AMADE day

Testing and simulation of a composite-aluminium wingbox assembly subjected to thermal loading

Josep Costa

José Manuel Guerrero García

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Jordi Llobet

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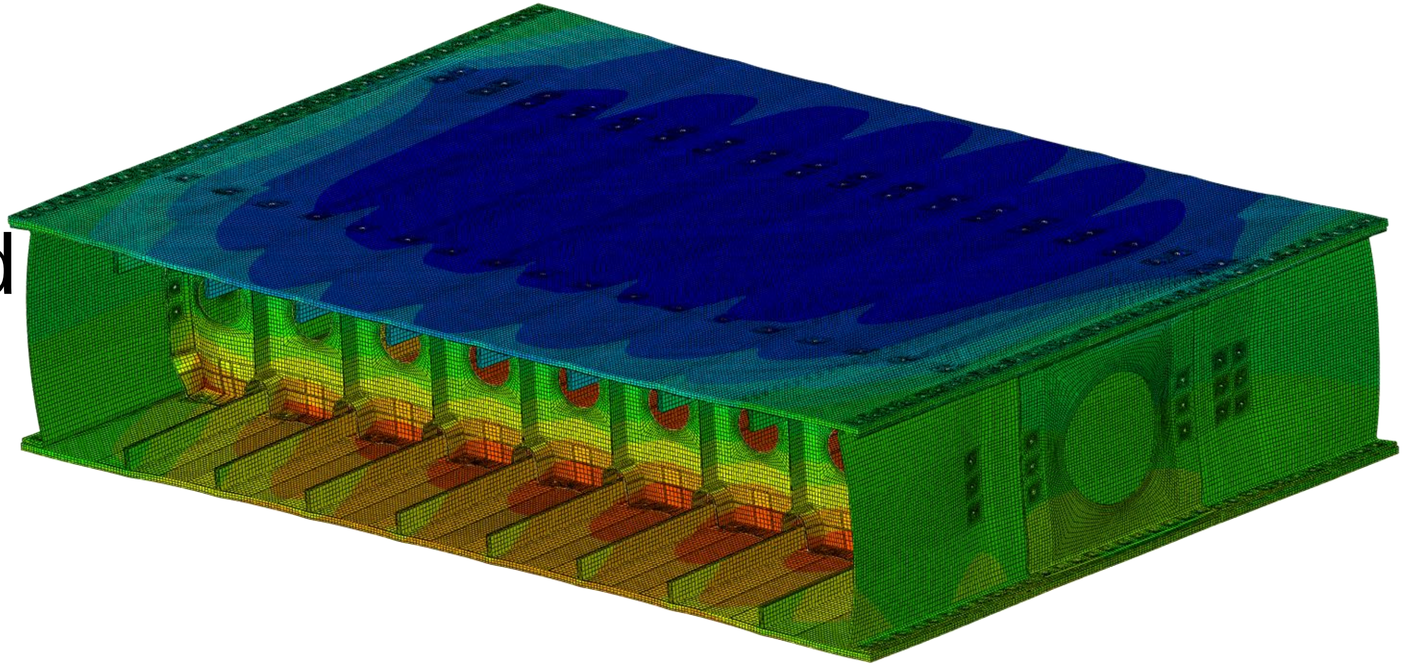

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INNOHYBOX

H2020 Clean Sky 2 Project

Ref: 785433)

AMADE day

Girona, 16th July 2021

Universitat de Girona

AMADE
ANALYSIS AND ADVANCED MATERIALS FOR STRUCTURAL DESIGN

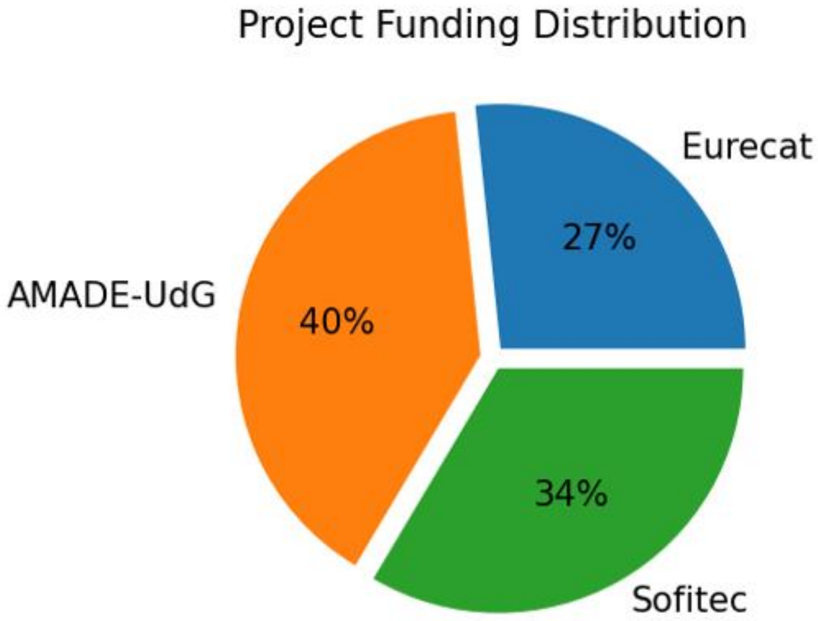
Contents

Introduction

Project consortium

- Project INNOHYBOX - Innovative solutions for metallic ribs or fittings introduced in a composite box to optimally deal with thermo-mechanical effects
- H2020 Clean Sky 2 Project (Call H2020-CS2-CFP06-2017-01, reference 785433)

- **Topic Manager** — Dassault Aviation — Benoit Morlet
- **Project Leader** — eurecat, Centre Tecnològic de Catalunya — Angel Lagraña
- **Partners** — AMADE, Analysis and Advanced Materials for Structural Design, UdG — Dr. Josep Costa
- sofitec — José Manuel Llamas



Project participants: AMADE

- **Main reasercher:** Dr. Josep Costa

- **Post Docs**

Dr. José Manuel

Dr. Aravind Sasikumar

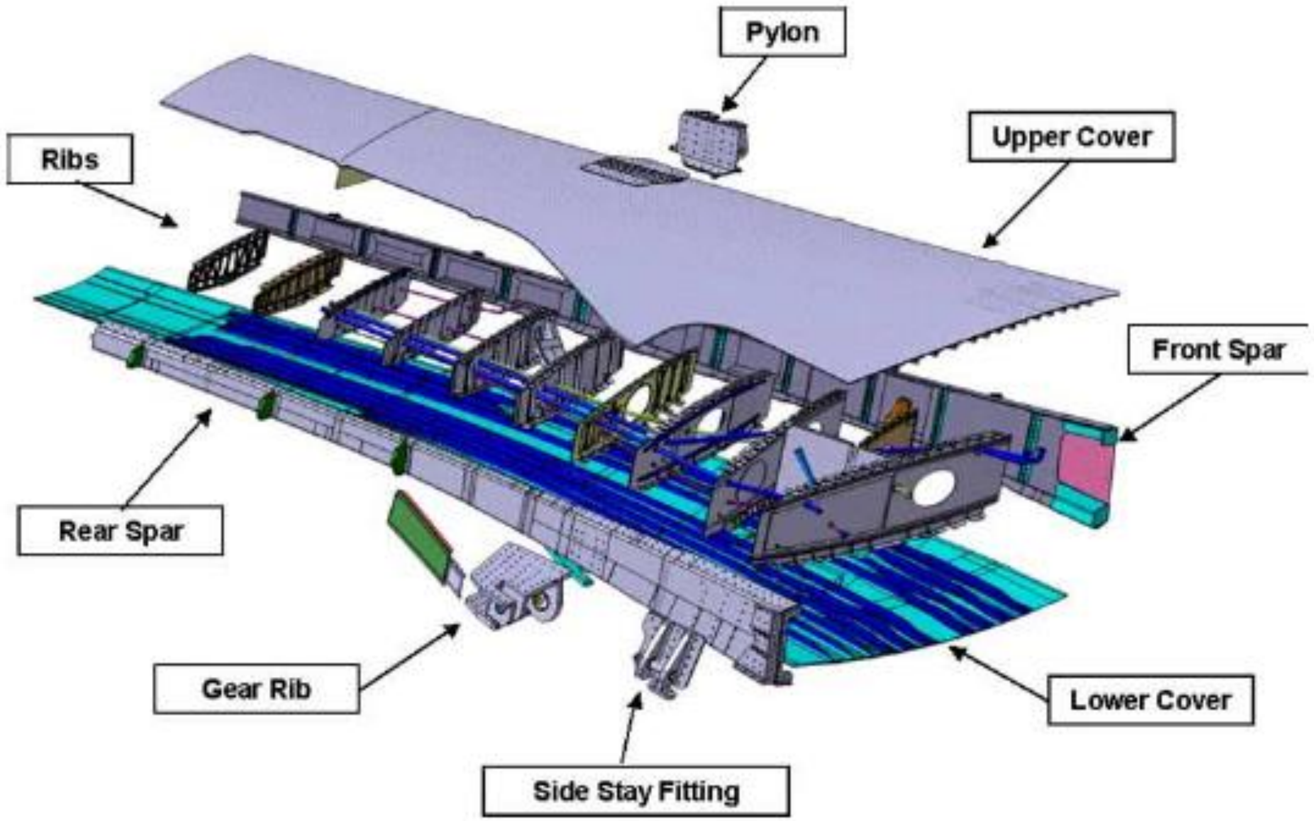
Dr. Jordi Llobet

- **Master Students:** Marc Martinez, Carlos Samaniego Arguello
- **AMADE lab team**

Background

- CFRP laminates increasingly used in the aeronautical industry while metallic parts are also maintained → **hybrid assemblies**
- Due to their high strength and ease to disassemble, these hybrid assemblies are usually **bolted**

Wing of an aircraft



Background

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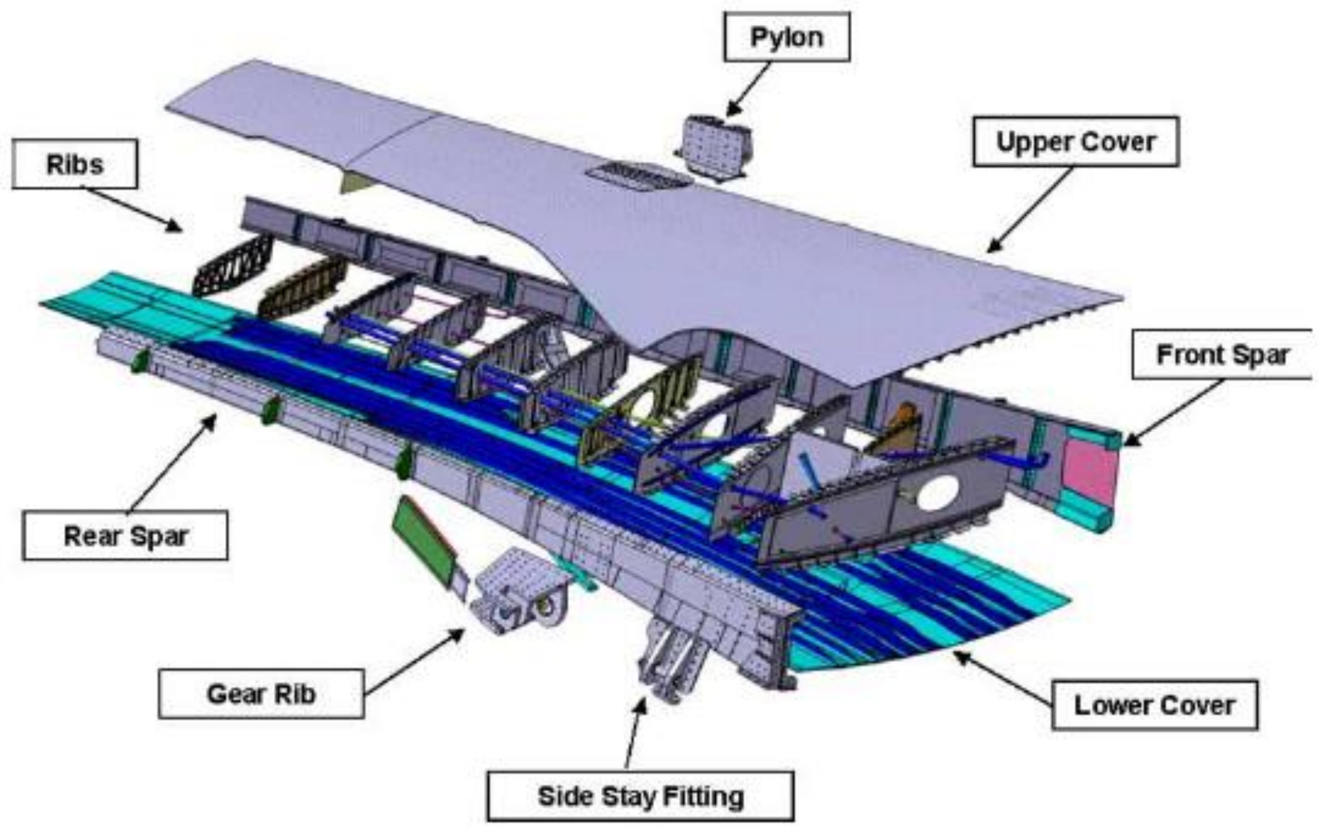
- Due to their high strength and ease to disassemble, these hybrid assemblies are usually **bolted**

- During aircraft operation, **high thermal jumps** occur (temperature difference between a landed plane and one flying can reach 140 ºC) → high thermal stresses

