WEBINAR: QUENCHING SIMULATION

A Simulation Approach for the Thermal Treatment of Engine- & Automotive Components

Dr. Sascha Seidl, Fabian Uhlig

AVL Deutschland GmbH, AVL Schrick GmbH

Public

WHO IS PRESENTING TODAY?

Moderator

Dipl.-Ing. Ingolf Thiele
Senior Sales Manager
AVL Deutschland GmbH

Technical Experts

Dr.-Ing. Sascha Seidl
Simulation Engineer
AVL Deutschland GmbH

Dipl.-Ing. Fabian Uhlig
Lead Simulation Engineer
AVL Schrick GmbH

MOTIVATION

- Optimization of the thermal treatment of cast parts
- Improvement of quality and durability of components in service

➢ **AVL provides a highly developed multi-phase boiling model for Quenching applications**

  - **Direct, air and spray** quenching approaches available
  - **Any metal** material
  - **Oil, water and water-polymer emulsions** as quenchants

➢ **Goal:** Create a quenching simulation methodology that can be used in production

WHY SIMULATE QUENCHING?

Problems to solve:

- Cracks under operational loads
- Deformations during machining / final part

Reasons:

- Material limit exceed due to combination of high operational loads and residual stresses.
- Residual stresses during production.

Consequences:

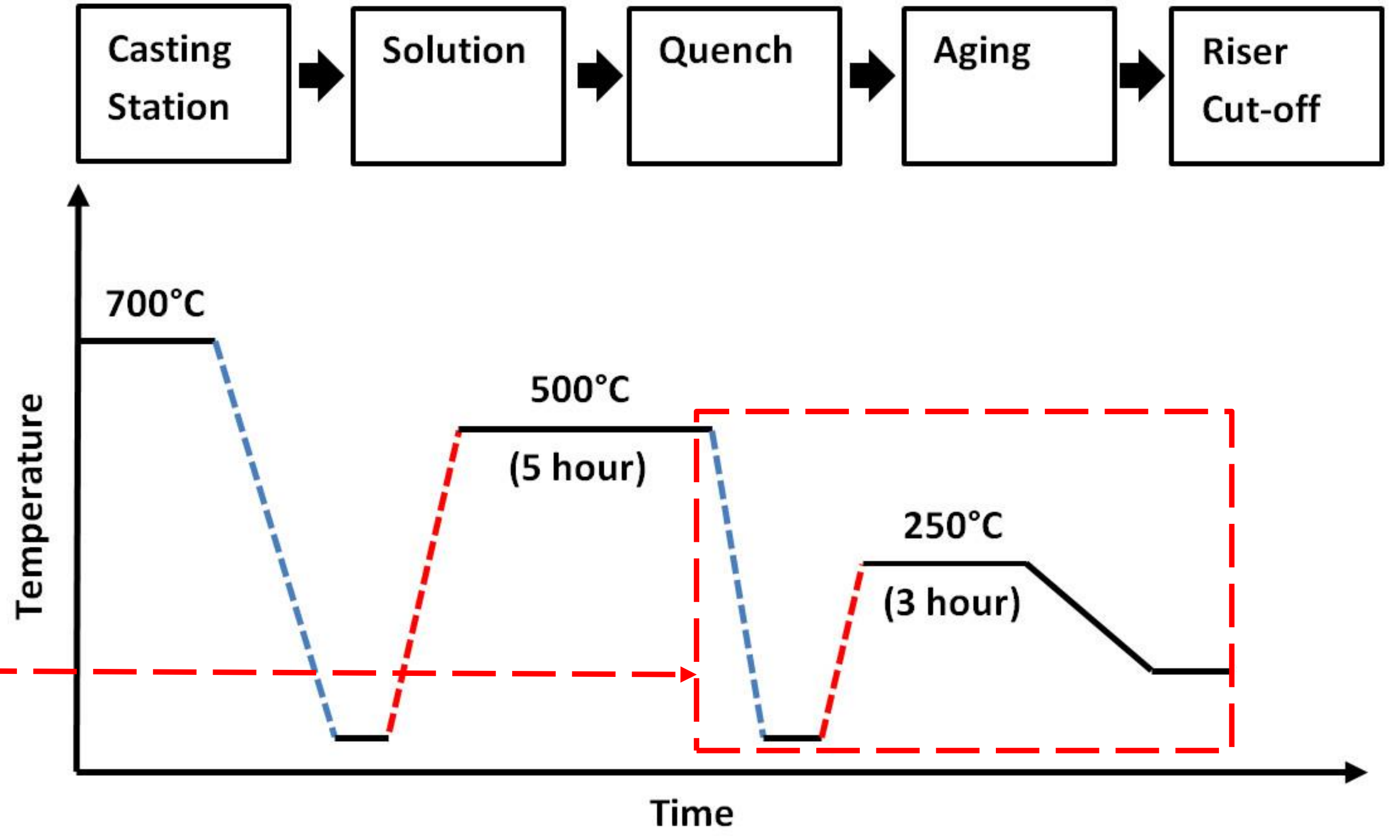
- Leakages & breakages, engine failure
- Part not within tolerances

AVL's solution:

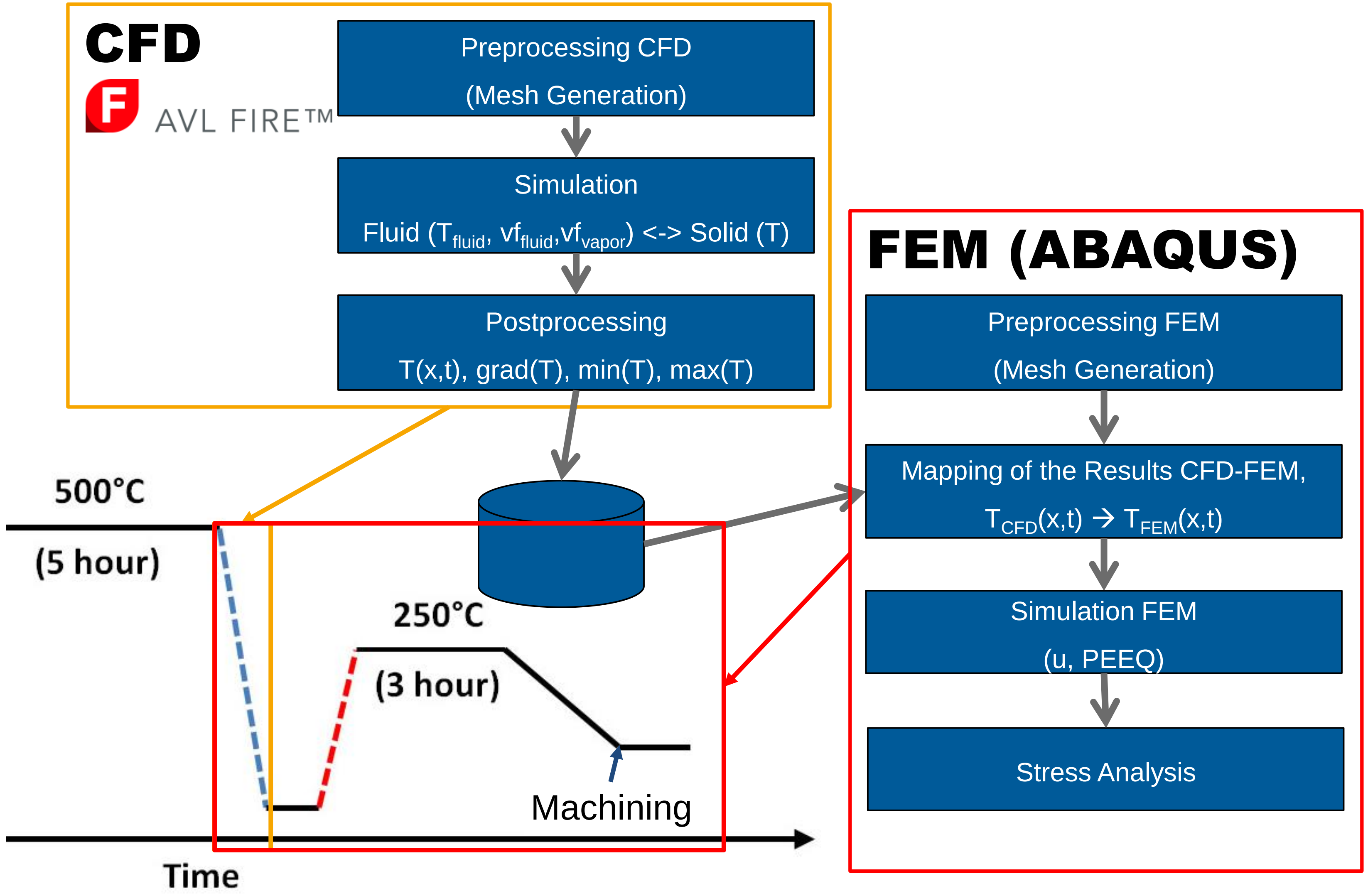
- Simulation based residual stresses reduction
- Optimization of heat treatment

