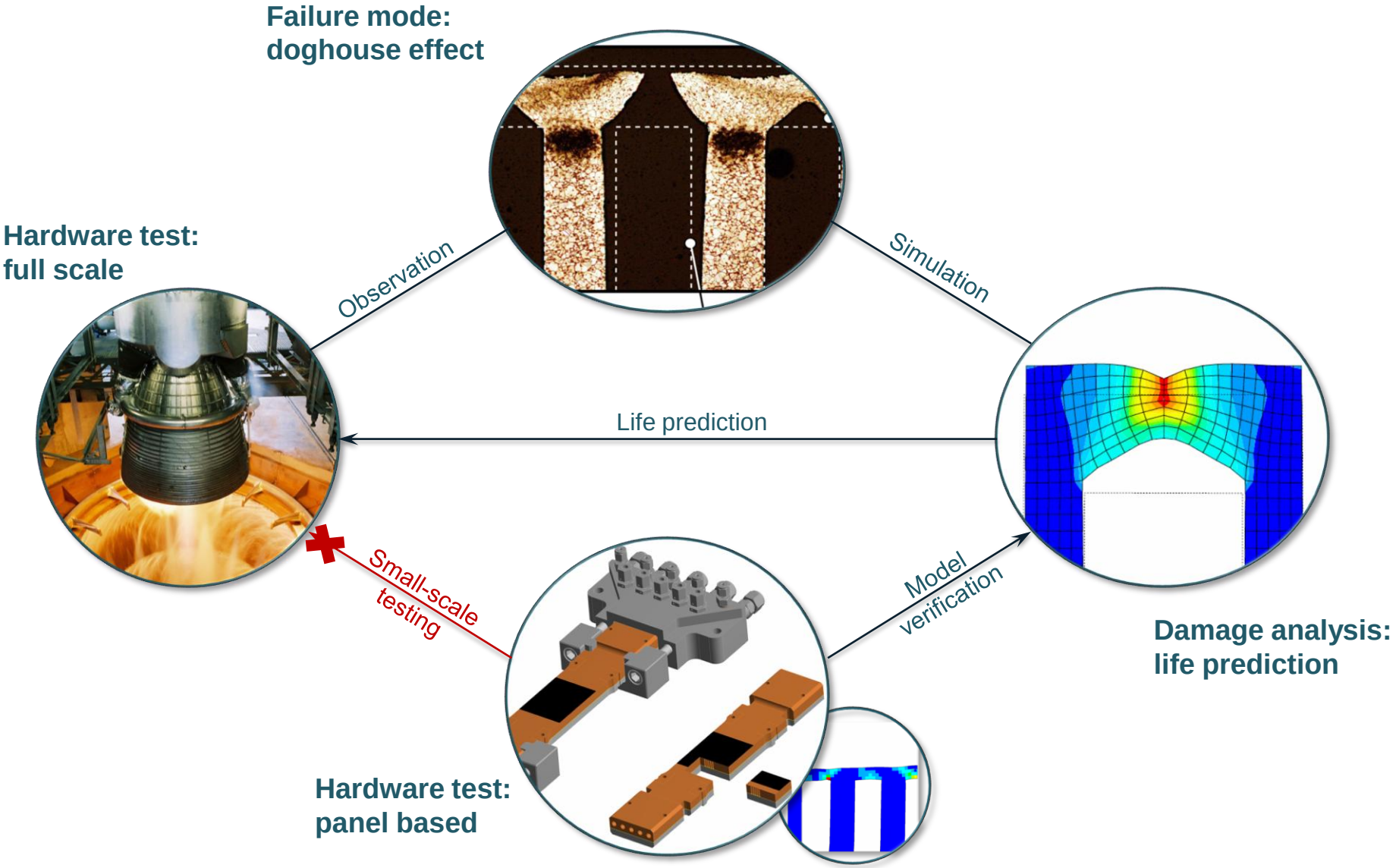
Chamber – reference





4 Summary

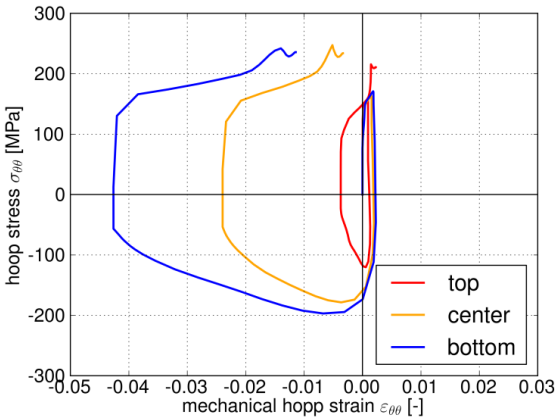
4 / Summary



Enhancement of the panels deformation behavior

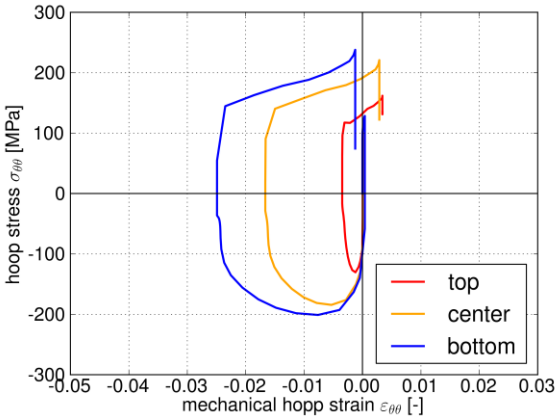
Initial TMF Panel

Damage accumulation under compressive deformation

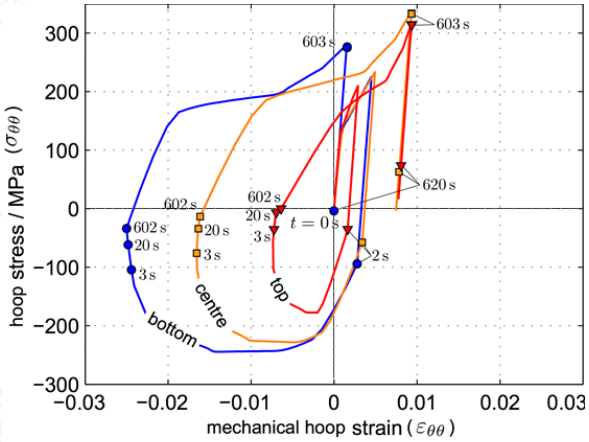


Optimized Panel

Damage accumulation under tensile deformation



Chamber behavior



4 / Summary