Surface Contacts II

IGF Project No. 21803 N

4th Project Advisory Committee Meeting

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28th November, 2023

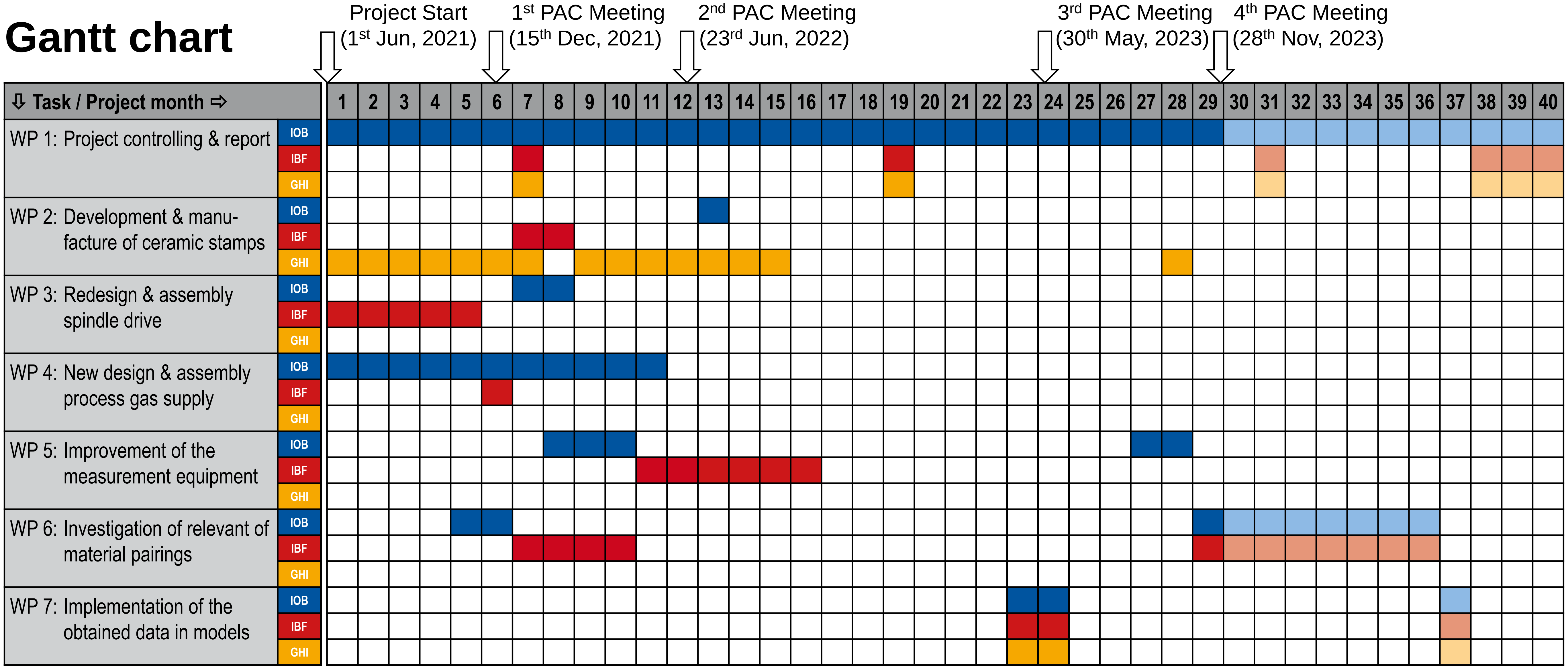
Project Framework

Project advisory committee (PAC)

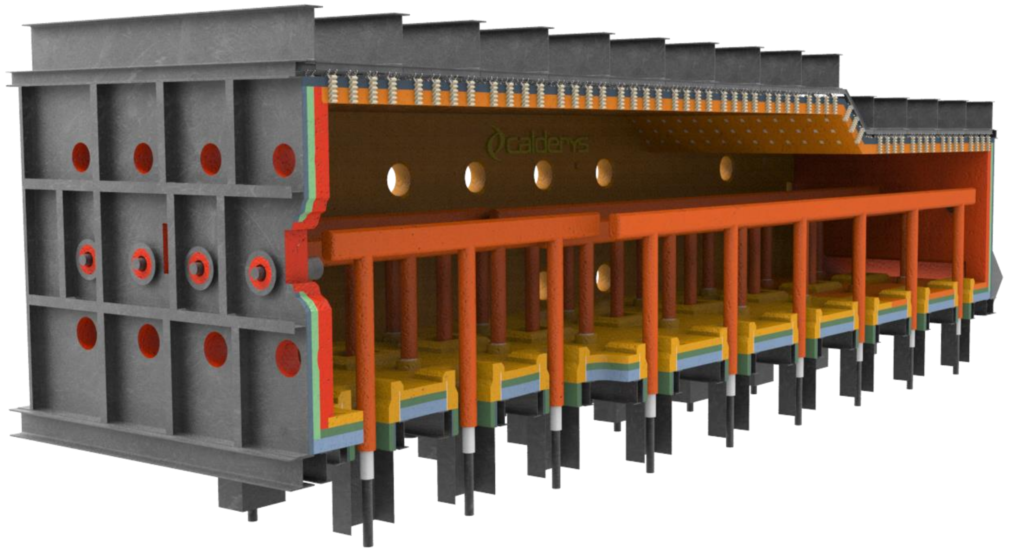
PAC chairperson: *Dr. Christian Wuppermann, LOI Thermprocess GmbH*