HEAT TREATMENT

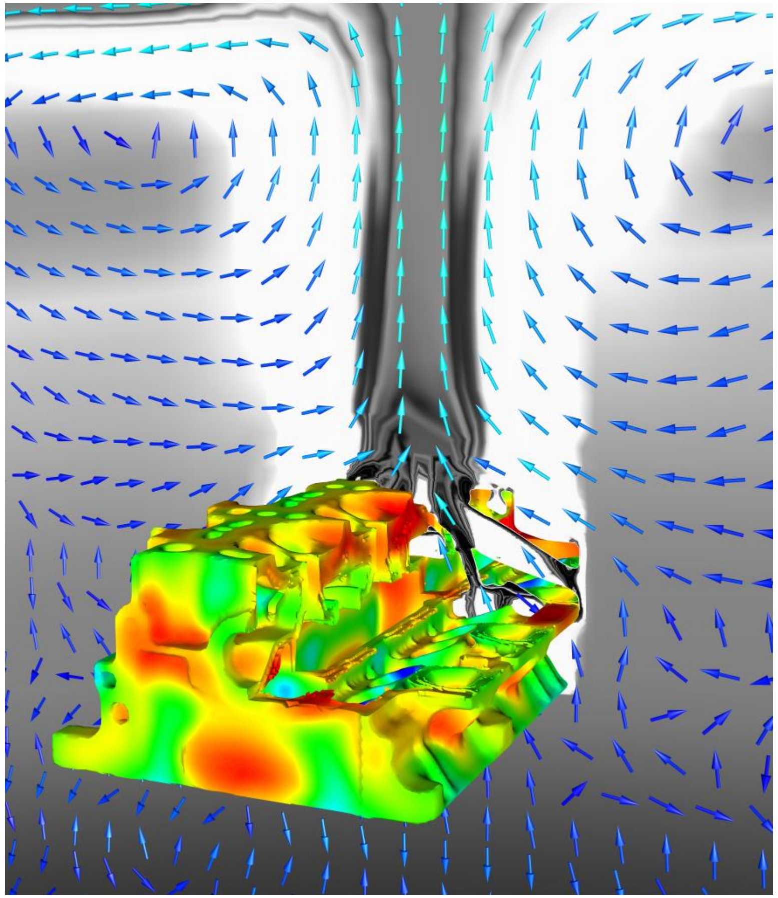
- Casting or forging
- Cooling of parts
- Reheating to about 500°C
- Quenching
- Reheating to about 250°C
- Aging
- Machining



OVERVIEW OVER THE SIMULATION APPROACH



SIMULATION OF THE QUENCHING PROCESS

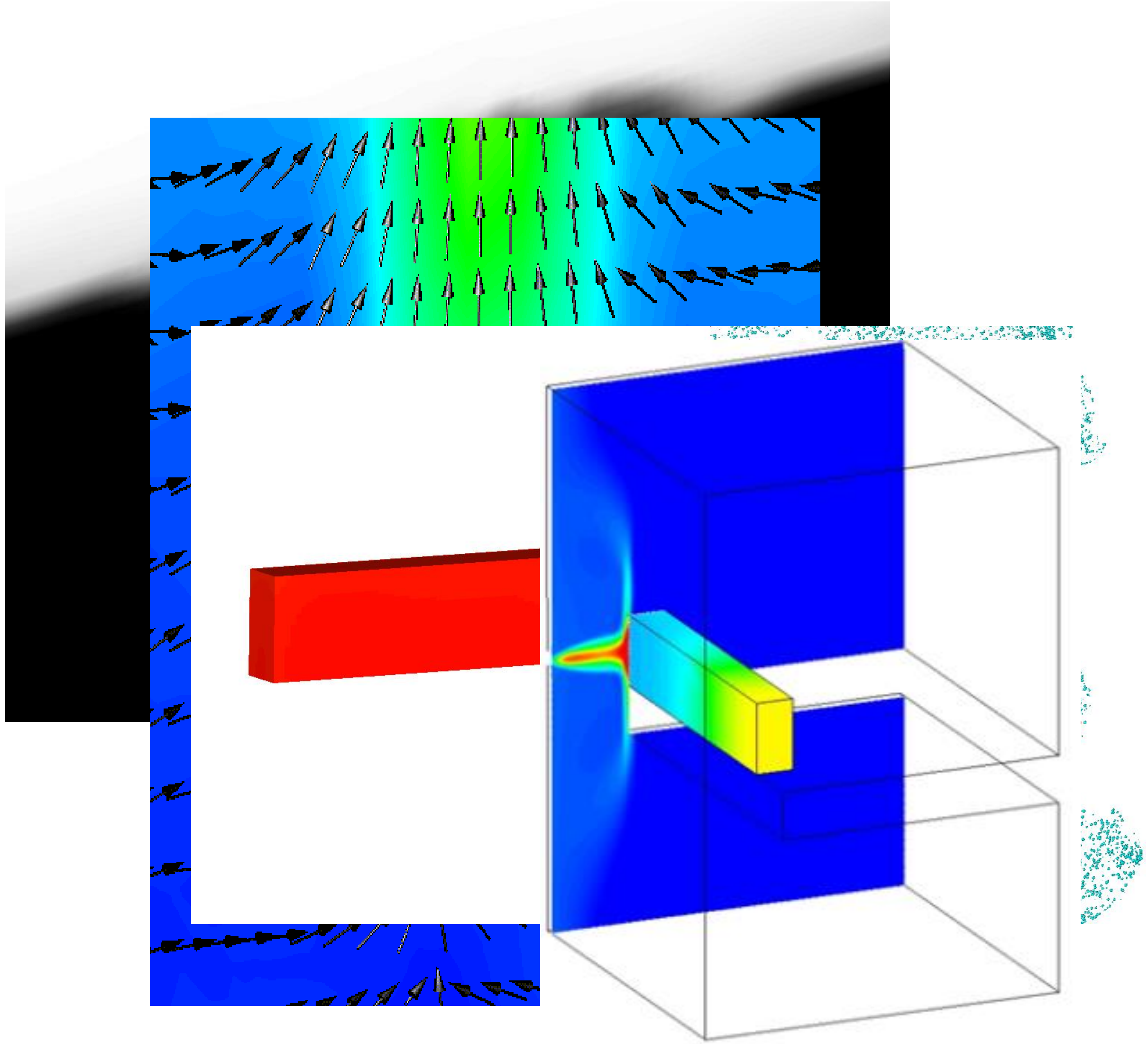


Simulation of the Quenching Process with

AVL FIRE™

- Calculation of the temporal Temperature distribution in the SOLID caused by the flow field around the SOLID and boiling behavior at the SOLID surface
- Input-data for the Finite-Element-Analysis is generated
- Calculation of the Strain / Stress distribution with appropriate constitutive laws in ABAQUS
- Predicition of the residual stresses for the SOLID
- Basis for the evaluation and optimization of process parameters

SIMULATION OF THE QUENCHING PROCESS



Simulation of the Quenching Process with

AVL FIRE™

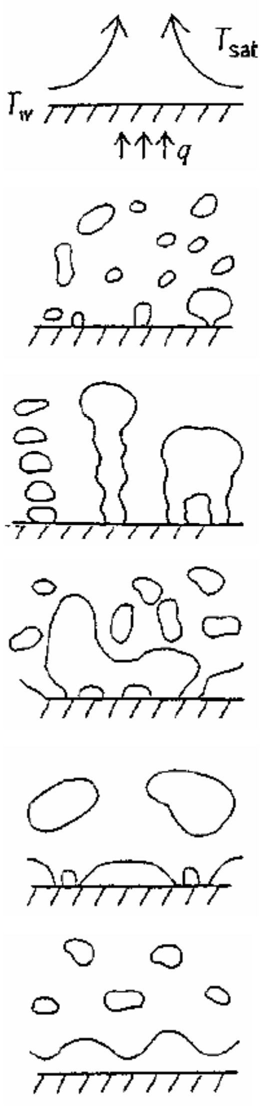
- With AVL FIRE™ it is possible to simulate
  - Immersion Quenching
  - Air Quenching
  - Spray cooling
  - Spray quenching

Under research!