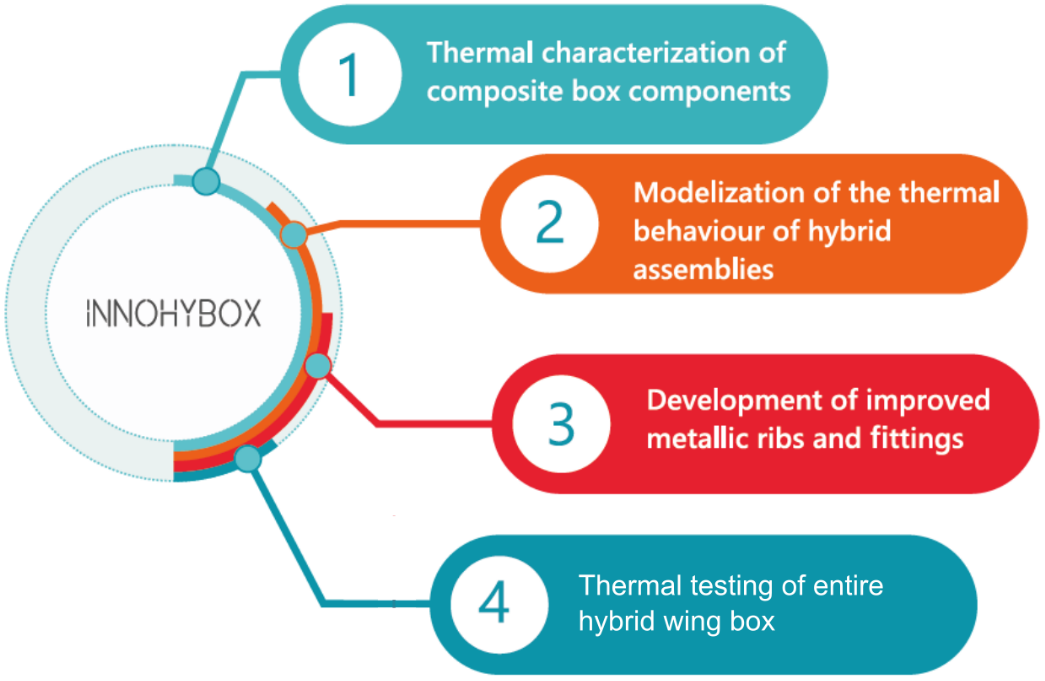
- Hybrid bolted joints → materials of the joint expand or contract differently leading to **thermal stresses and alterations of the bolted joint response**

Wing of an aircraft

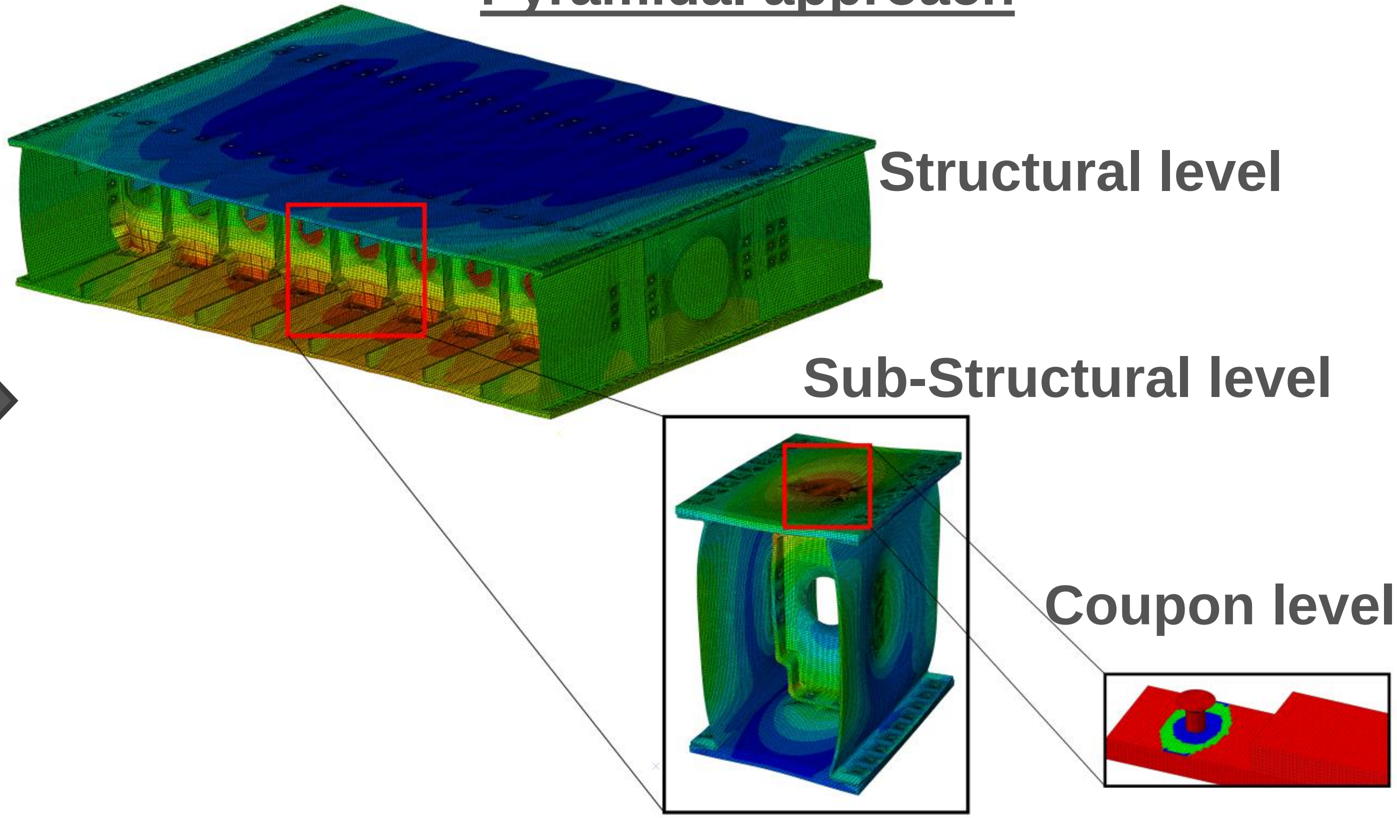


Project objective

Objectives



Pyramidal approach



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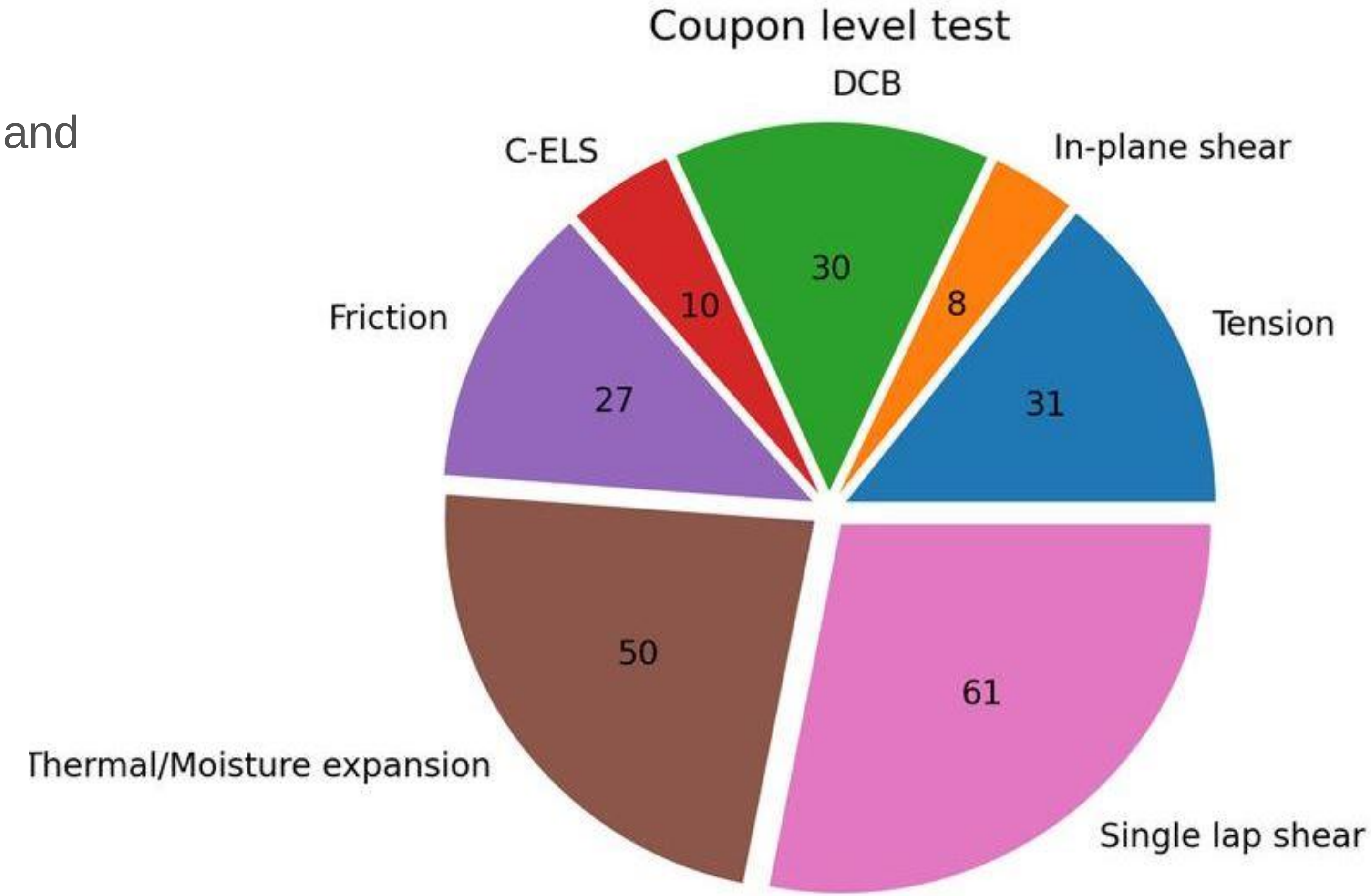
Coupon level

Project objective

Coupon level

- Many tests were done to characterize and understand hybrid bolted joints:
  - Friction tests
  - C-ELS
  - DCB
  - In-plane shear
  - Tension
  - Single-lap shear
  - Thermal/Moisture expansion



Coupon level

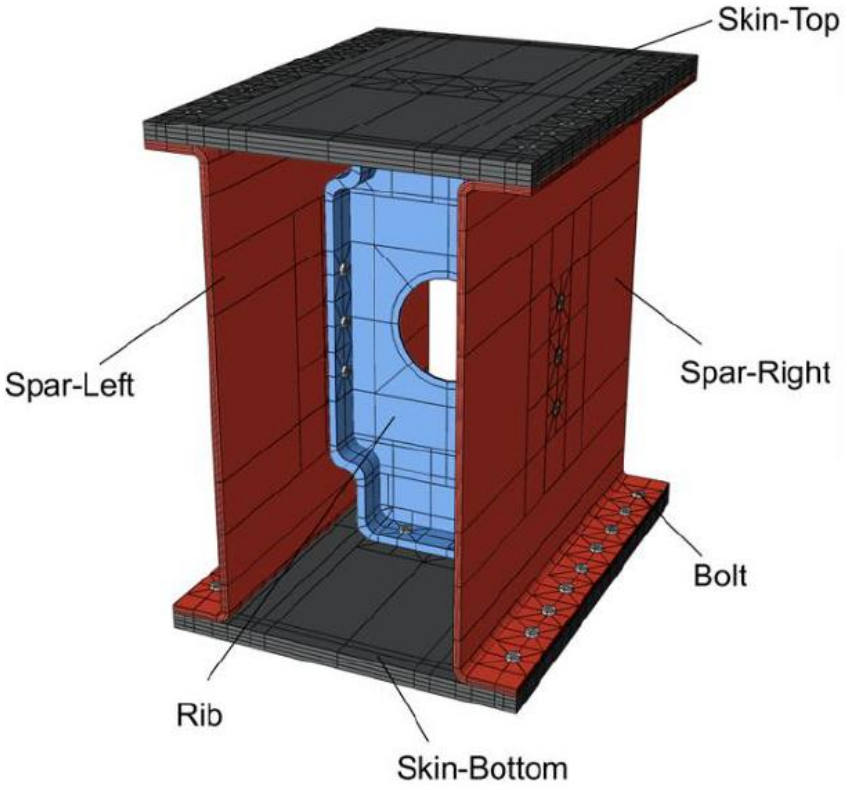
Testing at cryogenic and high temperatures

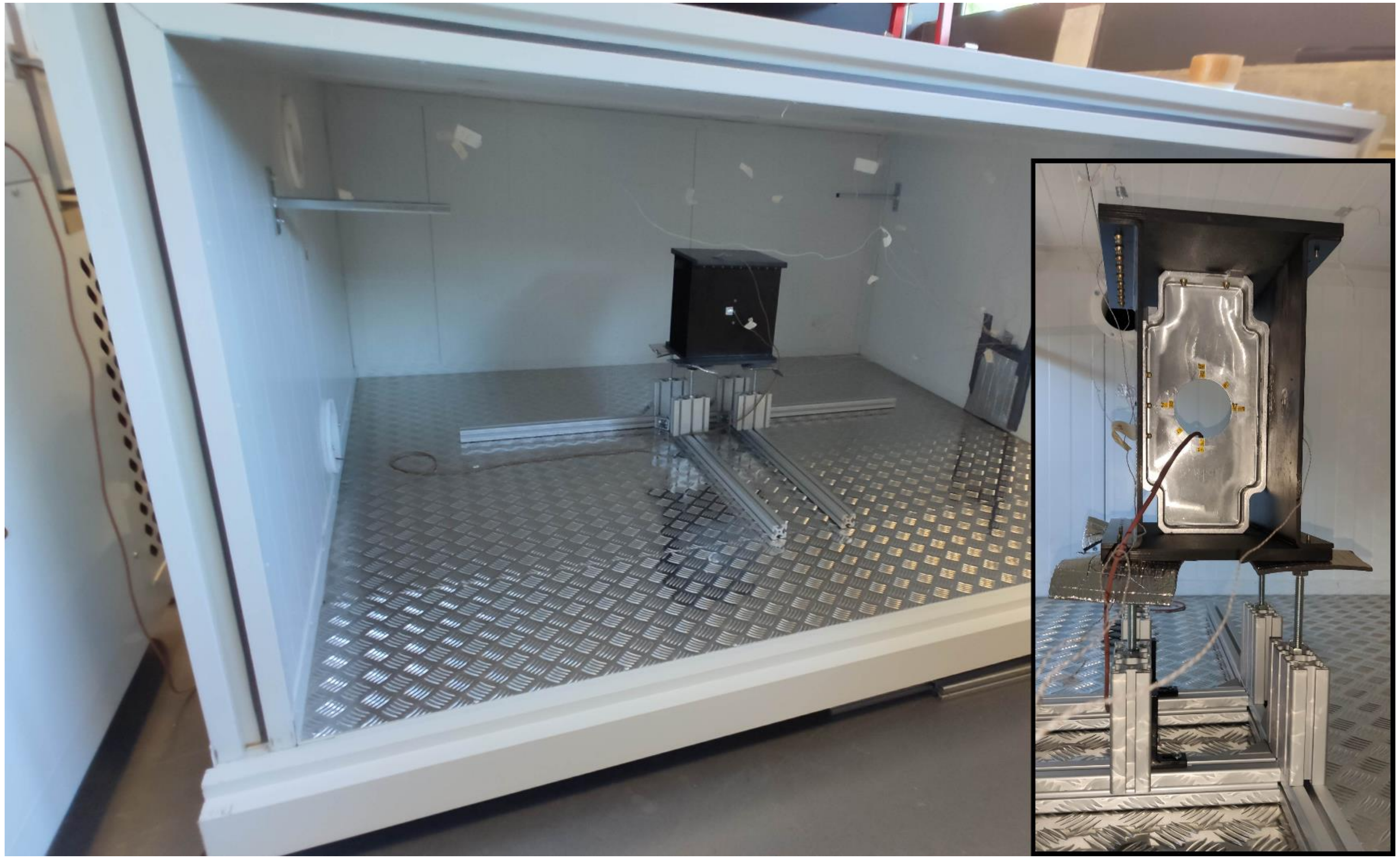
- Friction between dissimilar joints
- Interlaminar fracture toughness
- Single-lap shear joint