Project Extension

Gantt chart



Surface contacts



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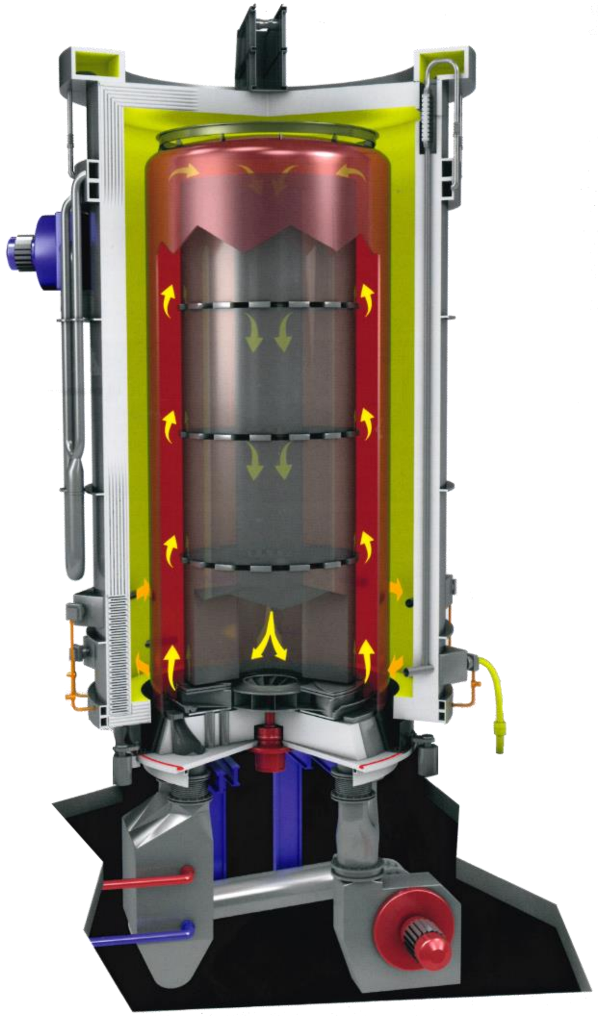

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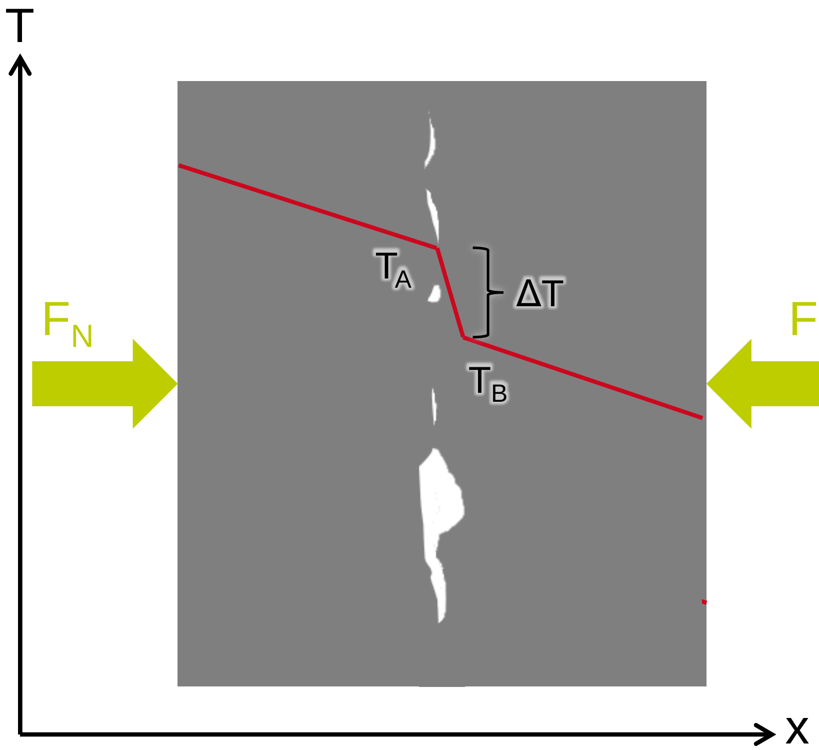
Thermal resistance at surface contacts



$$R_{th} = \frac{\Delta T}{\dot{Q}} \qquad R''_{th} = \frac{\Delta T}{\phi_q} = \left[\frac{m^2 K}{W}\right]$$