- Alongside Aluminum other alloys as well as Steel are possible!
- Usual Immersion Quenching takes place in Water as cooling medium, but also Oil as well as Water-Polymer-Emulsions are possible!

CFD QUENCHING SIMULATION

Behavior during heating of a plate



Free Convection

Initiation boiling

Nucleate boiling

Fully developed boiling

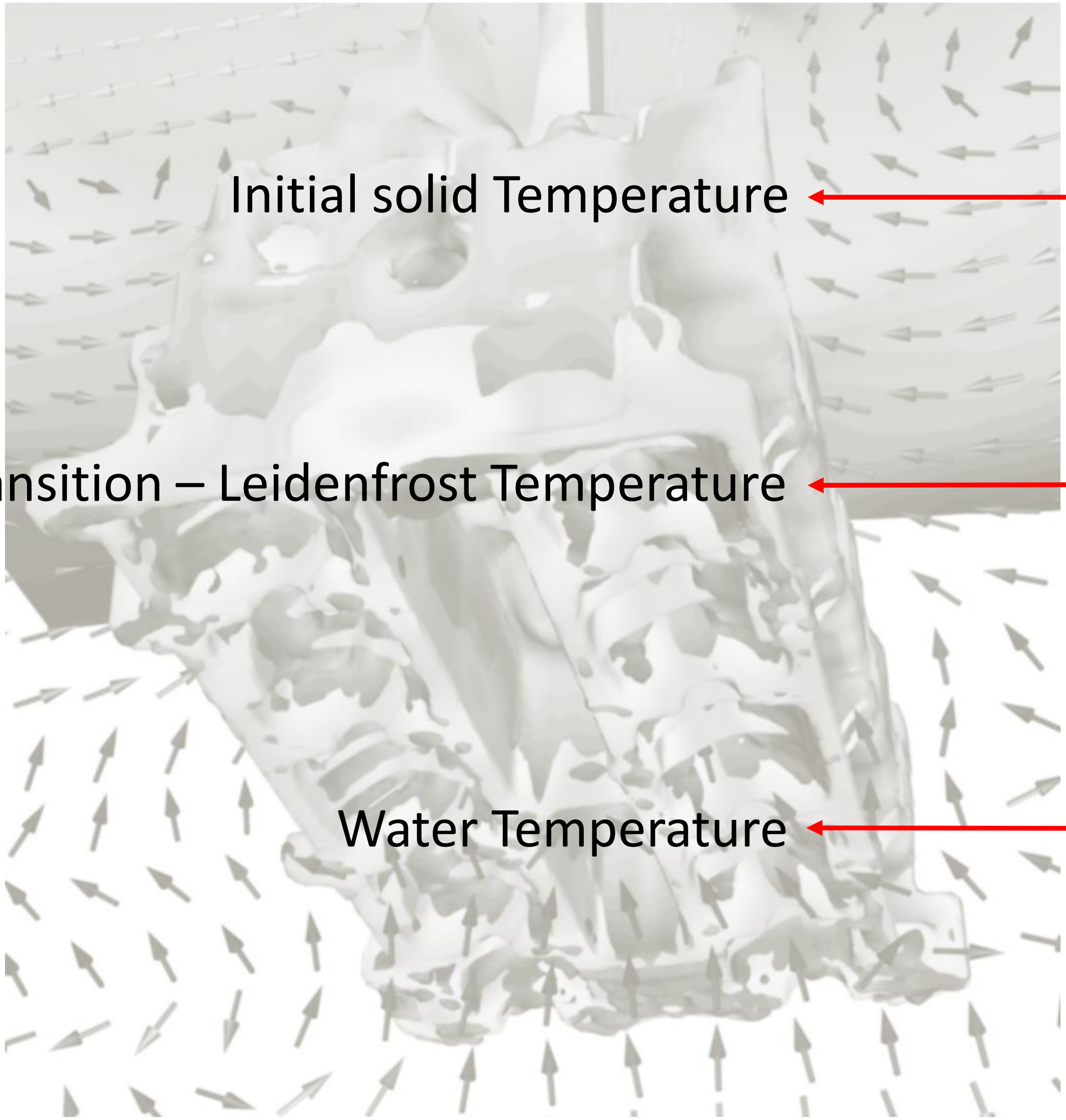
Transition boiling

Film boiling

Behavior during Quenching

- The analysis covers heat transfer evaluation over the complete quenching process
- Different boiling regimes require different modeling strategies