Subcomponent

Subcomponent experimental test

- Small representative **part of the wingbox**
- Instrumented with **strain gauges**
- **Negative and positive thermal test conducted**
- Compared with numerical model

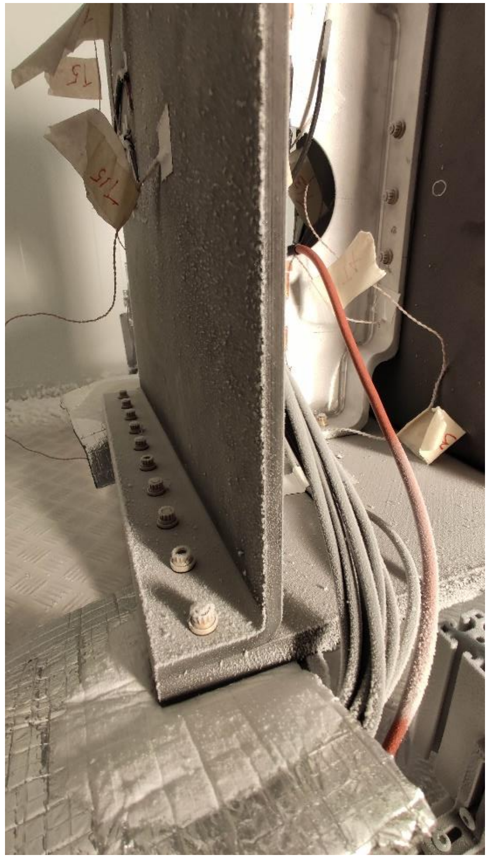
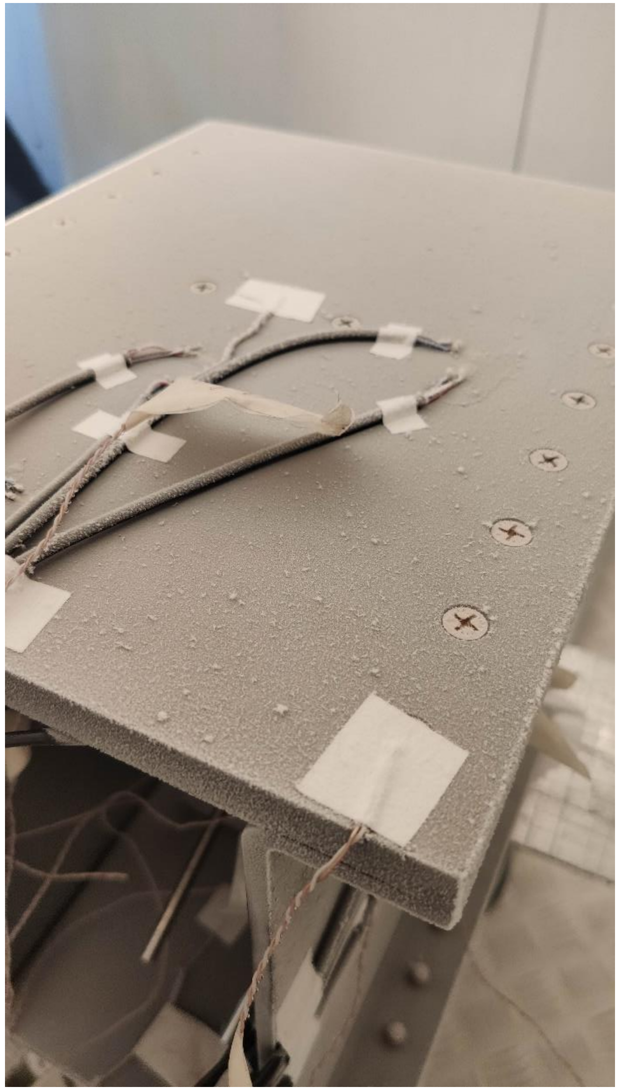




Subcomponent experimental test

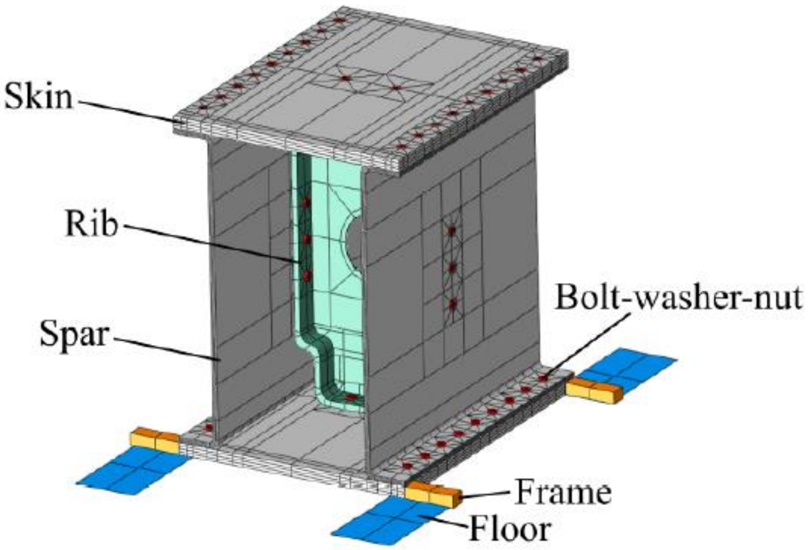
Pictures at end of test (-40 ºC)

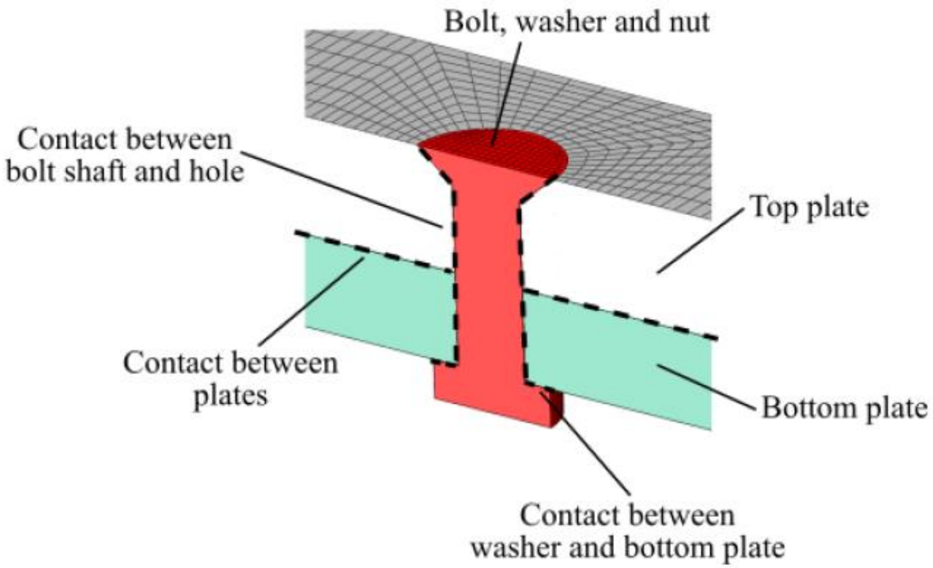


Subcomponent numerical model

3D solids





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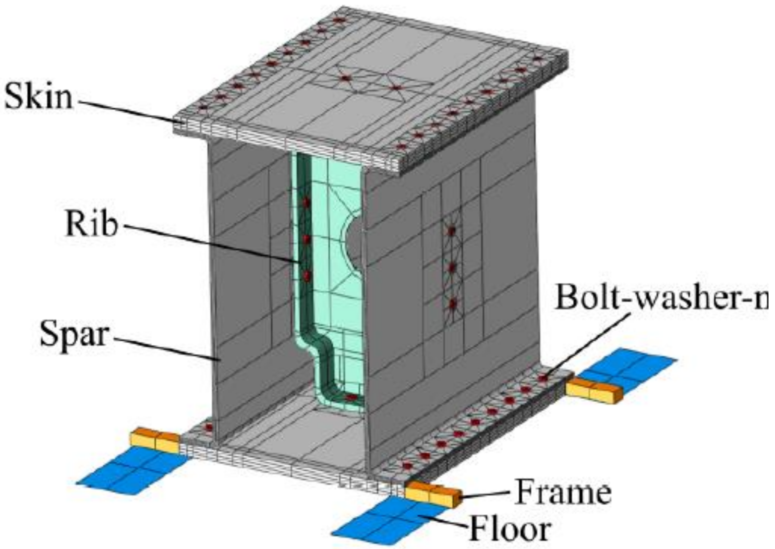
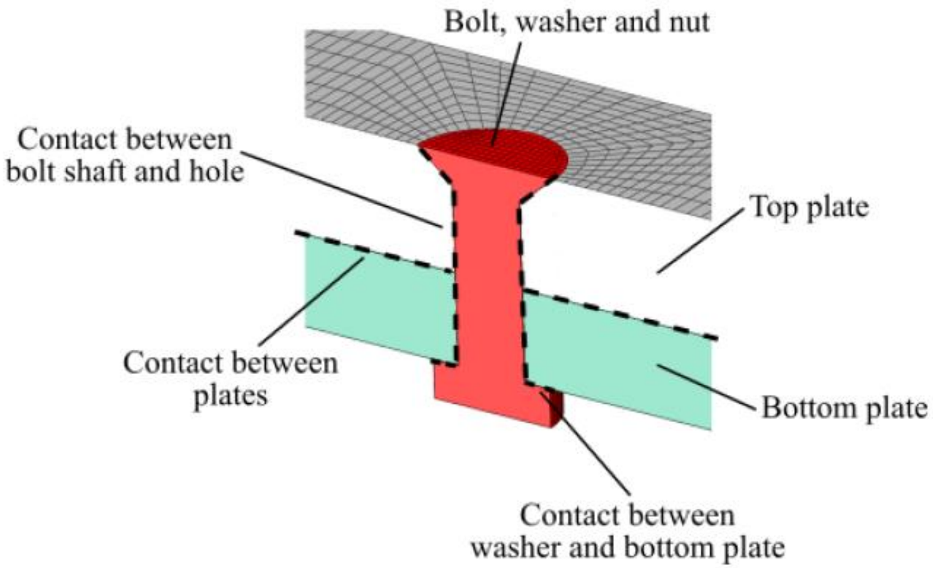
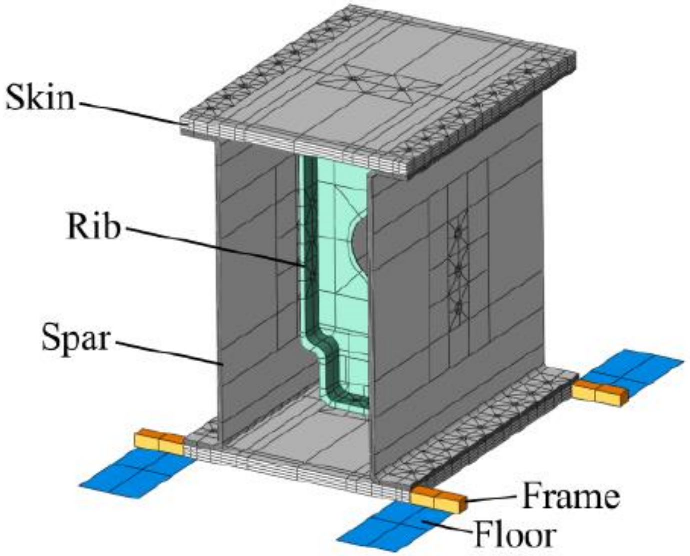
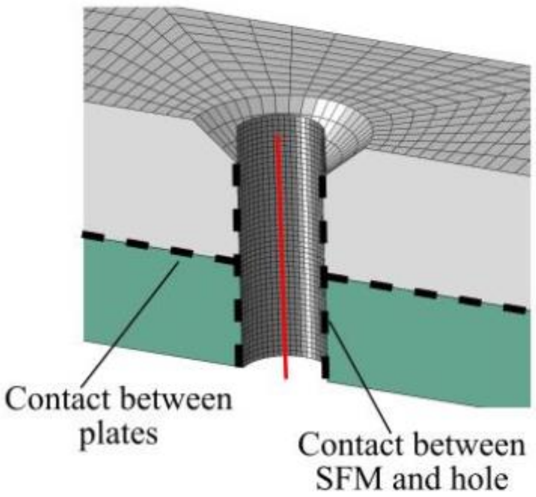