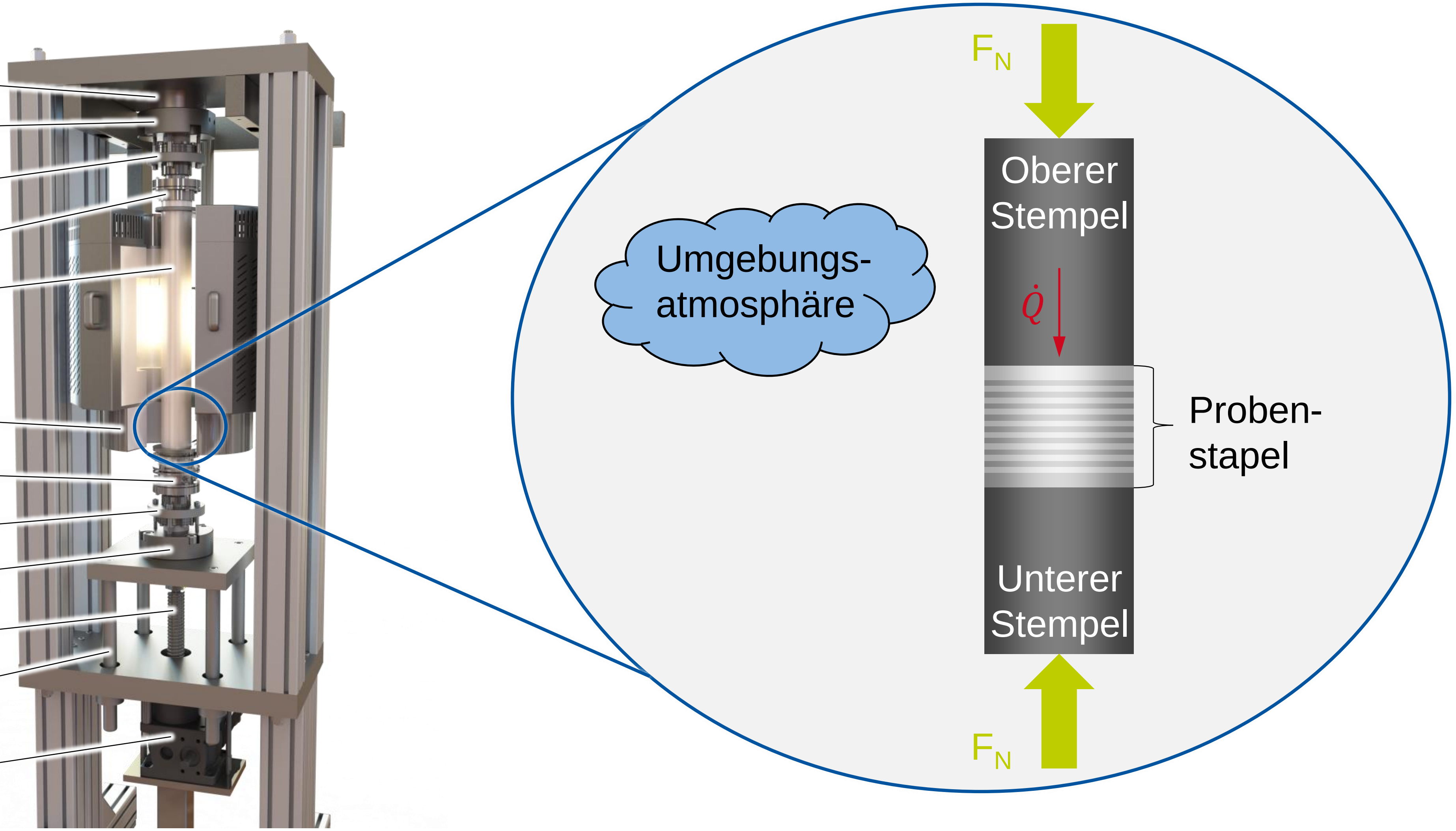
- Indirect measurement from
  - Temperature jump
  - Heat flux

Increase of the influence quantity	Effect on the resistance
Normal force	▼
Micro hardness	▲
Surface roughness	▲
TC (solid)	▼
TC (fluid)	▼
Temperature	▲▼

Research Project

Test rig

Normalkraftsensor
Obere Kühlung
Obere Stempelhalterung
Prozessgaseinspeisung
Ofenrohr
„Wärmetopf“
Prozessgasabführung
Untere Stempelhalterung
Untere Kühlung
Hubspindel
Führungsstangen
Getriebe & Motor



Research Project

Project objectives

1. Increase of the max. possible sample temperature to 1250 °C

2. Expansion of the contact pressure range to 0,1 MPa < σ < 25 MPa

3. Realisation of a process gas atmosphere of 100 % H_2

4. Reduction of the measurement error to max. 10% (globally)

5. Investigation of new material pairings

6. (Further) development of models for the calculation of temperature distributions in components / assemblies with surface contacts

Project structure

WP 1
Project controlling & report

WP 2
Development & manufacture of ceramic stamps

WP 3
Redesign & assembly spindle drive

WP 4
Redesign & assembly spindle drive

WP 5
Improvement of the measurement equipment

WP 6
Investigation of relevant of material pairings

WP 7
Implementation of the obtained data in models

Project Status

Target-performance comparison

Work Package	Progress	Status
WP 1: Project controlling & report	Act: 50 % Tar: 50 %	☺
WP 2: Development & manufacture of ceramic stamps	Act: 100 % Tar: 100 %	☺
WP 3: Redesign & assembly spindle drive	Act: 100 % Tar: 100 %	☺
WP 4: New design & assembly process gas supply	Act: 100 % Tar: 100 %	☺
WP 5: Improvement of the measurement equipment	Act: 92 % Tar: 100 %	😐
WP 6: Investigation of relevant of material pairings	Act: 50 % Tar: 50 %	☺
WP 7: Implementation of the obtained data in models	Act: 56 % Tar: 50 %	☺