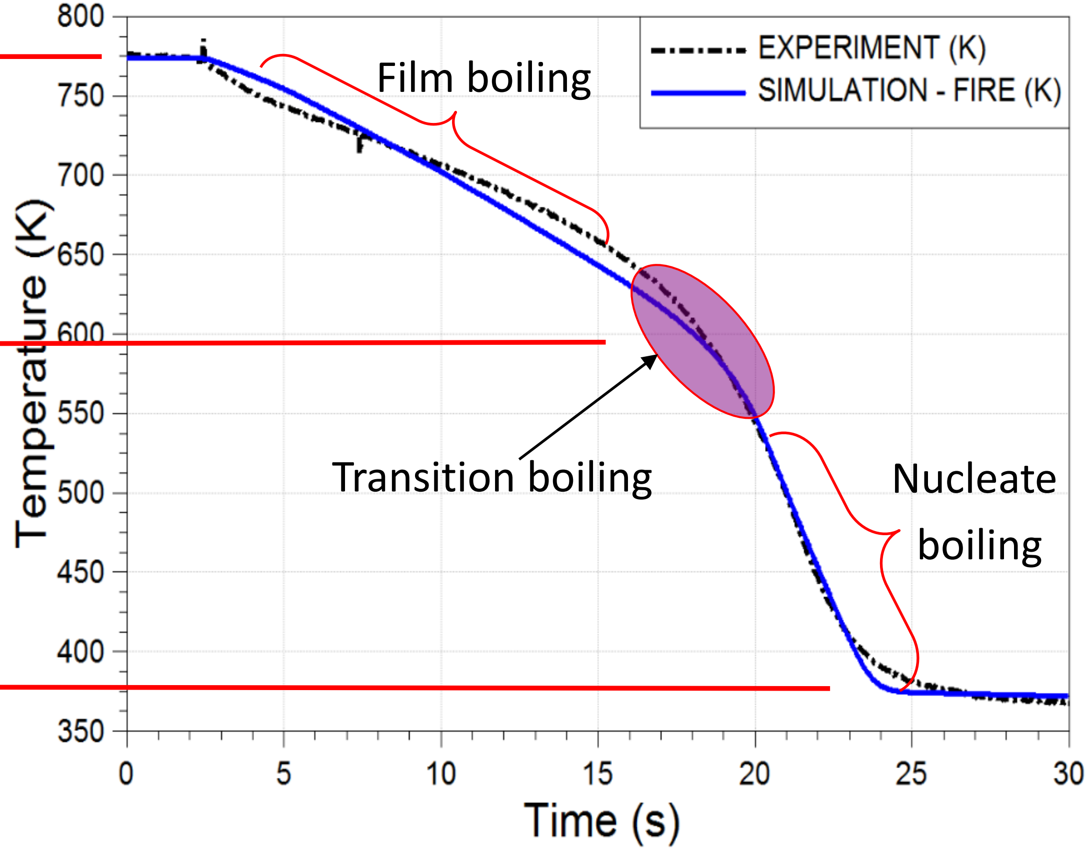
BOILING DURING QUENCHING



Initial solid Temperature

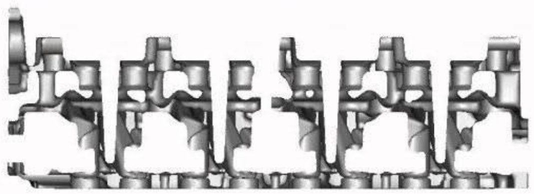
Transition – Leidenfrost Temperature

Water Temperature

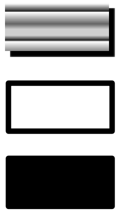


MODEL APPROACH FOR THE IMMERSION QUENCHING PROCESS

- Experiment

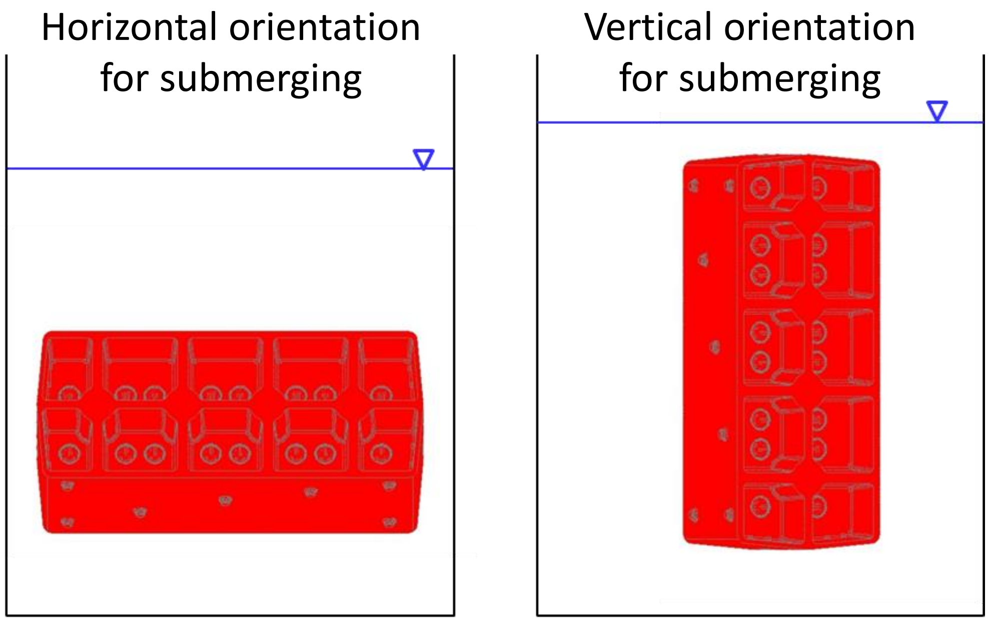


- AVL FIRE™ - Results



TEST GEOMETRY FOR VALIDATION PURPOSE

- FVV Project “Quench IT” with partner **NEMAK**
- The numerical approach has been validated against measured data
- Sample represents an abstraction of a cylinder head
- Capturing of orientation effects and coolant temperature effects