Continuum Shell





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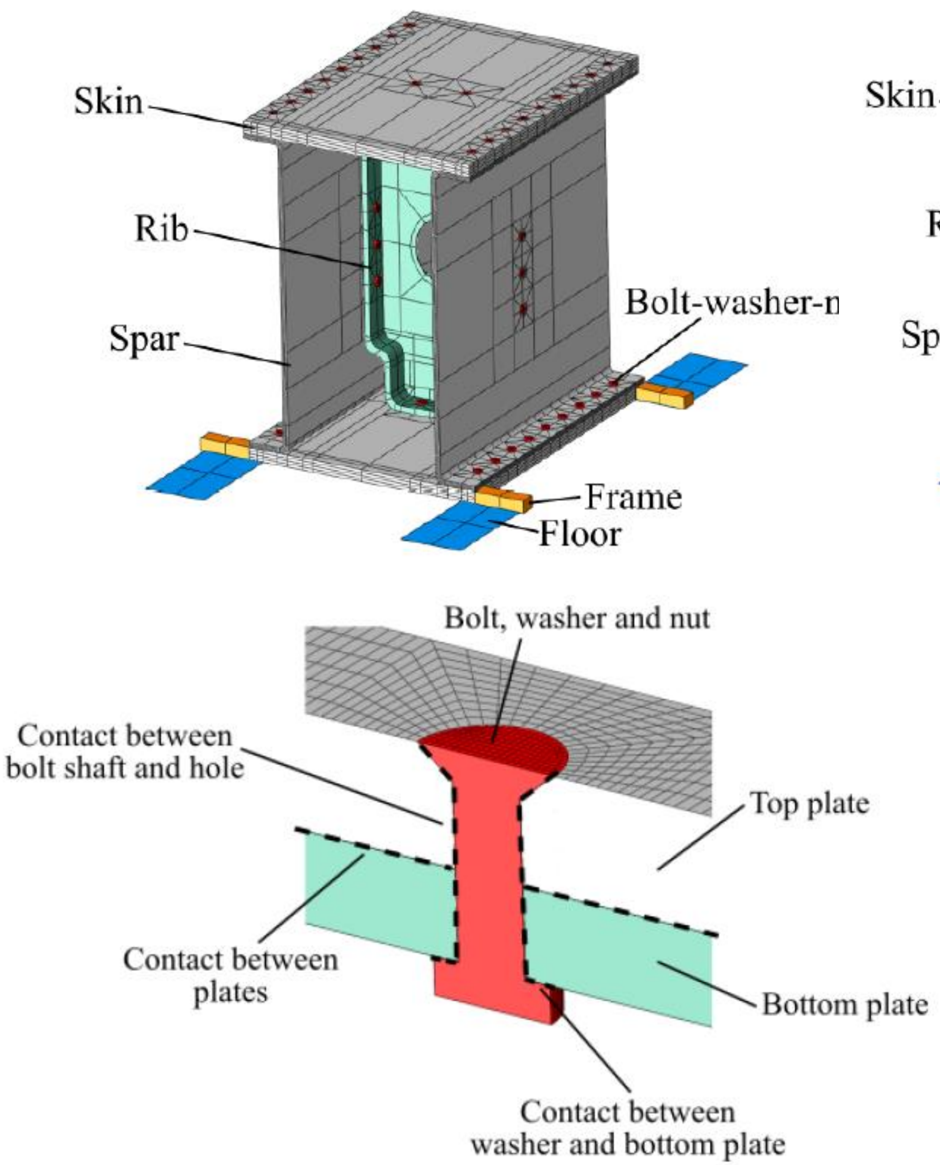
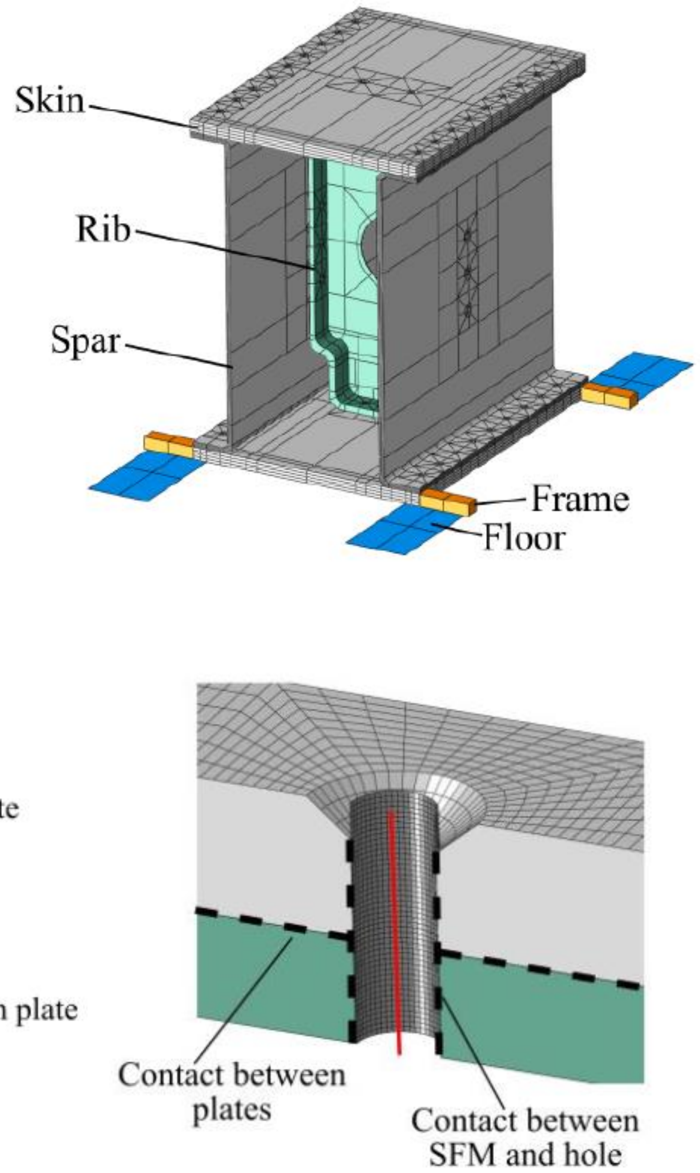
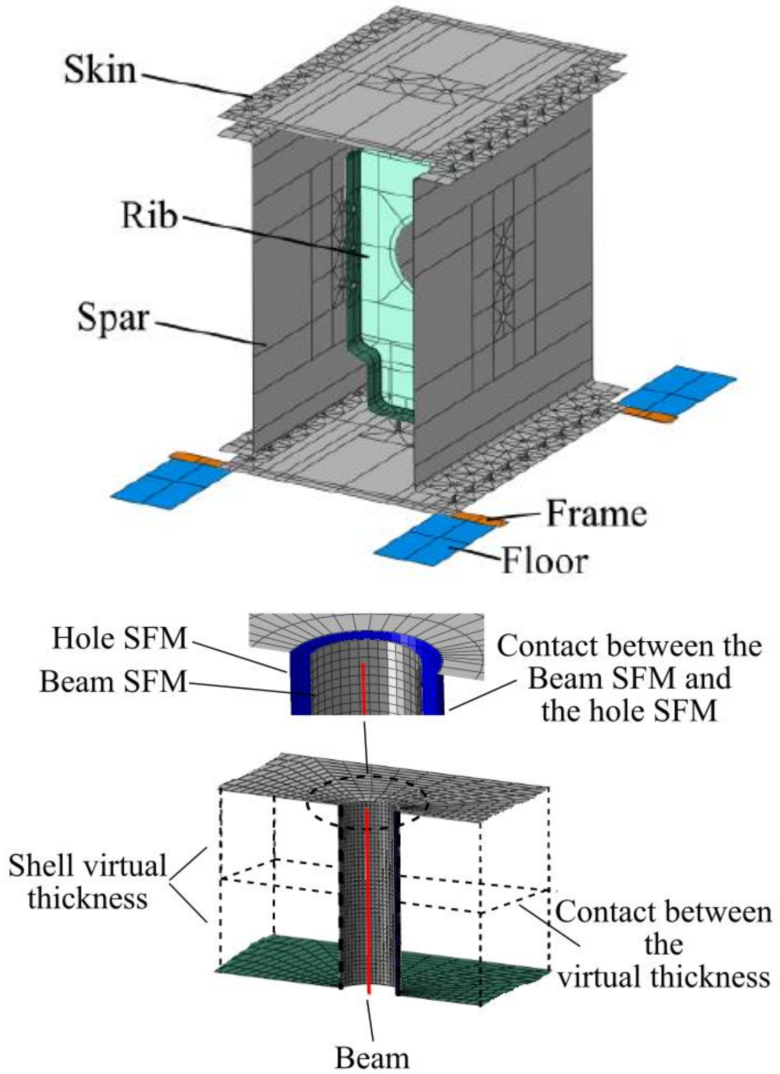


Continuum Shell



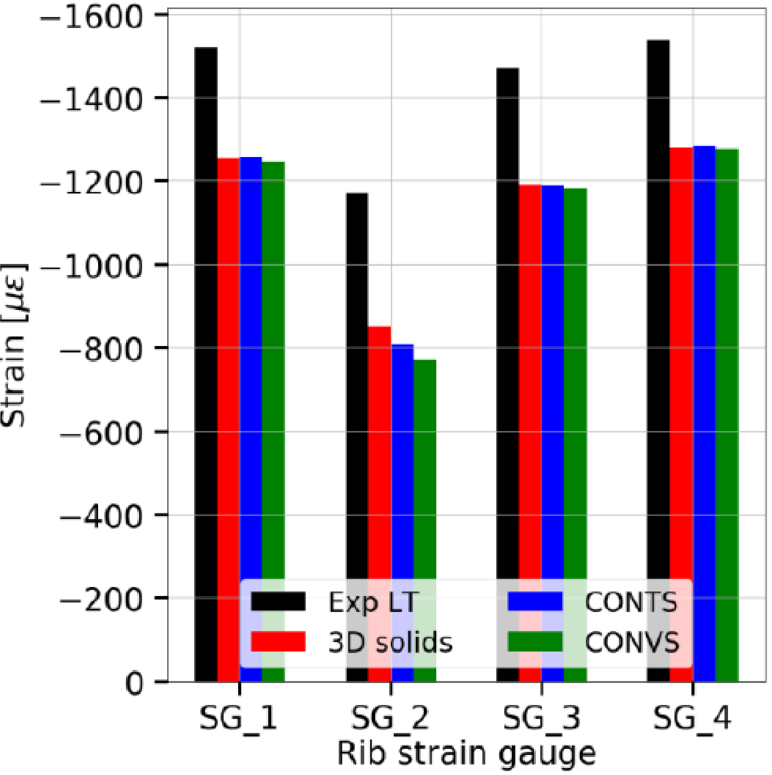
Conventional Shell



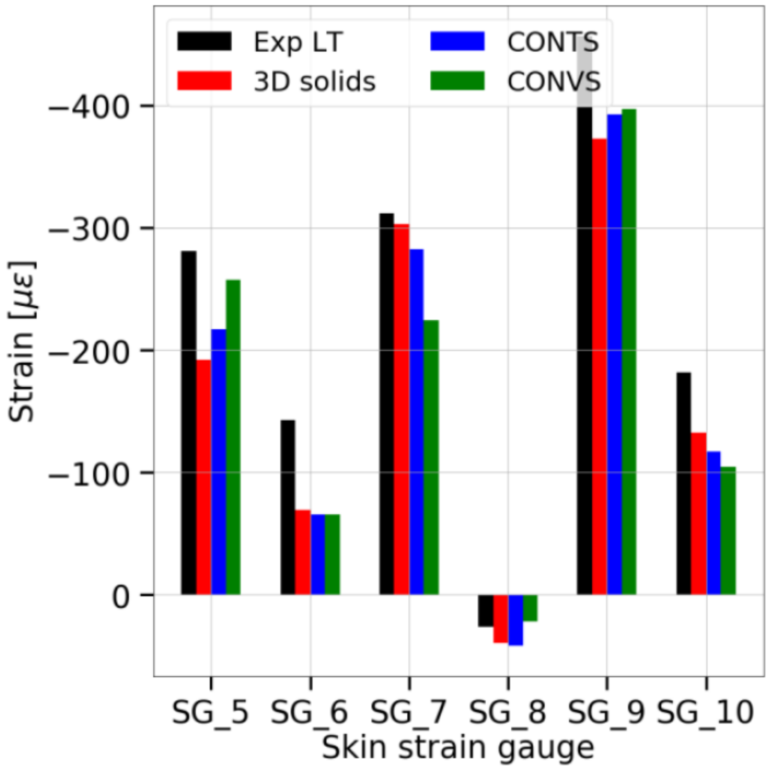
Subcomponent numerical vs experiment

- Compared at the end of the test (-40 ºC)
- Good agreement in all the strain gauges in all parts (rib, skin and spar)