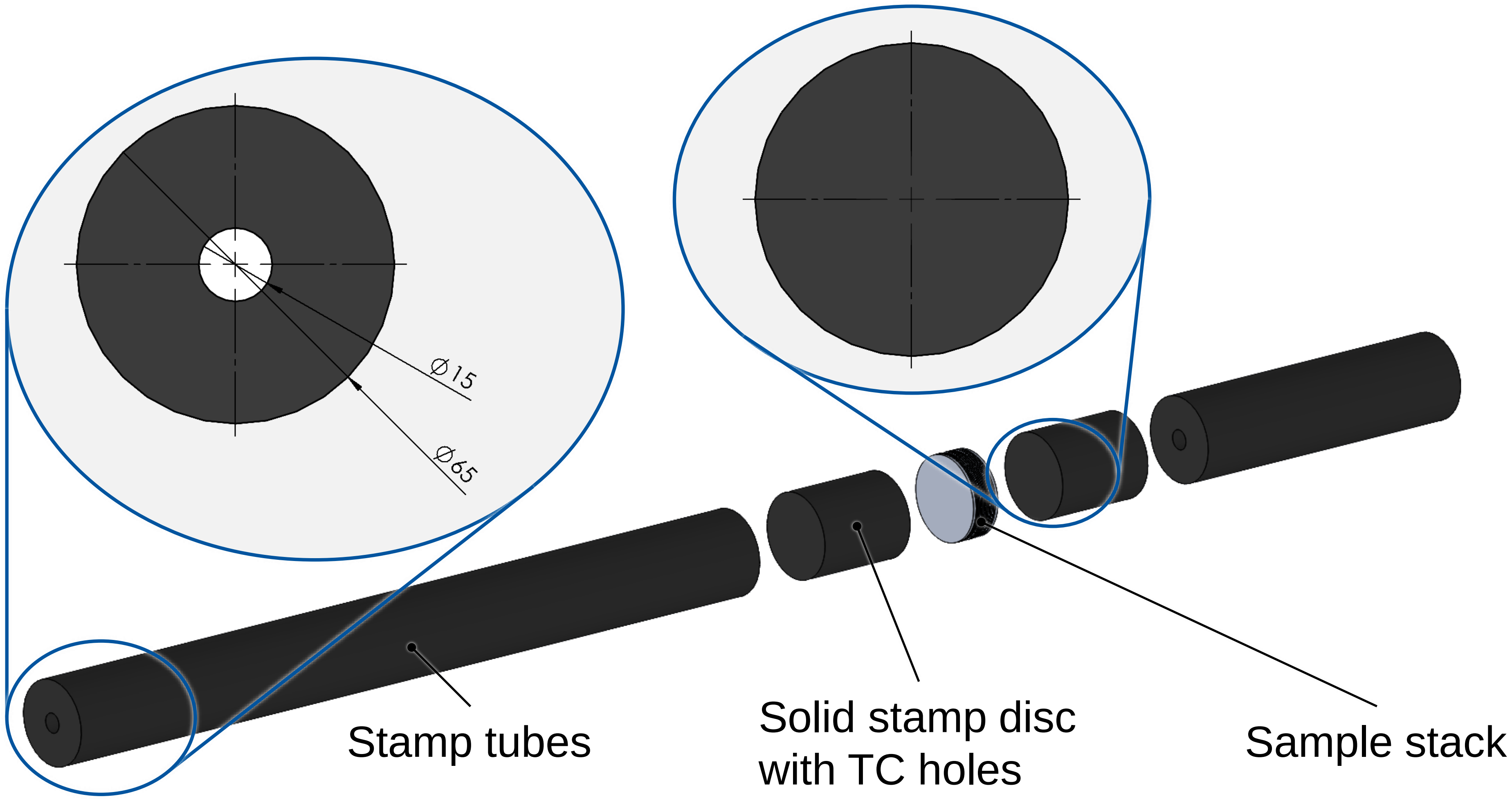
Project Status

Milestone schedule

Milestone	Target	Actual
M1: Project started	01st Jun, 2021	01st Jun, 2021 ✓
M2: Trial plan finalised	31st Dec, 2021	17th Jan, 2022 ✓
M3: Test rig relocated to IOB	31st Dec, 2021	27th Jan, 2022 ✓
M4: New spindle drive functional	28th Feb, 2022	14th Apr, 2022 ✓
M5: New process gas supply ready for use	30th Apr, 2022	15th Nov, 2022 ✓
M6: Ceramic stamps installed	31st Oct, 2022	*26th Sep, 2023* ✓
M7: Investigations completed	30th Jun, 2024	*exp. Q II / 2024*
M8: Project completed	31st Oct, 2024	*exp. Q IV / 2024*