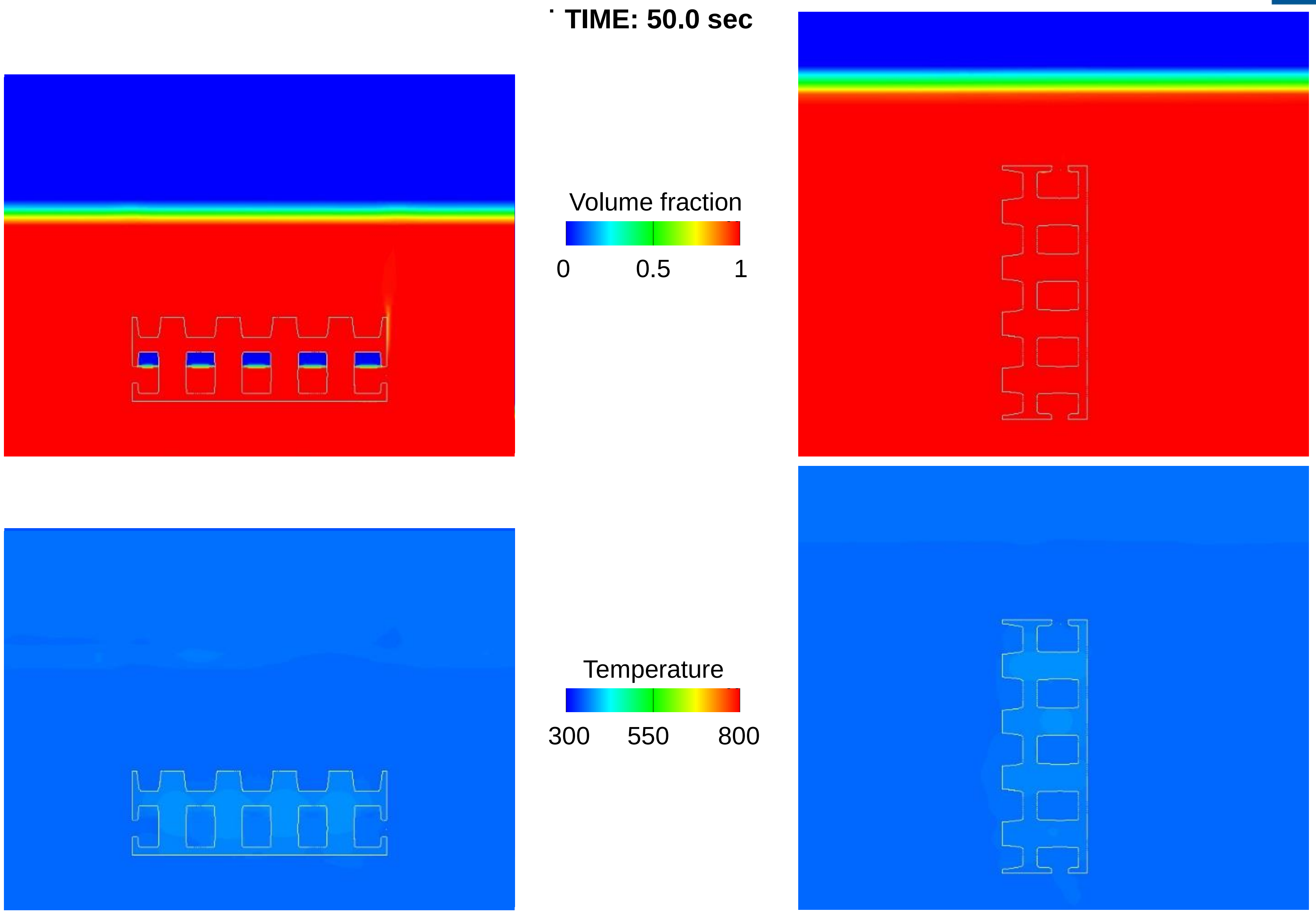


ORIENTATION EFFECT – CFD RESULTS

Side view VF

Side view TEM

Uniform cooling

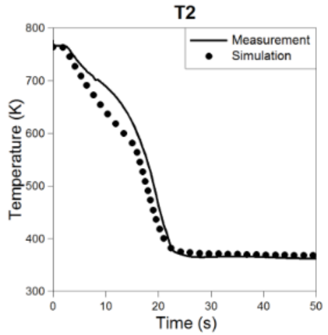


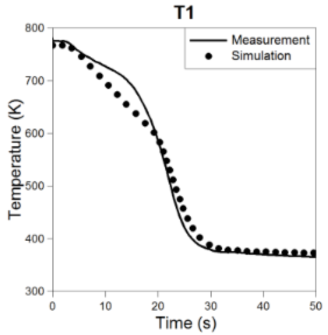
Non- uniform cooling

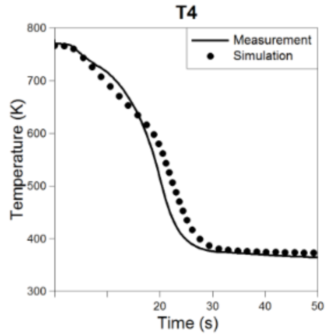
ORIENTATION EFFECT – CFD RESULTS

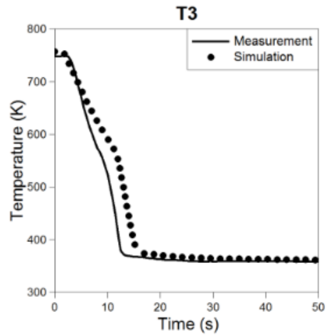
- **Horizontal** orientation

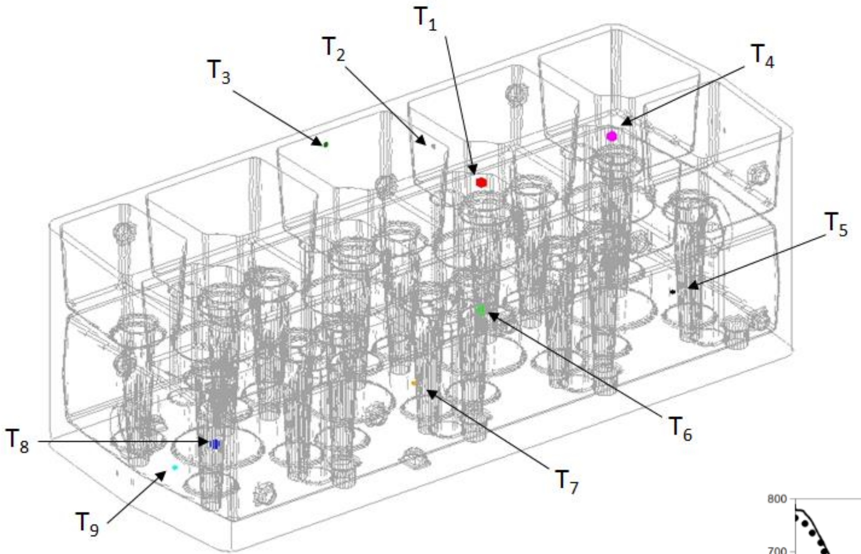
Measurement
Simulation

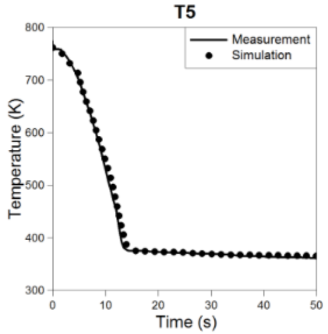


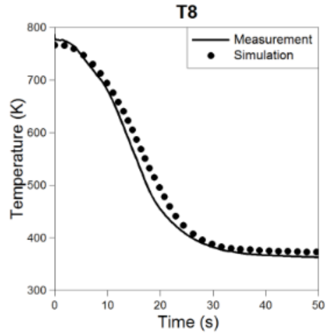


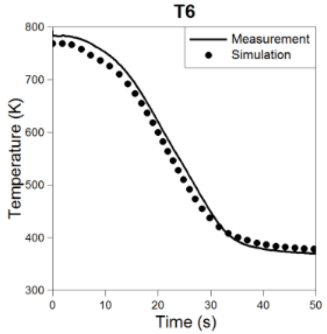


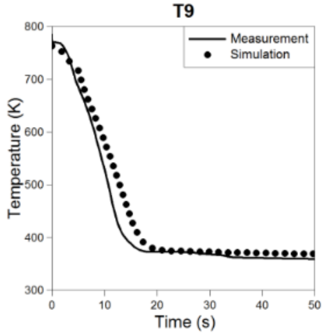


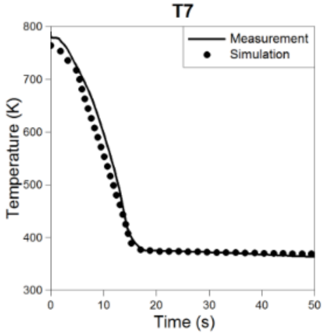










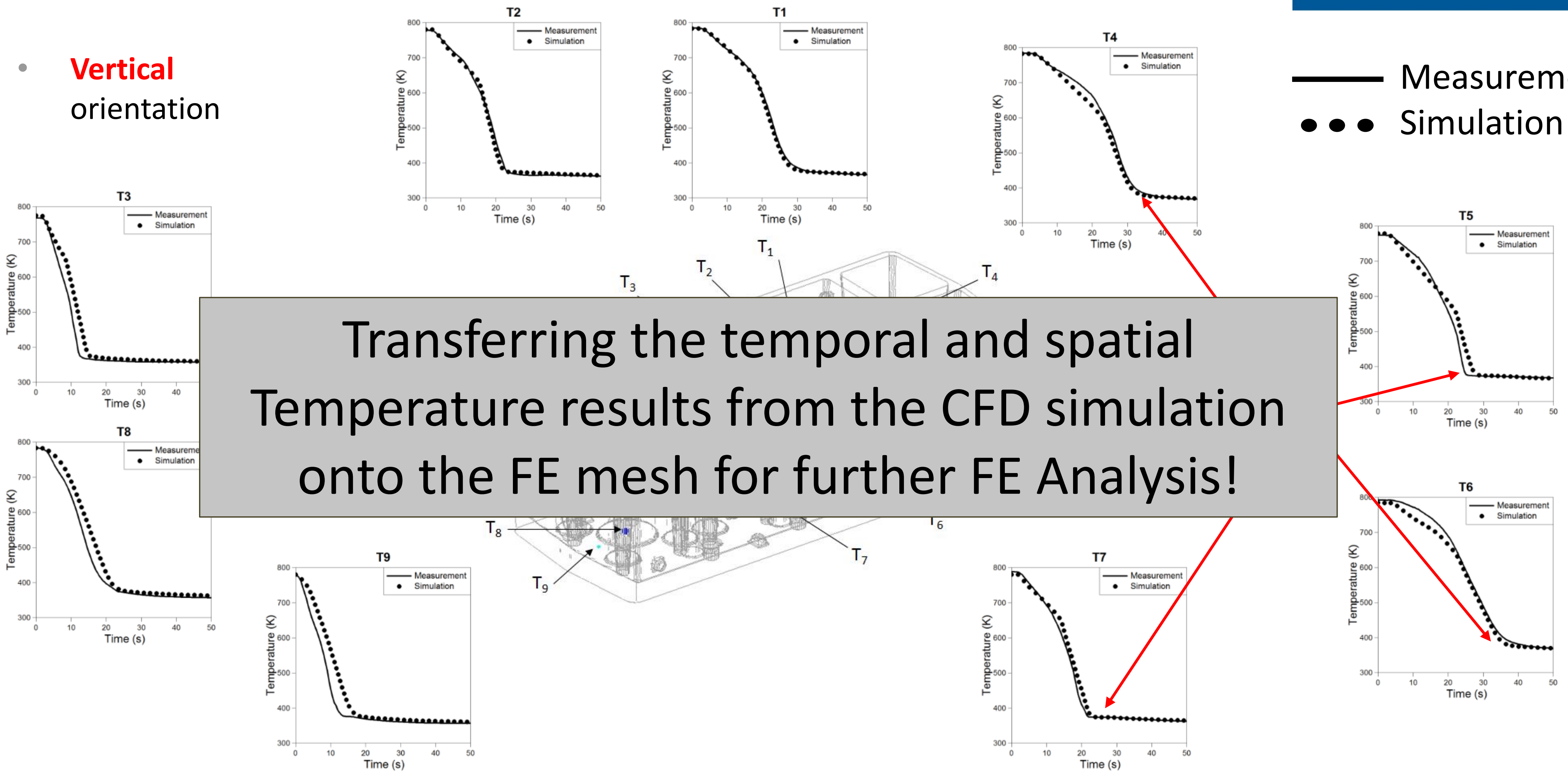


ORIENTATION EFFECT – CFD RESULTS

- **Vertical** orientation

Measurement

Simulation



Transferring the temporal and spatial Temperature results from the CFD simulation onto the FE mesh for further FE Analysis!