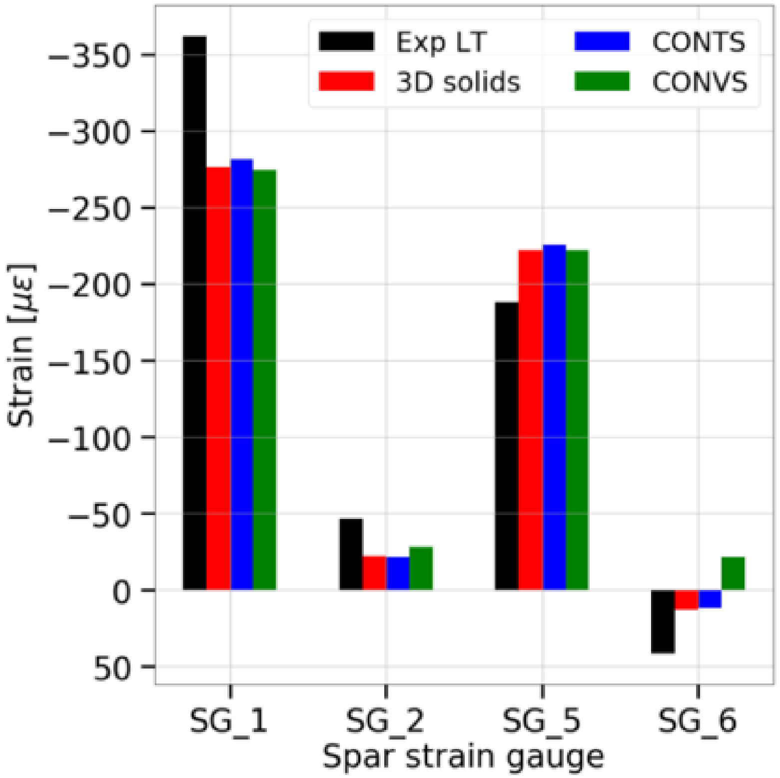
Rib



Skin

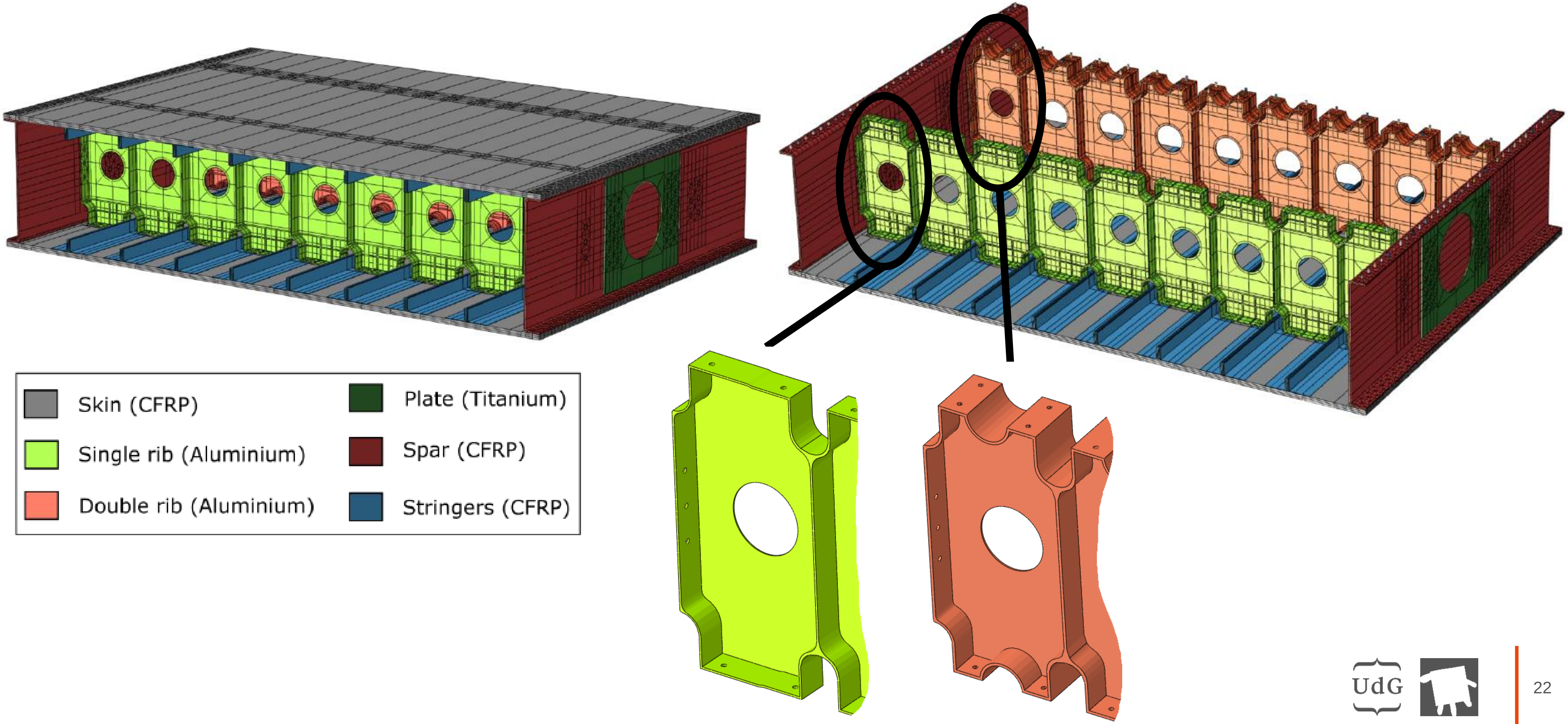


Spar



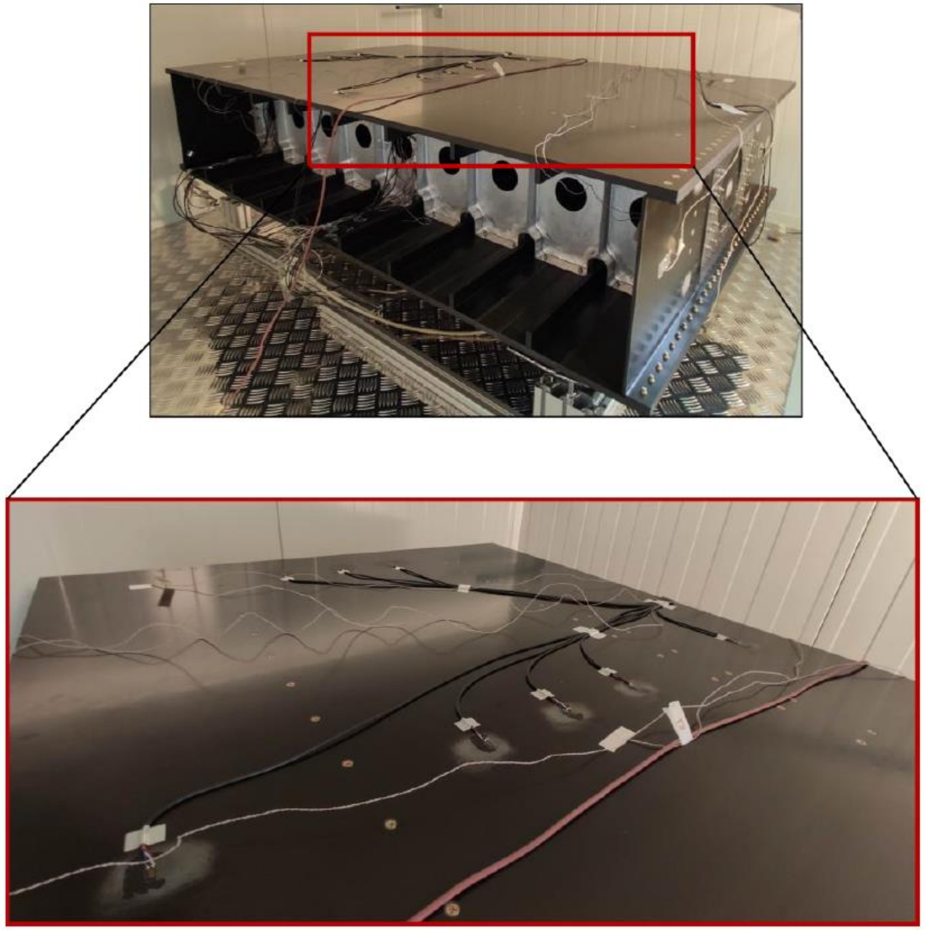
Wingbox results

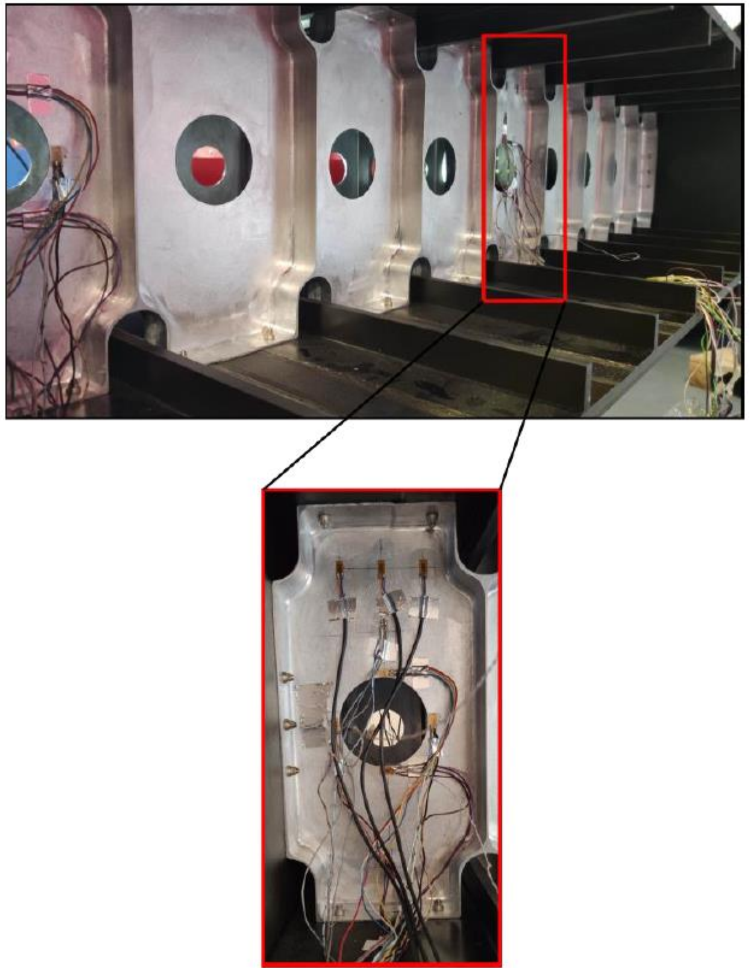
Wingbox assembly



Experimental testing: instrumentation

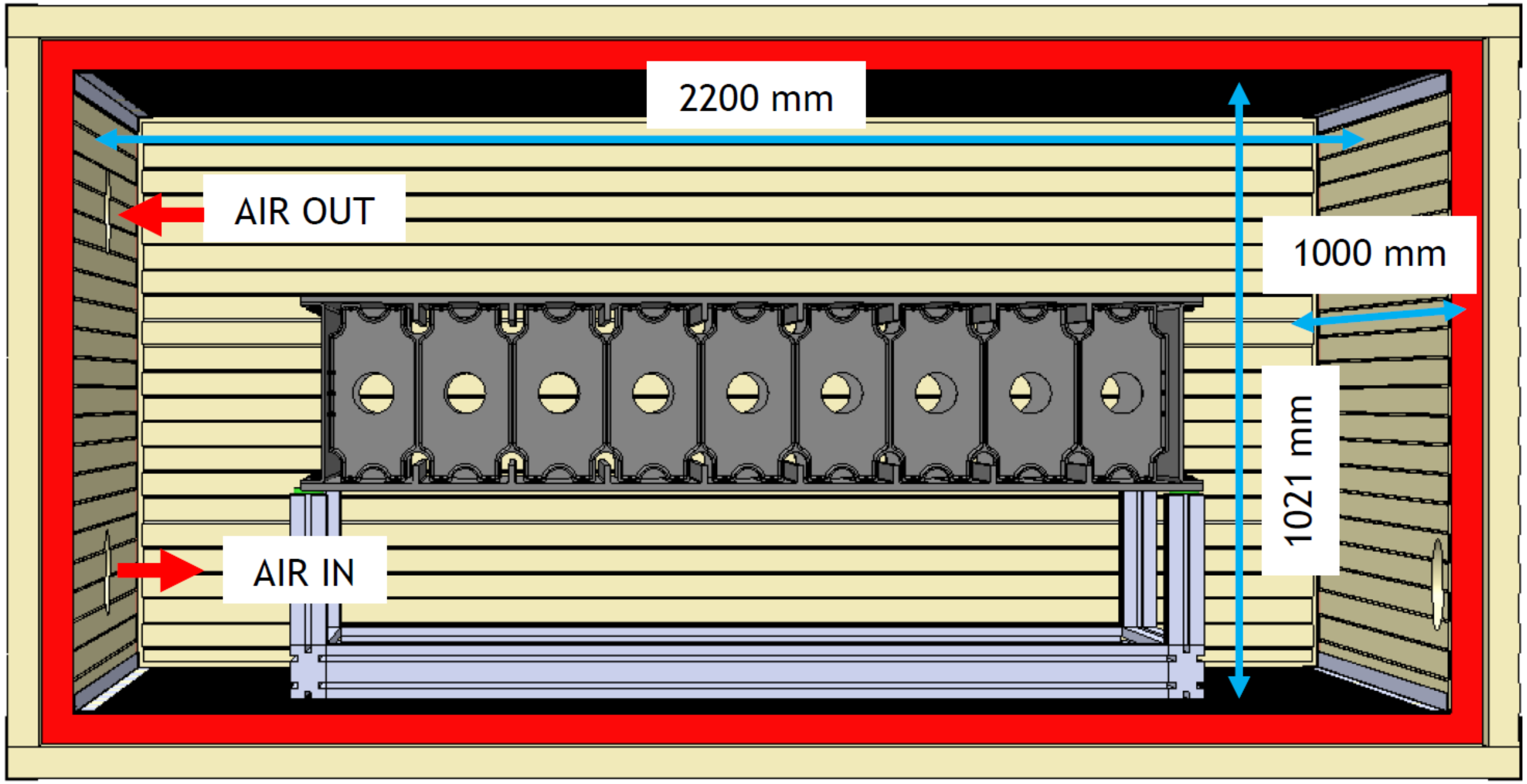
- 64 strain gauges placed at different locations
- Type of strain gauge selected according to the part material
- 16 thermocouples placed at different wingbox locations to track the global thermal field





Experimental testing: thermal chamber

- Big thermal chamber designed to accommodate wingbox
- Sandwich panels of 100 mm made of rock wool and steel