WP 2 – Development & manufacture of ceramic stamps

SiC Stamps



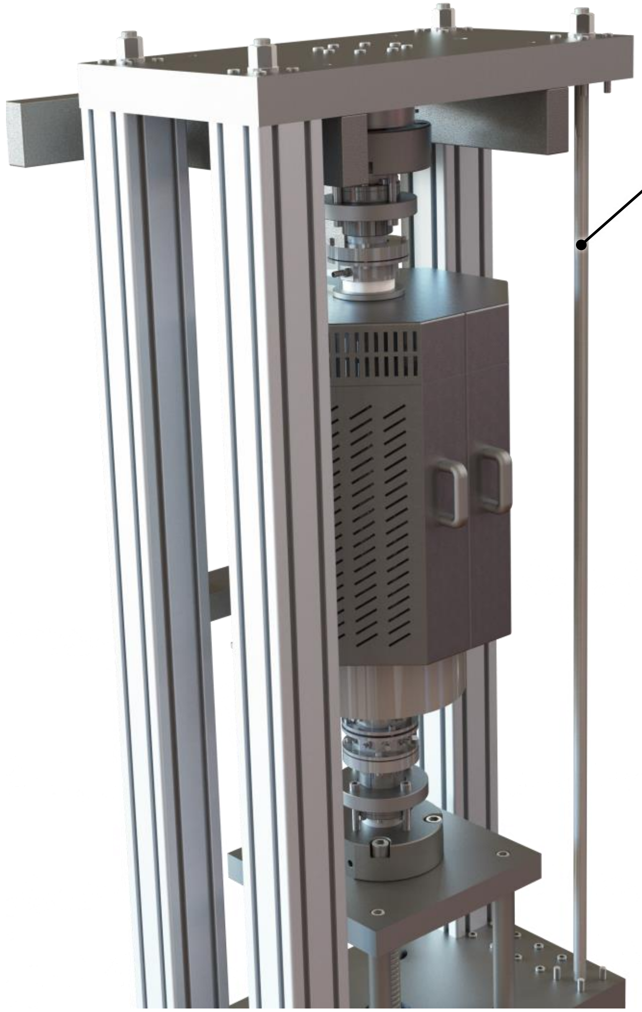
WP 2 – Development & manufacture of ceramic stamps

Work stages

- Identification of requirements and selection of a material ✓
- Manufacturing of the stamps ✓
- Testing of the components ✓
- Installation of the stamps in the test rig ✓

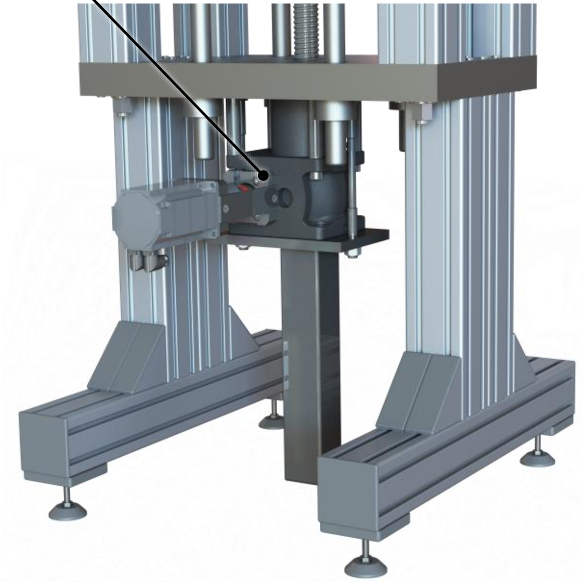
WP 3 & WP 4 – Construction of the New Test Rig

New test rig

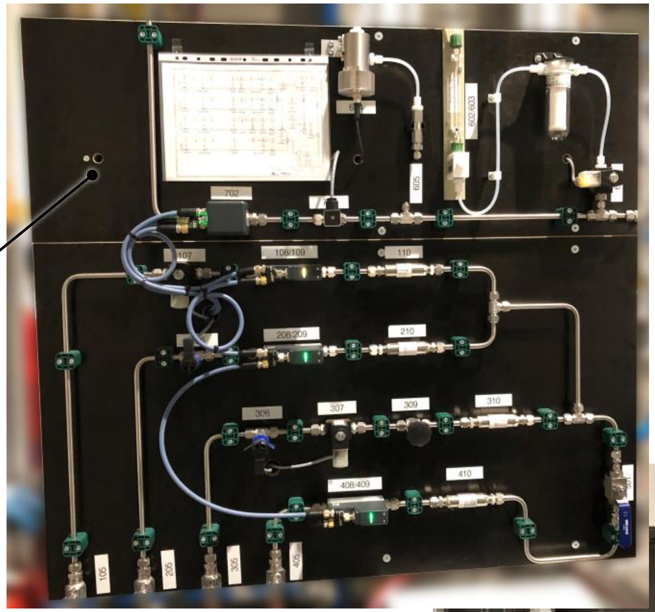


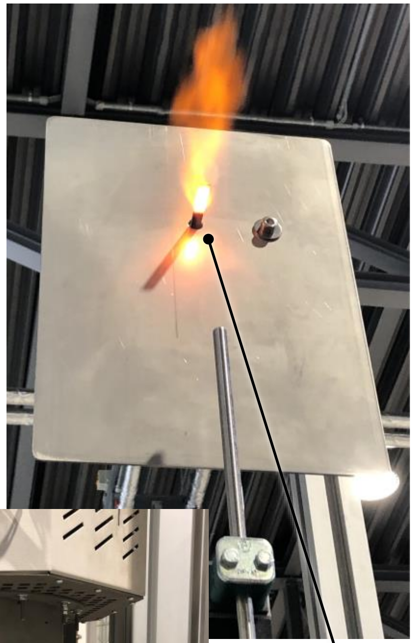
M24 threaded rod

new gear



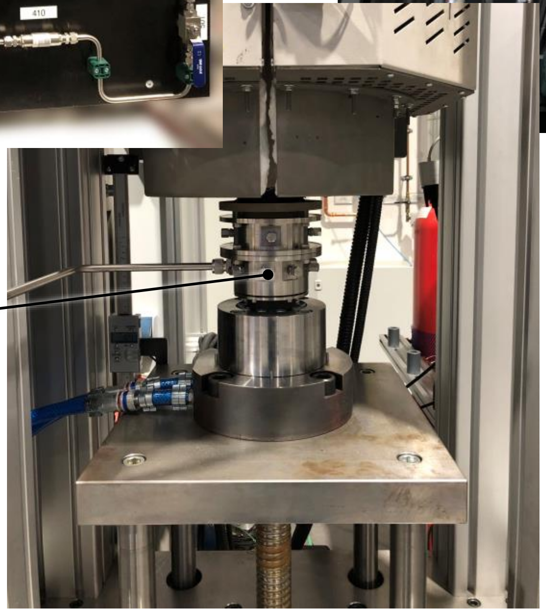
gas mixing line





torch

gas seal
(lower stamp)