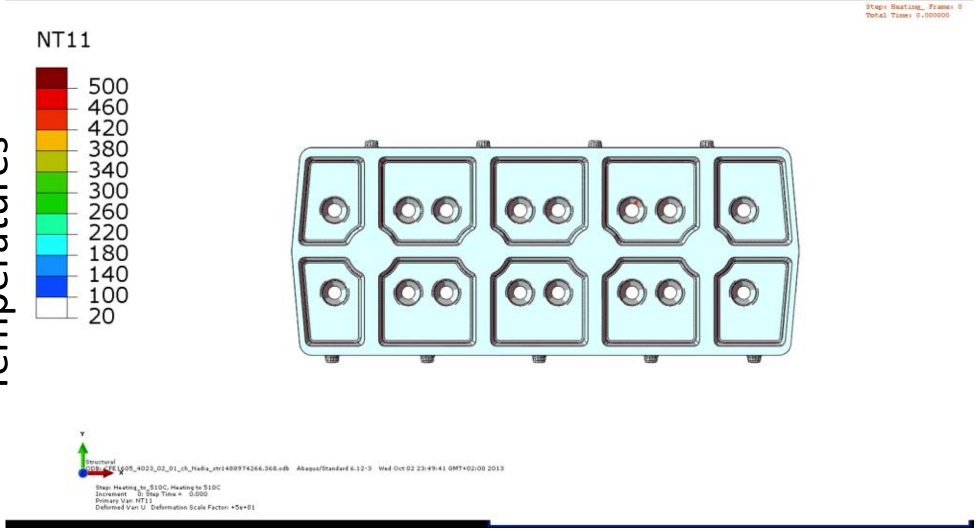
TRANSIENT SIMULATION RESULTS FROM FE-ANALYSIS

Visco-plastic stress strain analysis

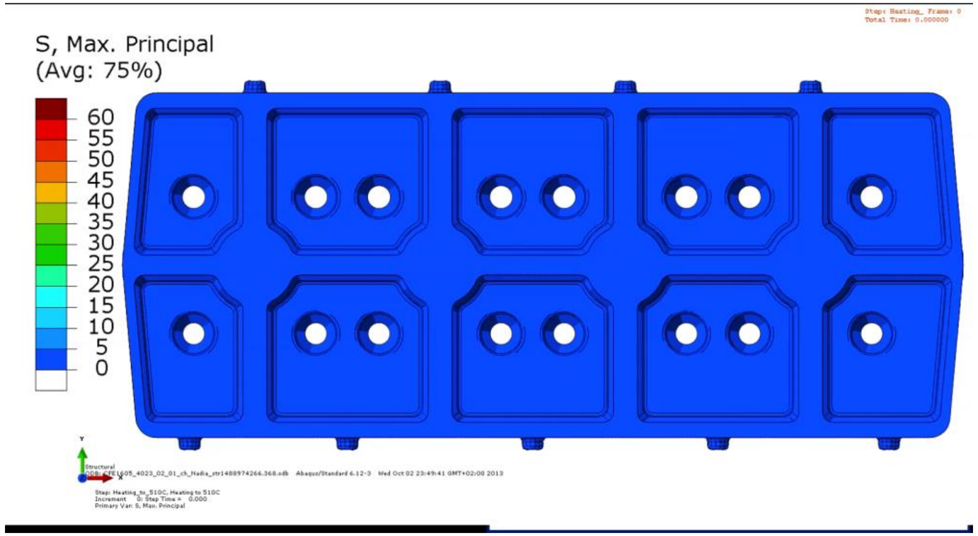
TRANSIENT SIMULATION RESULTS FROM FE-ANALYSIS

Horizontal Dipping Direction

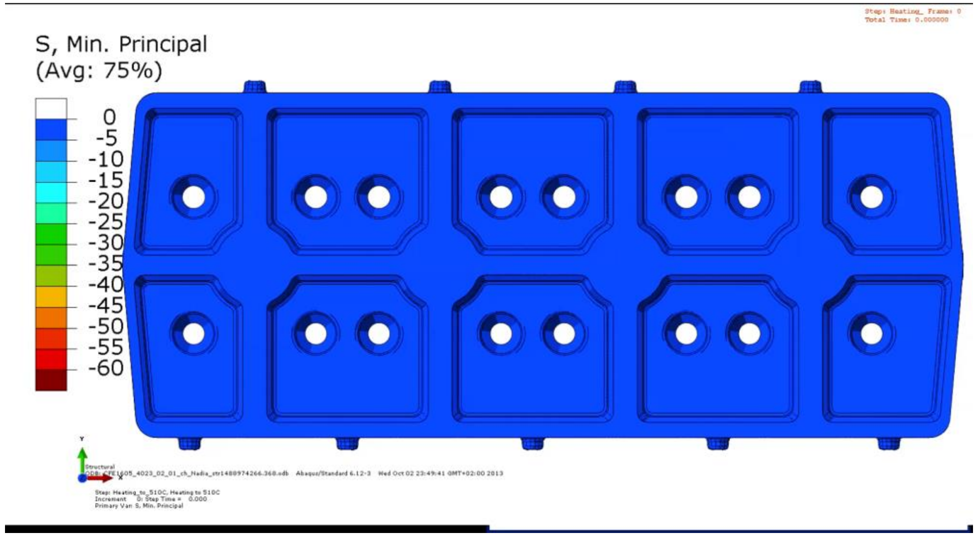
Temperatures



Tensile Stresses



Comp. Stresses



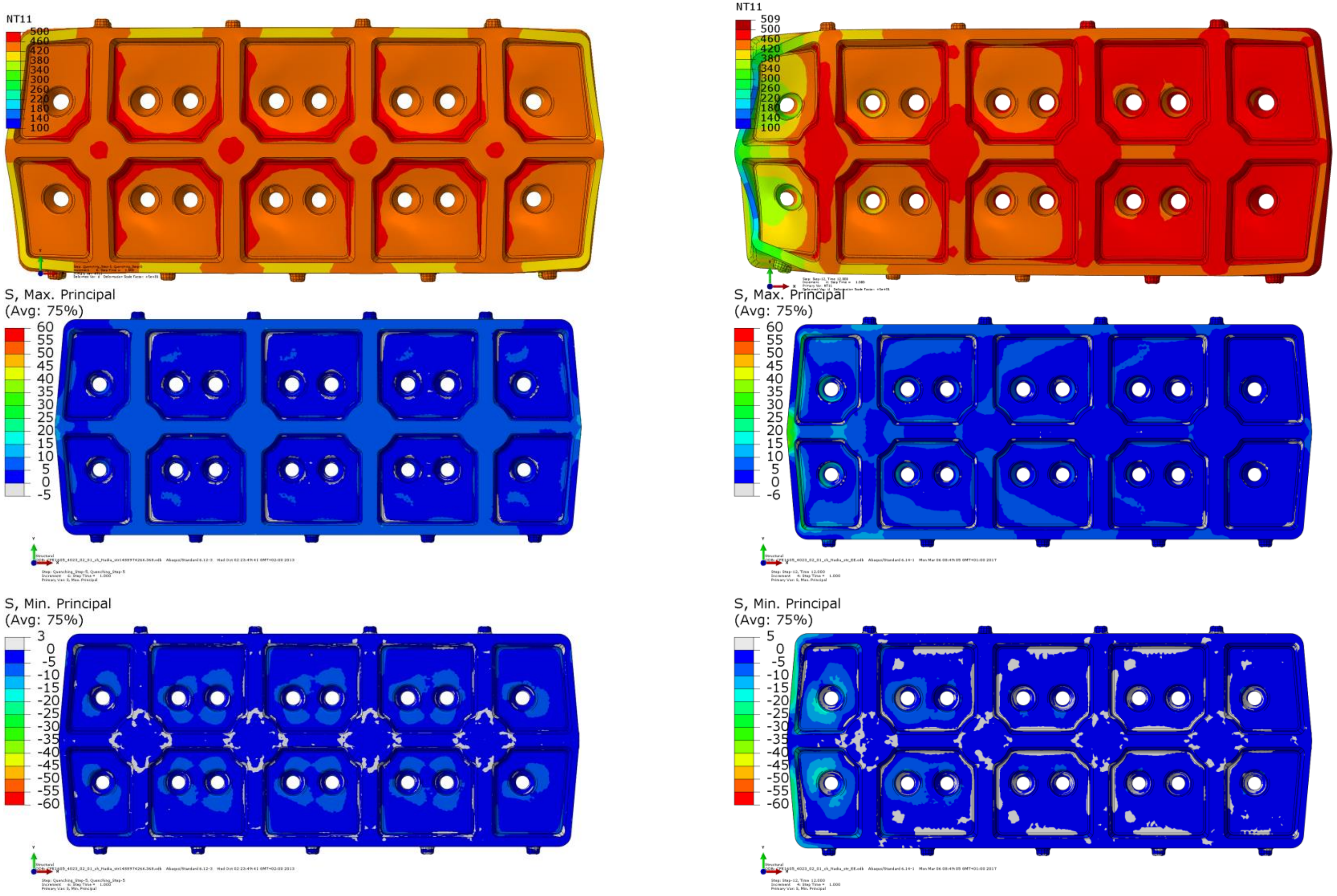
TRANSIENT SIMULATION RESULTS FROM FE-ANALYSIS

Horizontal Dipping Direction | **Vertical Dipping Direction**

Temperatures

Tensile Stresses

Comp. Stresses



Time t = 5 s

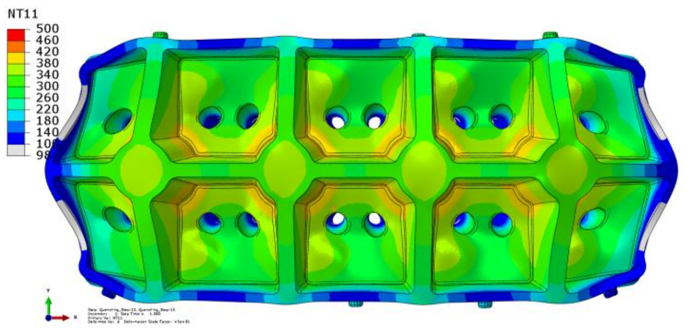
Scaling factor for deformation: 50