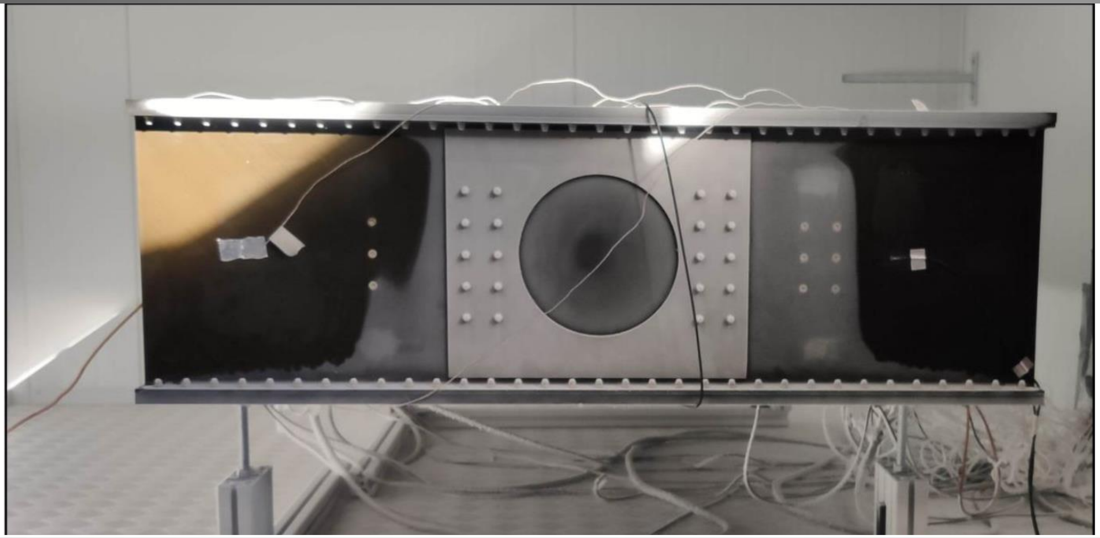


Experimental testing: thermal chamber

- Pictures of real testing chamber and wingbox inside

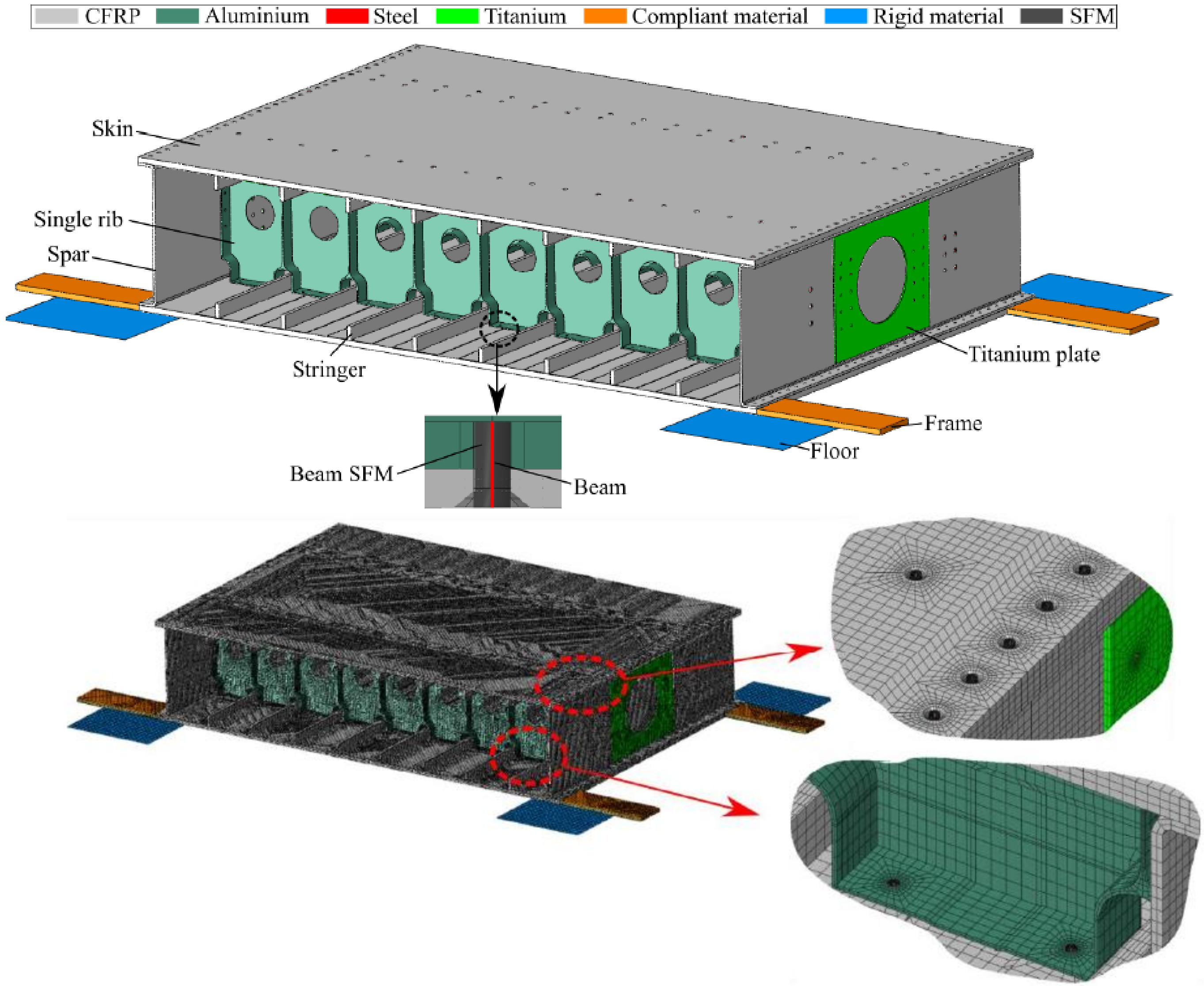
Experimental testing: thermal chamber

- Negative and positive thermal test were done
- Tests were 8 hours long and uniform temperature was achieved



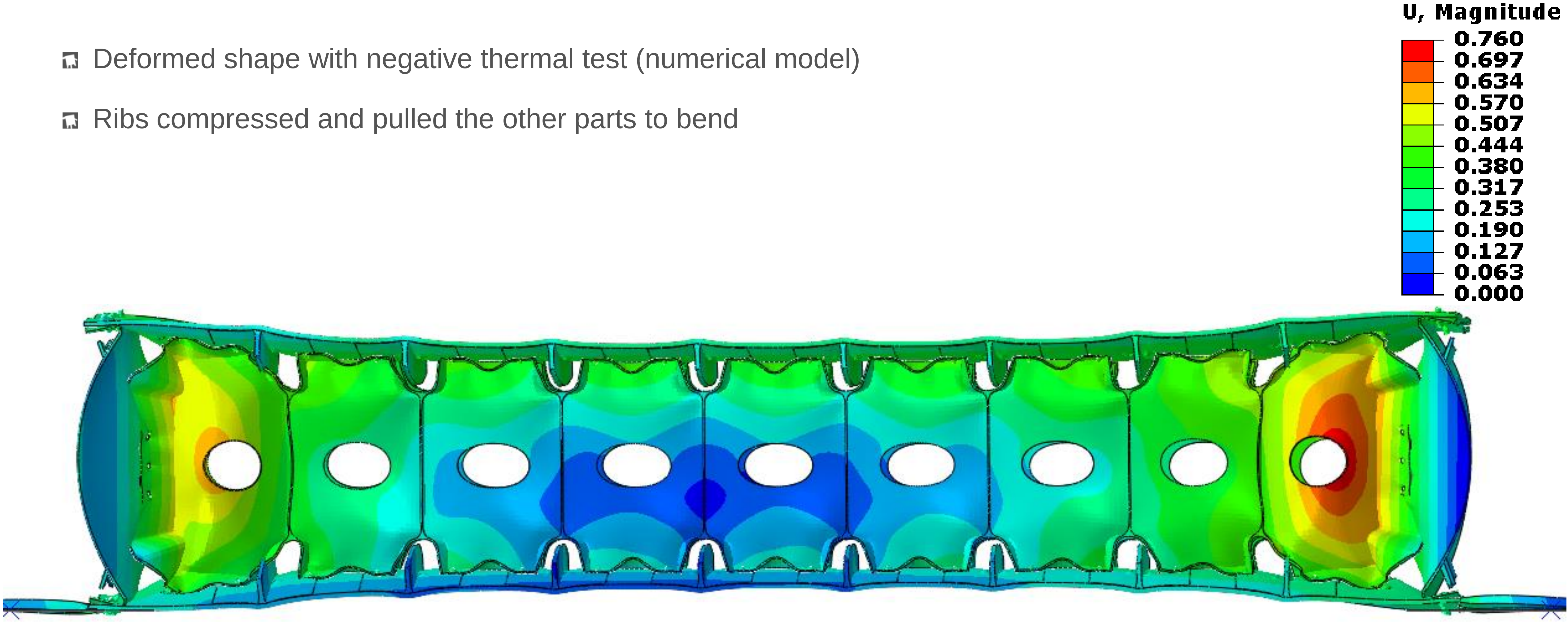
Wingbox finite element model

- Parts as continuum shells
- Bolts as beam + SFM (more than 200)
- Contact with friction
- Fully automated using Python
- 1.2 million elements
- 7-9 hours of simulation time

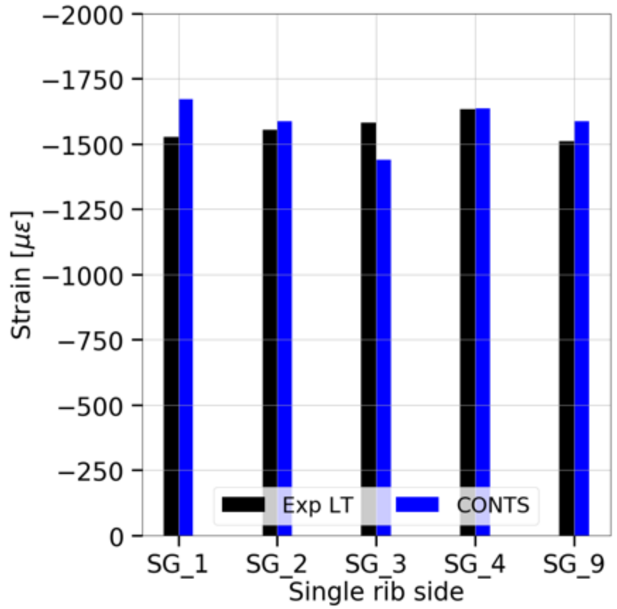


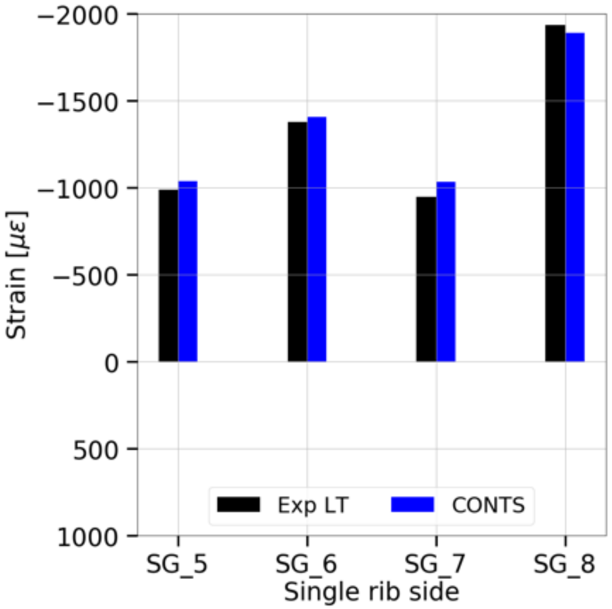
Global deformation

- Deformed shape with negative thermal test (numerical model)
- Ribs compressed and pulled the other parts to bend