WP 3 & WP 4 – Construction of the New Test Rig

Work stages

- Design of the new drive unit and new gas control system ✓
- Procurement & assembly of new plant components ✓
- Revision and test of the control scheme ✓
- Test of the safety infrastructure ✓

WP 5 – Improvement of the measurement equipment

Work stages

- Procurement of new thermocouples (measuring range up to 1600 °C) ✓
- Calibration of all thermocouples ⋮
- Measurement / research of the temperature-dependent material values ✓
- Revision of the evaluation algorithm ✓

WP 6 – Investigation of relevant of material pairings

Trial plan

Material 1	Material 2	Temperature [°C]	Stress [MPa]	Atmosphere	Application
C45		100 … 870	0,1 … 25	N_2 , H_2	Coil annealing (bell-type furnace)
AA1050A		100 … 350	0,1 … 10	Exhaust gas	Coil annealing (chamber furnace)
AA5754		100 … 420	0,1 … 10	Exhaust gas	Coil annealing (chamber furnace)
M600-100A		100 … 1200	0,1 … 25	H_2	Coil annealing (bell-type furnace)
CuFe2P		200 … 600	0,1 … 10	F75/25	Coil annealing (bell-type furnace)
CuAl6Ni2		100 … 600	0,1 … 10	F75/25	Coil annealing (bell-type furnace)
X10CrAlSi13	S355JR	100 … 1250	0,1 … 1,0	Exhaust gas	Slab preheating (walking beam furnace)
S355JR	$CaSiO_3$	100 … 800	0,1 … 0,5	Air	Melt transport (steel ladle)

WP 6 – Investigation of relevant of material pairings

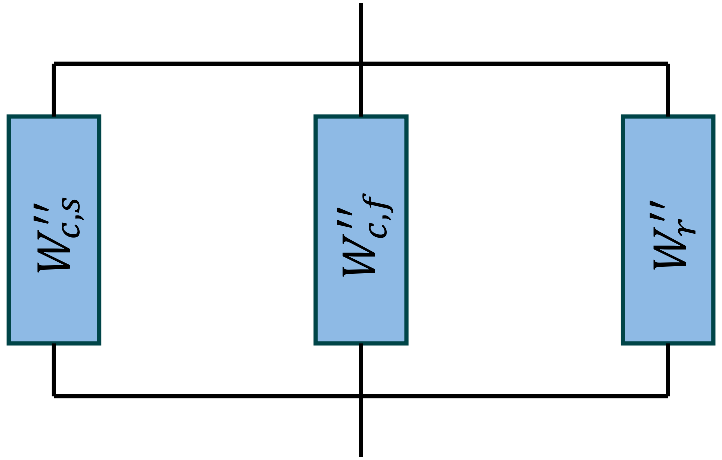
Work stages

- Design of a trial plan ✓
- Procurement and preparation of sample material ✓
- Surface characterization ⋮
- Conduction & evaluation of measurements ▢

WP 7 – Implementation of the obtained data in models

Analytical model

- Thermal contact resistance = parallel connection of single resistances
  - Thermal conduction resistance due to solids at contact points $W''_{c,s}$
  - Thermal conduction resistance due to fluid in the gap $W''_{c,f}$
  - Thermal resistance due to radiation exchange W''_{r}