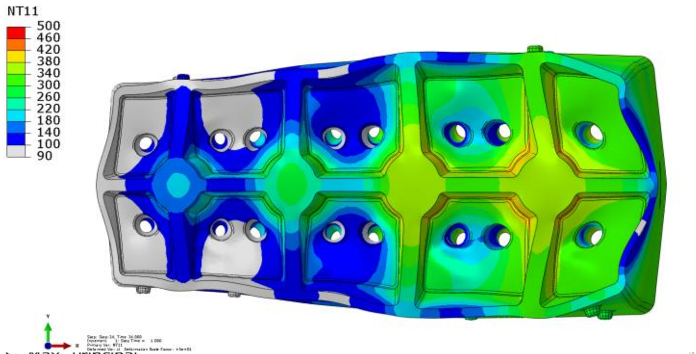
TRANSIENT SIMULATION RESULTS FROM FE-ANALYSIS

Horizontal Dipping Direction | **Vertical Dipping Direction**

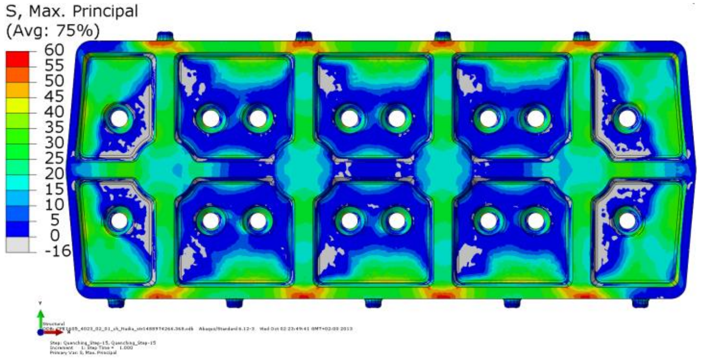
Time t = 15 s

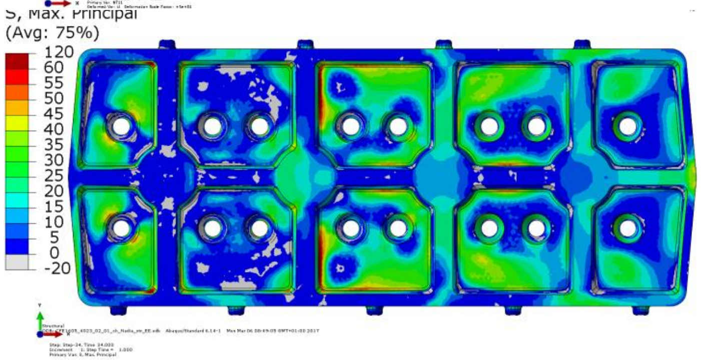
Temperatures



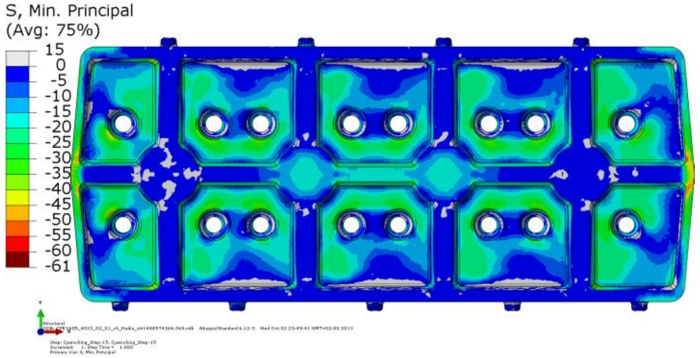


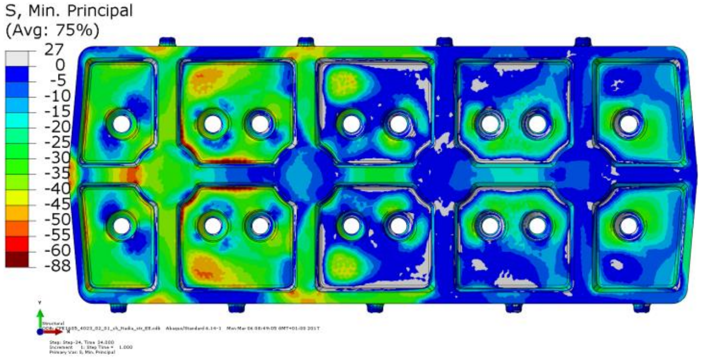
Tensile Stresses





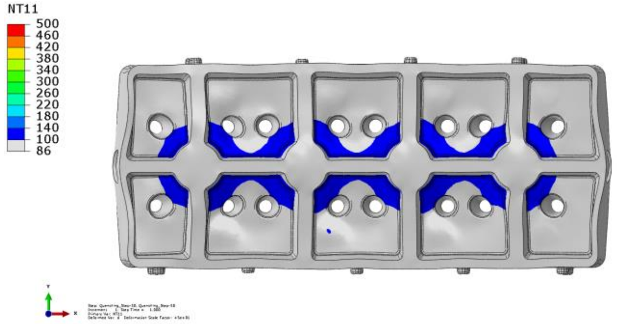
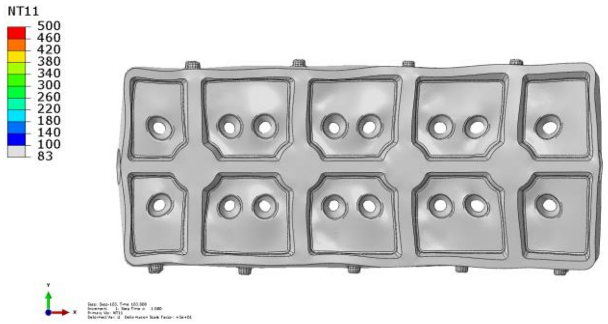
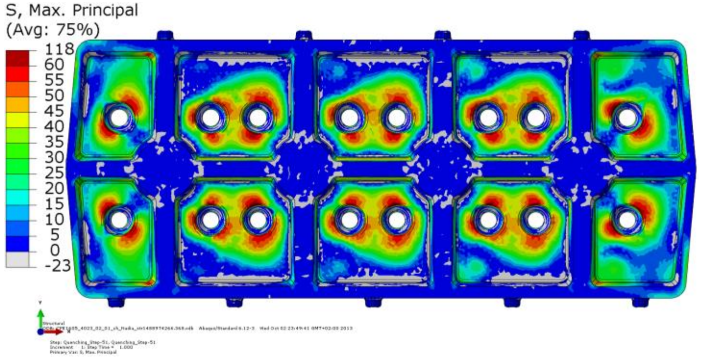
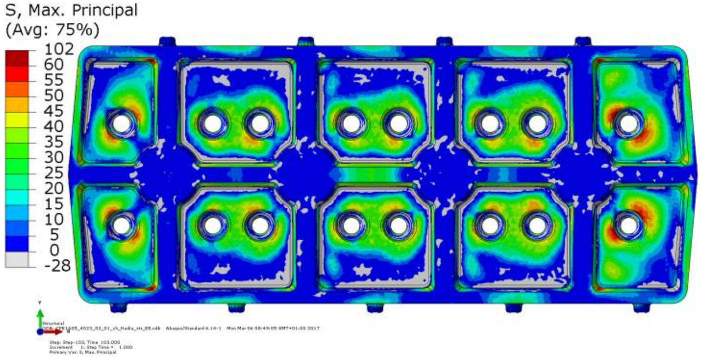
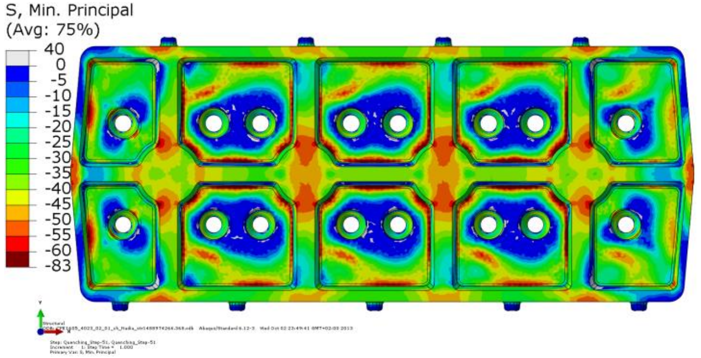
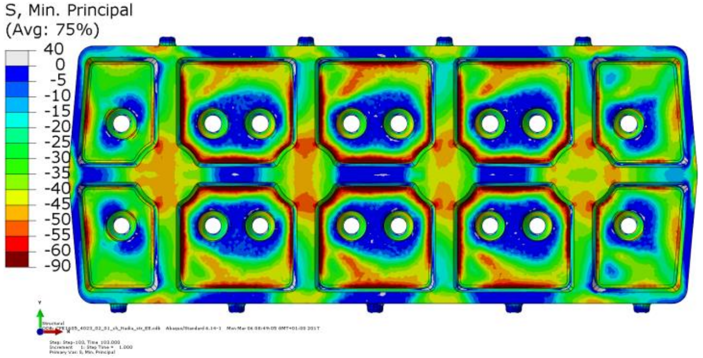
Comp. Stresses