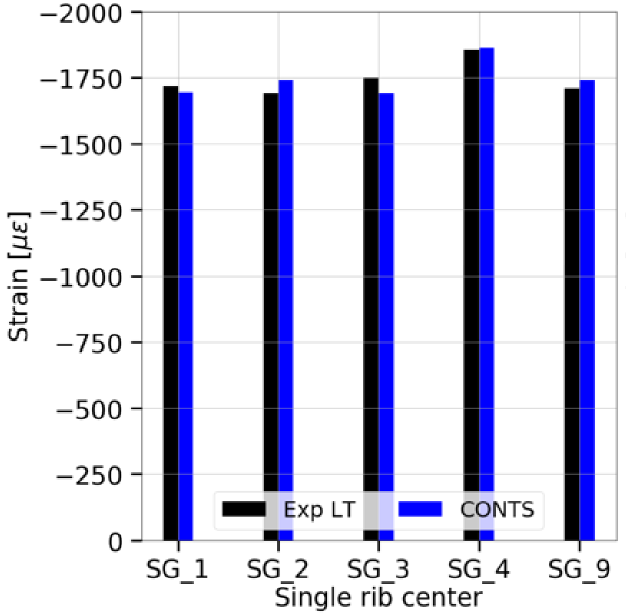


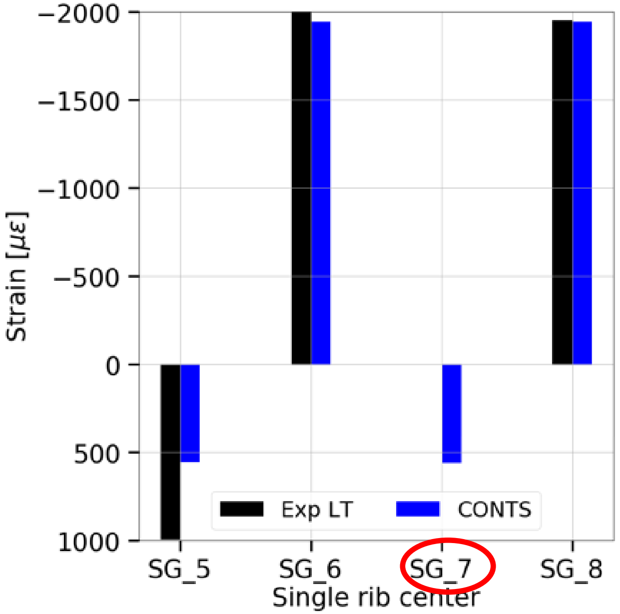
Single rib



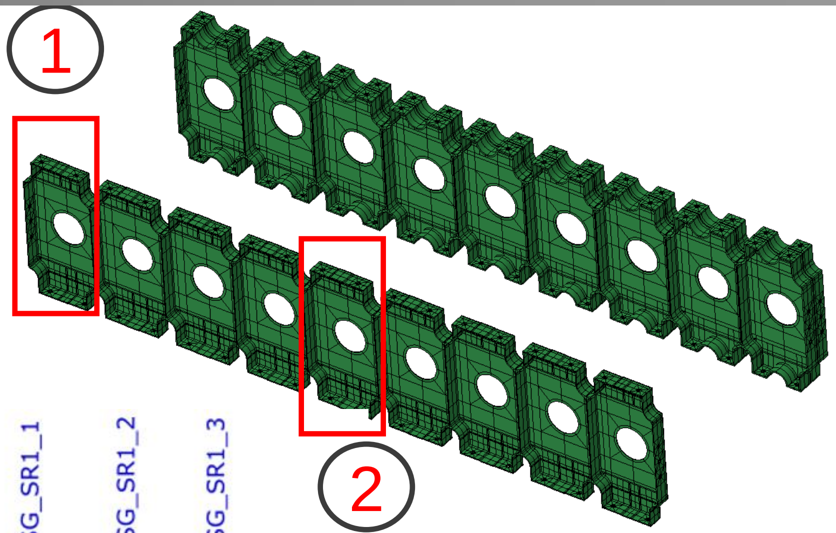


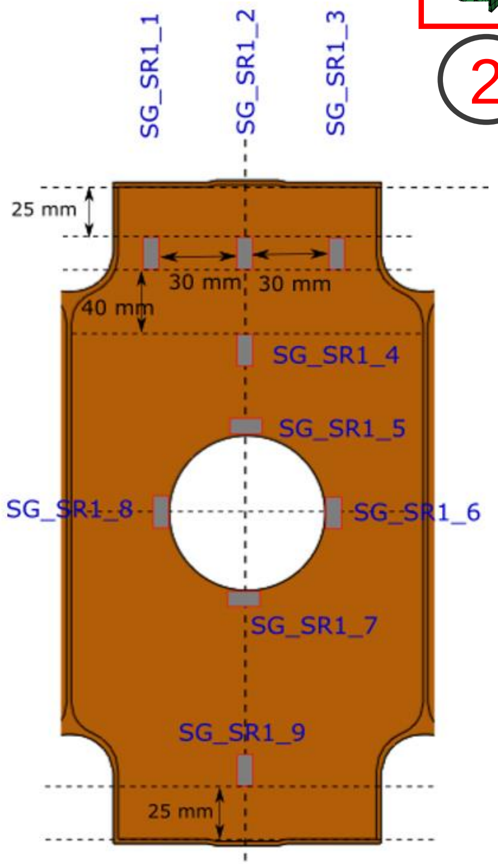
1



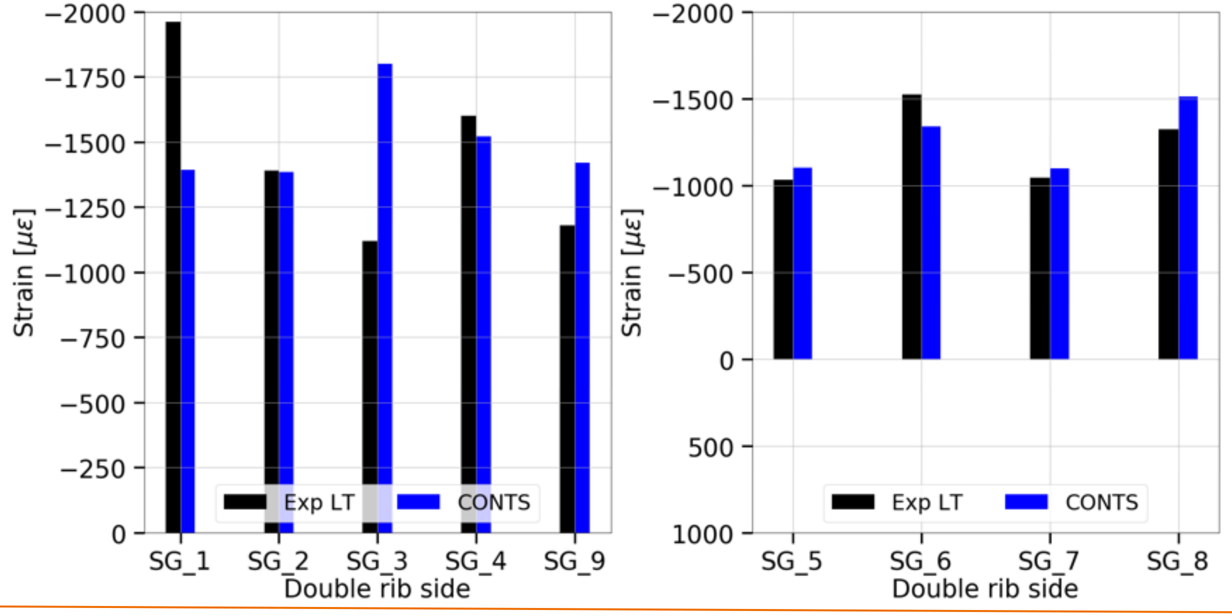


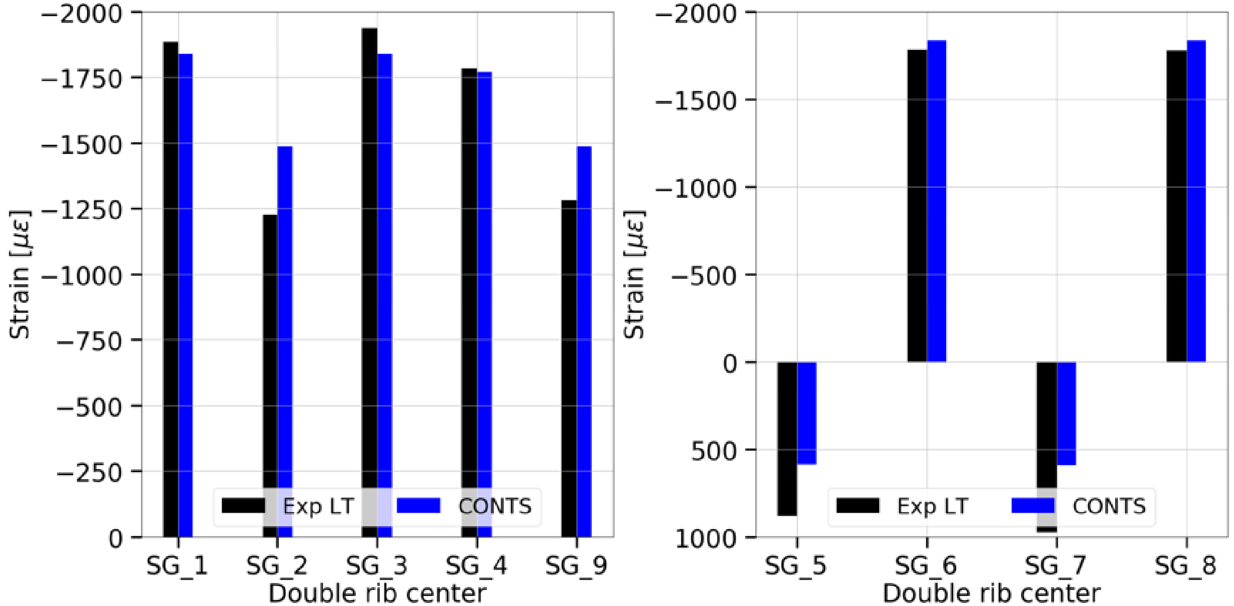
2





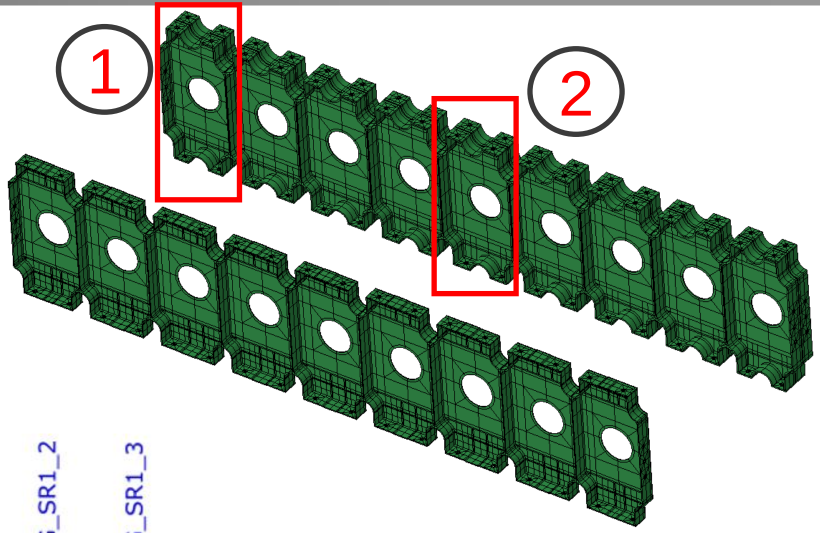
Double rib

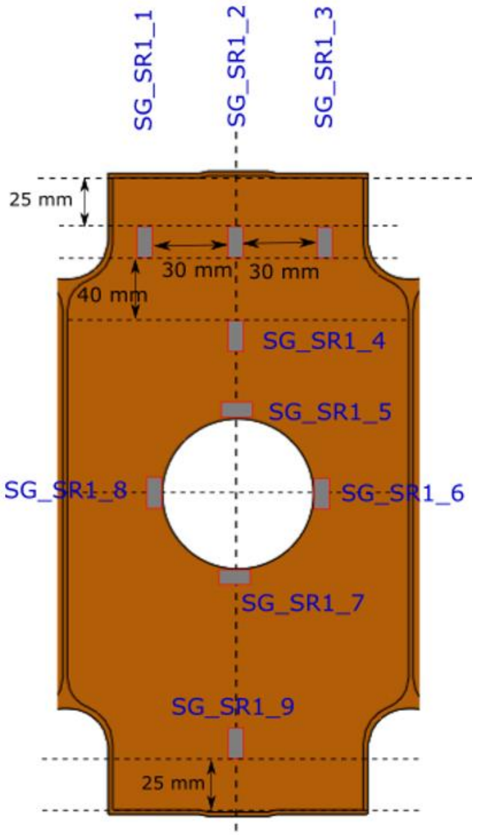




1

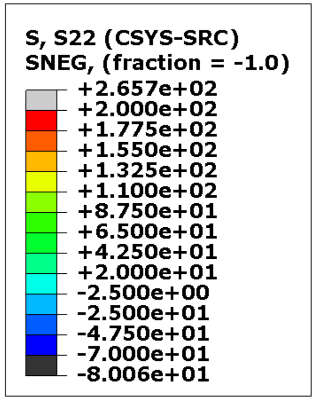
2

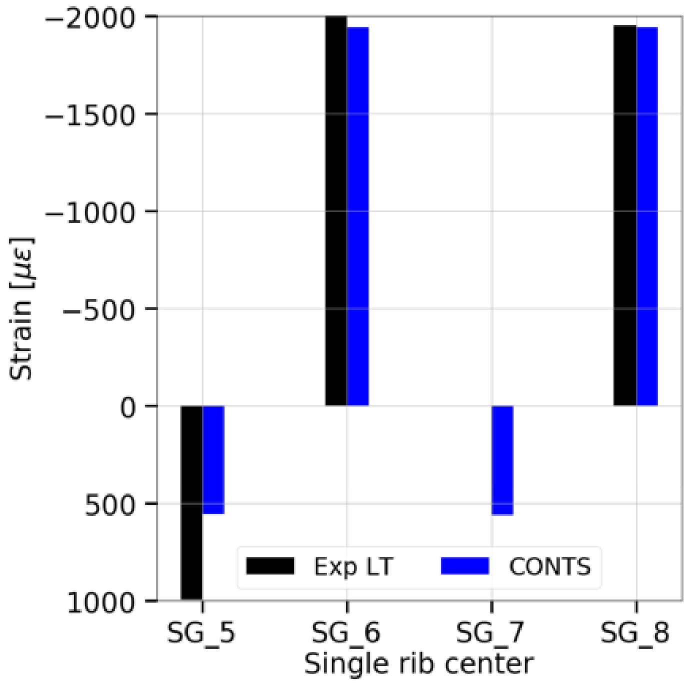


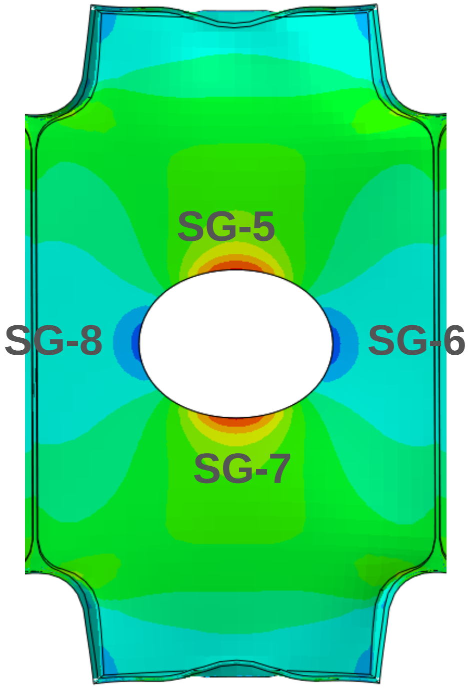


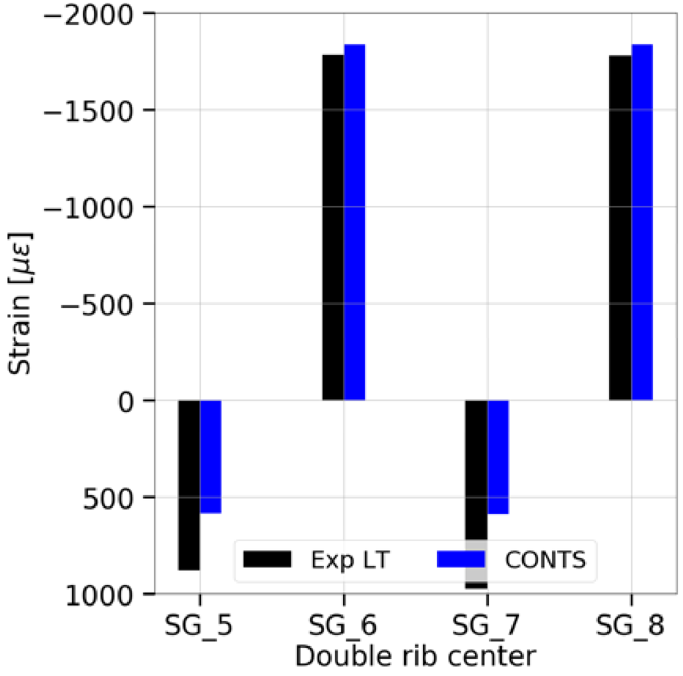
Double rib vs single rib hoop stress

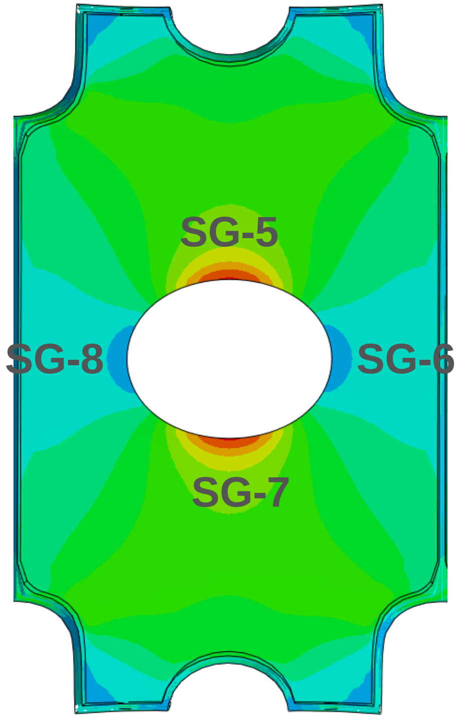
- Critical hoop stresses (200 Mpa) around hole for both ribs
- Single rib slightly larger values