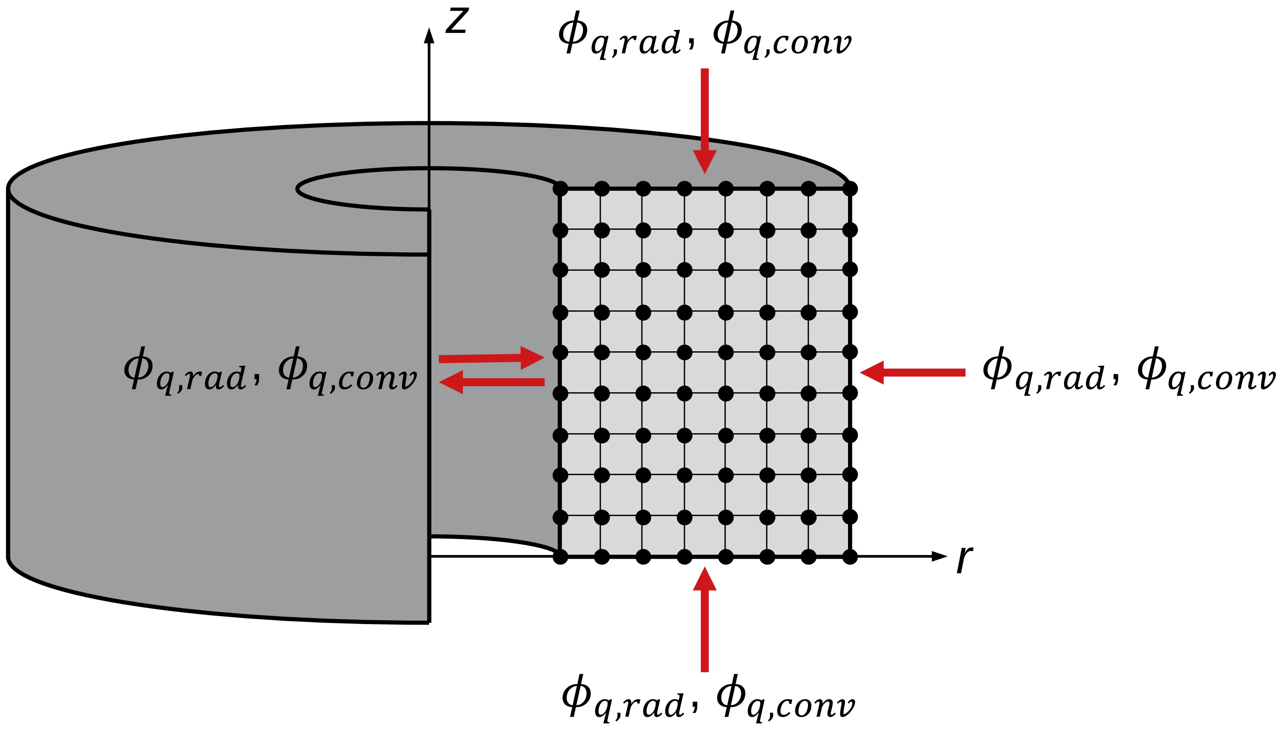


$$\rightarrow \text{Total resistance } W''_{C} = \left(\frac{1}{W''_{c,s}} + \frac{1}{W''_{c,f}} + \frac{1}{W''_{r}}\right)^{-1}$$

- Influencing variables in analytical models:
  - Contact pressure → Variation in measurement campaign
  - Micro hardness of the samples → Measurement in the project
  - Surface characteristics of the samples → Measurement in the project
  - Temperature-dependent thermal conductivity of the sample material → Measurement in the project
  - Temperature-dependent thermal conductivity of the fluid in the gap → Variation in measurement campaign

Process model: Coil annealing

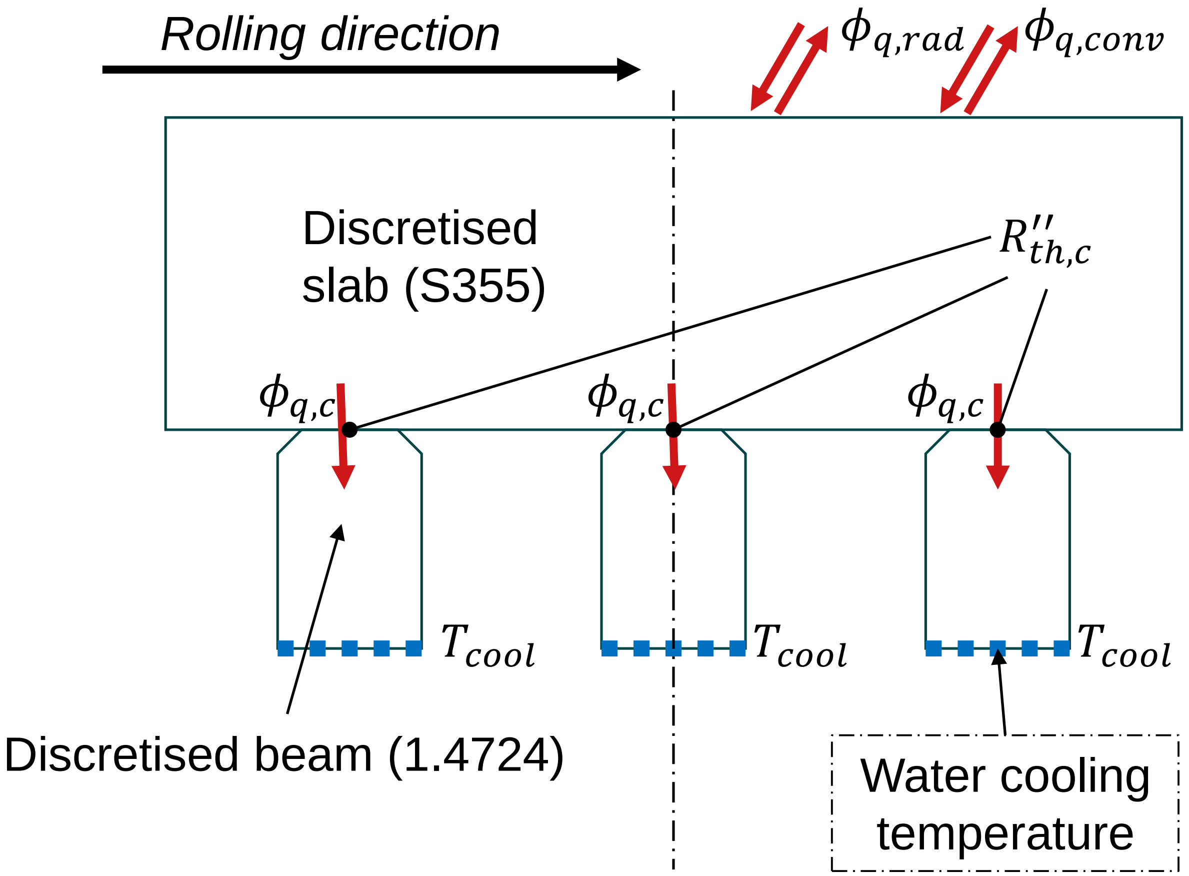
- Optimisation of the process time
- Modelling
  - Numerical Solution of the Fourier equation with FDM
  - Rotation-symmetric 2D mesh
  - Anisotropic thermal conductivity
  - Boundary conditions from CFD simulation
- Results:
  - Radial stress distribution (input for TCR calculation)
  - Time-dependent temperature distribution



Process model: Walking beam furnace

ABAQUS

- Identification of skid marks for subsequent hot rolling simulation
- Modelling
  - Finite Element Analysis (Abaqus)
  - 2D planar mesh
  - Measured thermal contact resistances
- Sensitivity analysis: TCR → Skid marks



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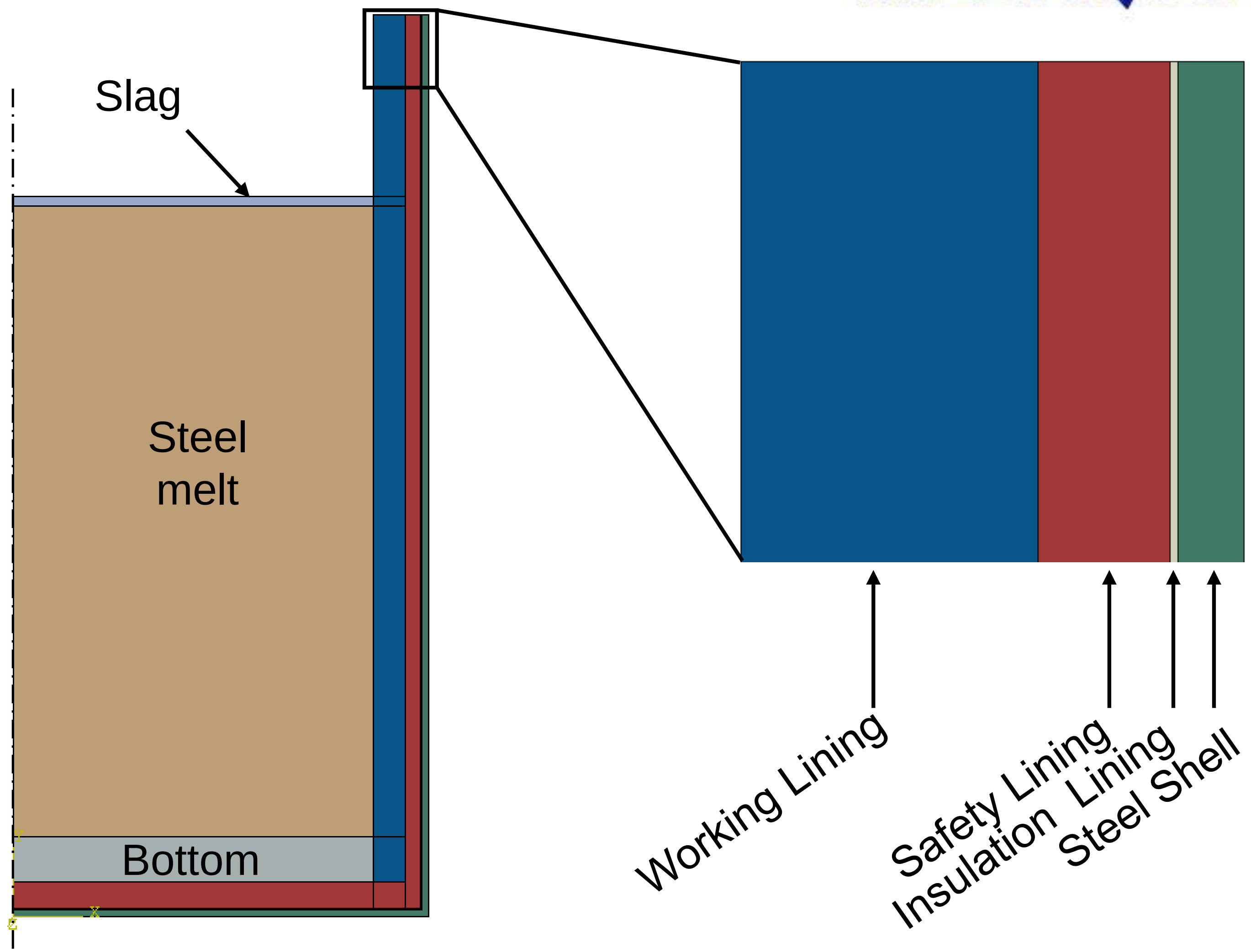
WP 7 – Implementation of the obtained data in models

Process model: Steel ladle

- Temporal temperature involvement of the ladle
- Modelling
  - Finite Element Analysis (Abaqus)
  - Rotation-symmetric 2D mesh
  - Melt and slag as solid material
  - Measured thermal contact resistances
- Results may be used in lifetime analyses of ladle structure



WP 7 – Implementation of the obtained data in models

Work steps

- Revision of analytical model ⋮
- Development of process models ✓
- Testing of the model software ⋮
- Validation of the models ▢

Surface Contacts II

Summary

- Test rig technically ready
- Calibration of measurement equipment pending
- Material- and surface characterisation (prior the trials) completed
- Process models are ready for testing
- Measurements planned to start in January 2024

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Industrielle
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Thinking the Future
Zukunft denken

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