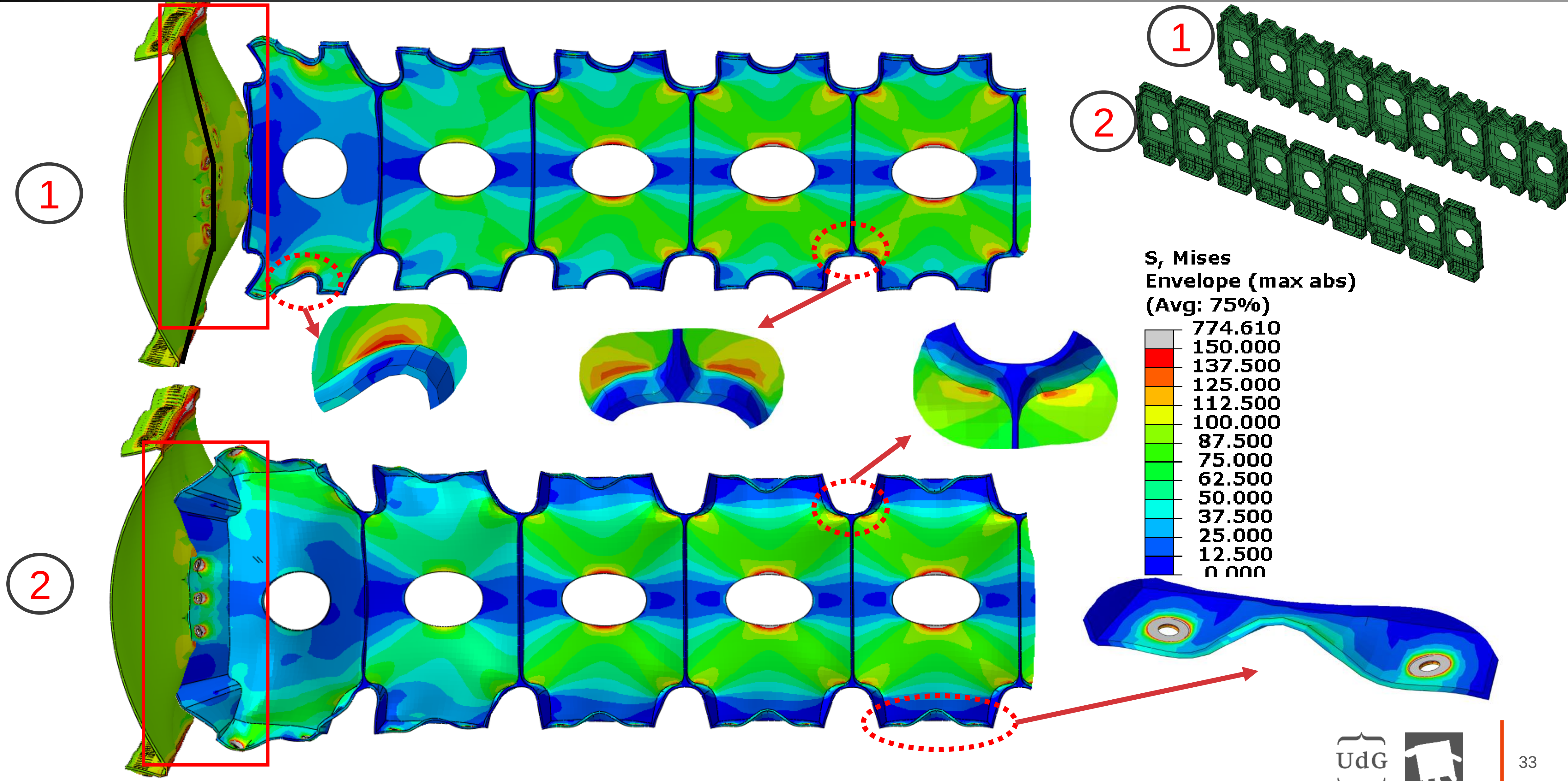




Single rib

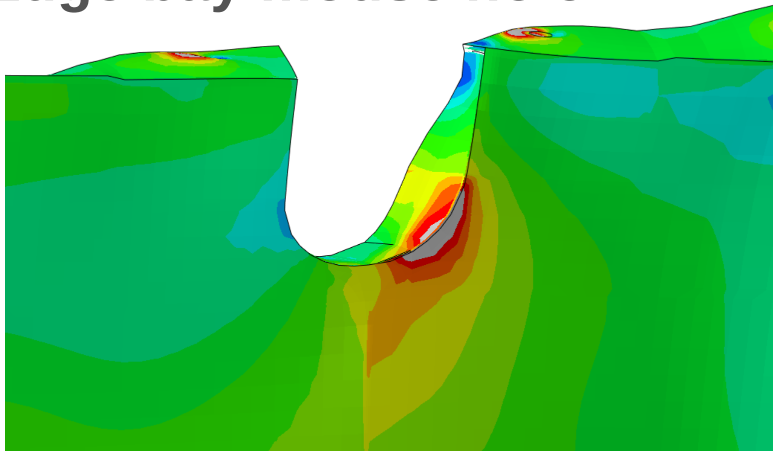
Double rib

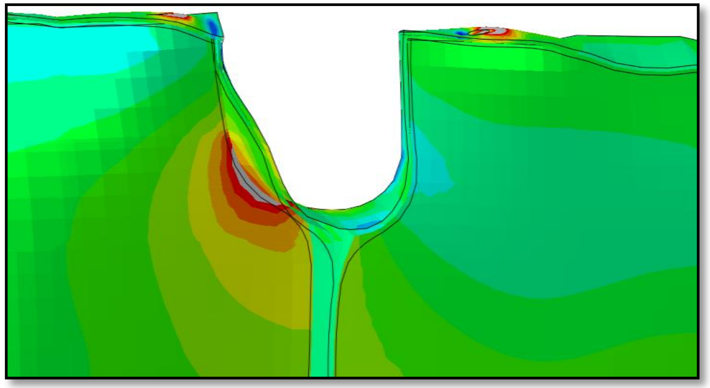
Ribs edge vs center deformation and stress



Ribs mouse hole edge bay comparison

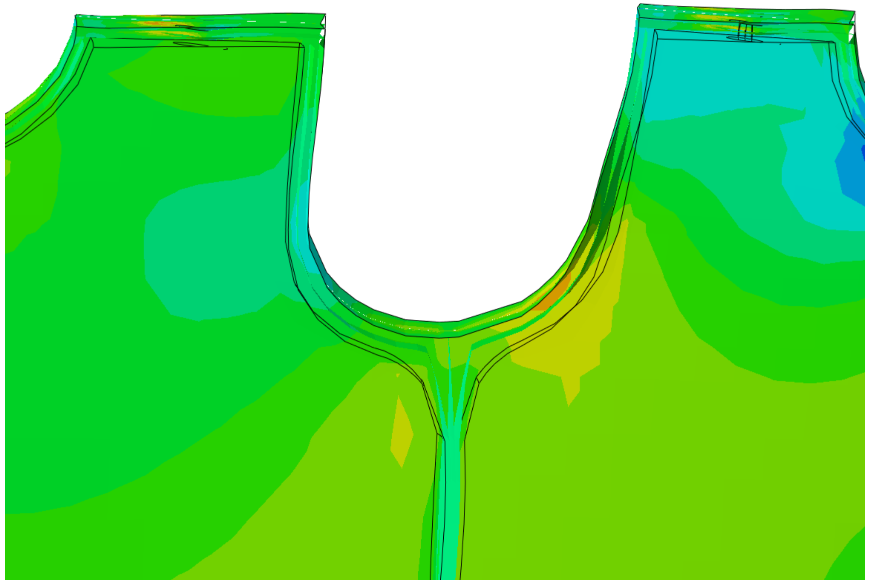
Single rib
Edge bay mouse hole

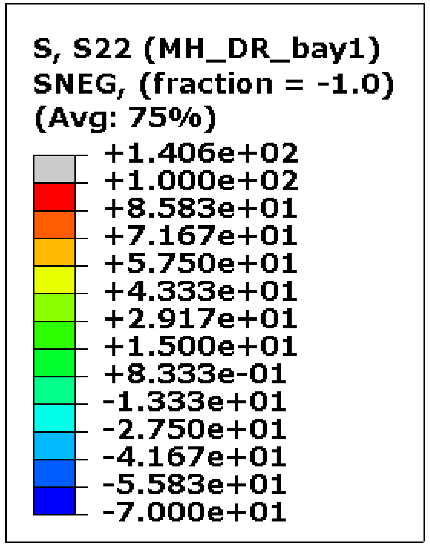




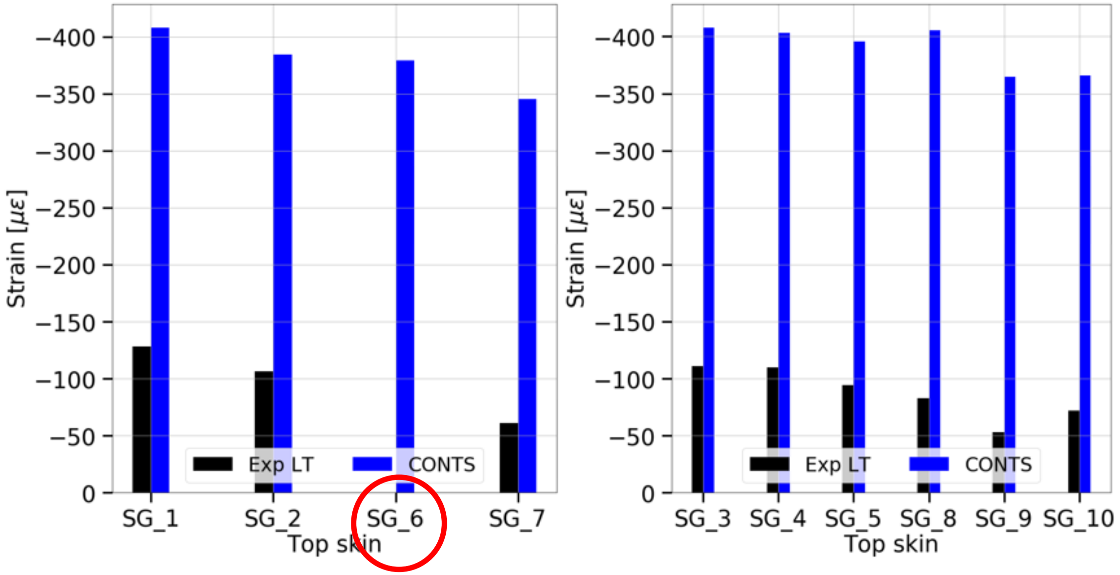
Other side

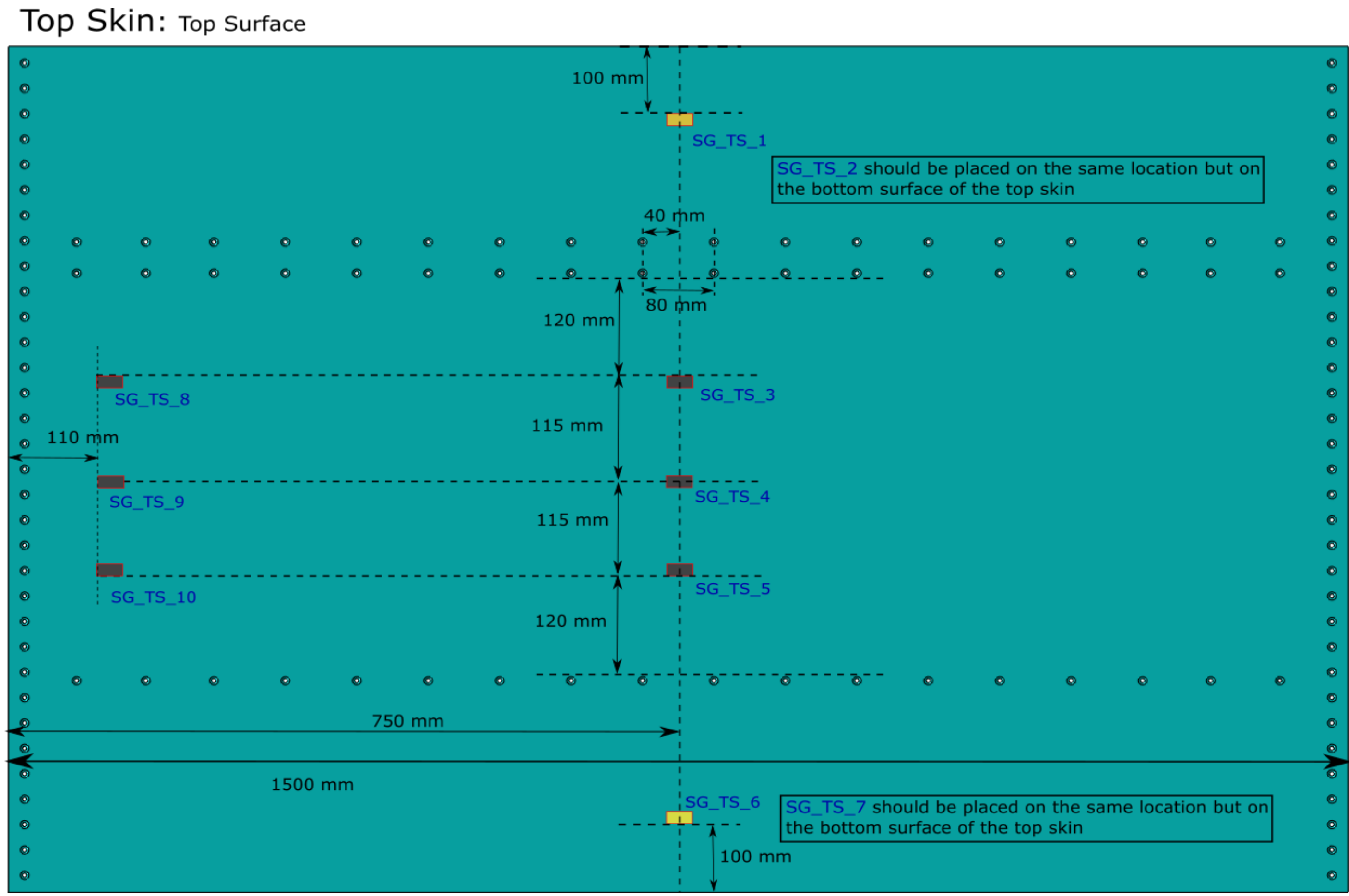
Double rib
Edge bay mouse hole

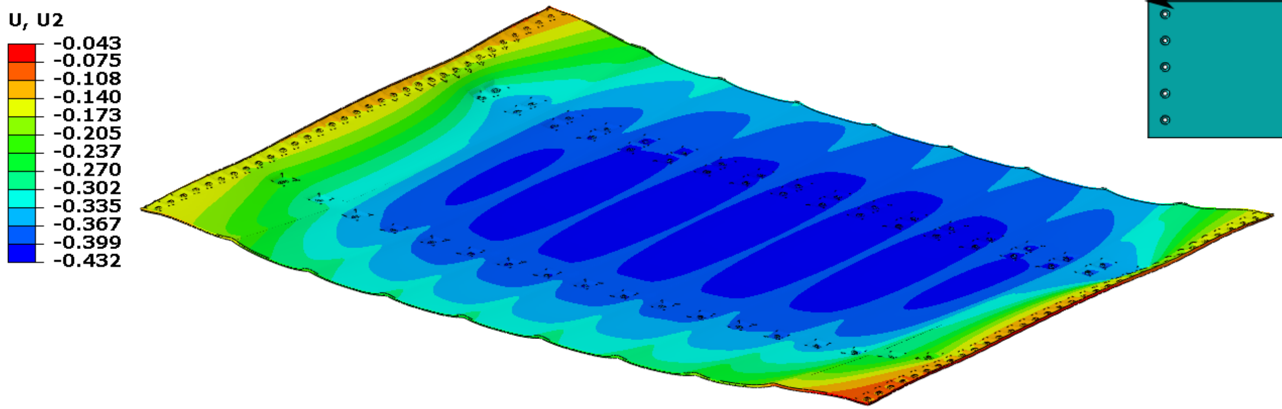




Top skin







- Qualitative trends predicted correctly
- But quantitatively, simulations overpredict
- Residual stresses from the assembly process?

Concluding remarks

Conclusions

- Successfully measured the evolution of the strain in a transient temperature test in a big structure
- We learnt how to correct strain measurements under temperature testing

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- We developed a new tooling for friction that was used to establish the friction coefficient at different temperatures and for dissimilar materials
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- Discrepancies between the numerical and experimental results may be attributed to:
  - Thermal residual stresses during the manufacturing process
  - **Stresses due to the assembly**
  - **Associated uncertainty** when measuring strains with gauges under temperature changes (**±50** microstrains)

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- We have 2 manuscripts under review and 4 more are planned

THANKS FOR YOUR ATTENTION

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