Scaling factor for deformation: 50

TRANSIENT SIMULATION RESULTS FROM FE-ANALYSIS

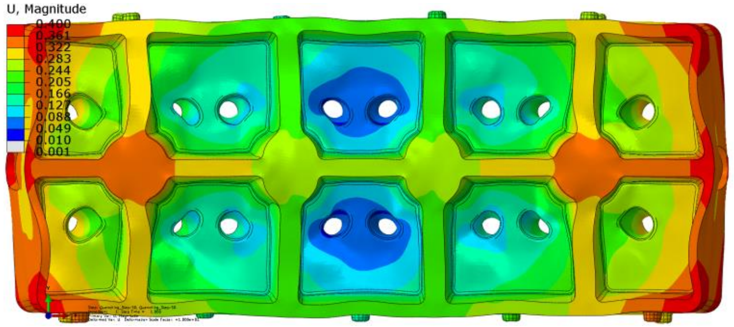
	Horizontal Dipping Direction	Vertical Dipping Direction
Temperatures		
Tensile Stresses		
Comp. Stresses		

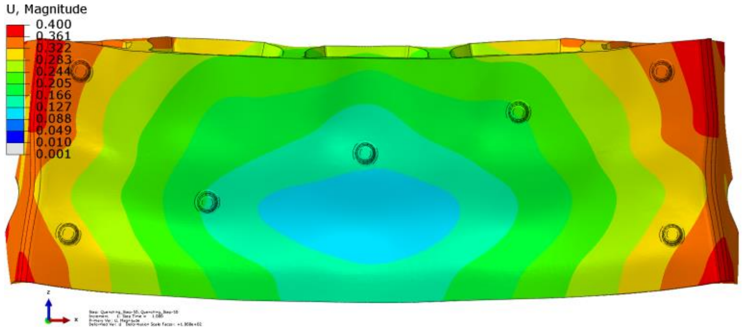
Time *t* = 50 s

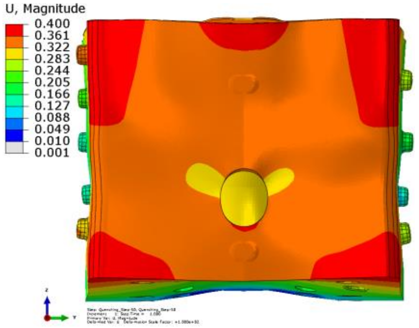
Scaling factor for deformation: 50

TRANSIENT SIMULATION RESULTS FROM FE-ANALYSIS

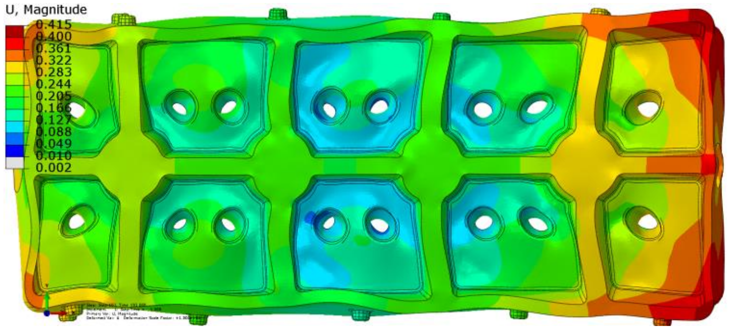
Horizontal Dipping Direction

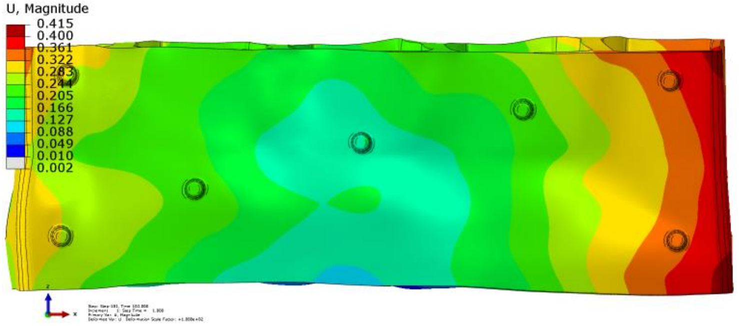


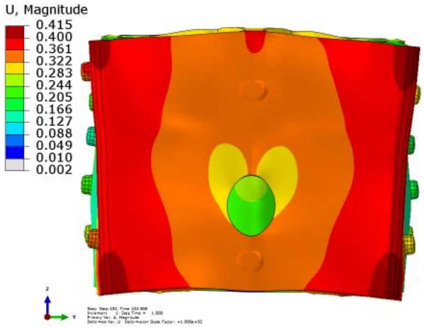




Vertical Dipping Direction



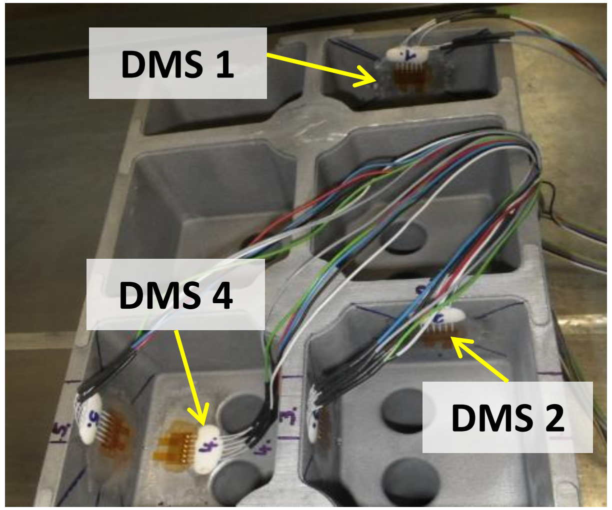


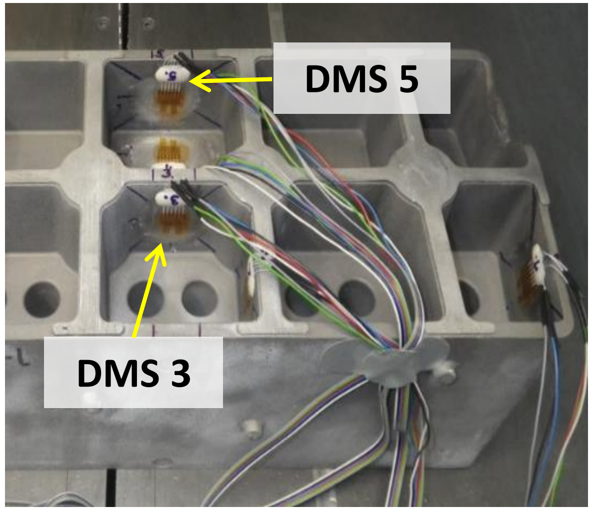


Time *t* = 50 s

Scaling factor for deformation: 50

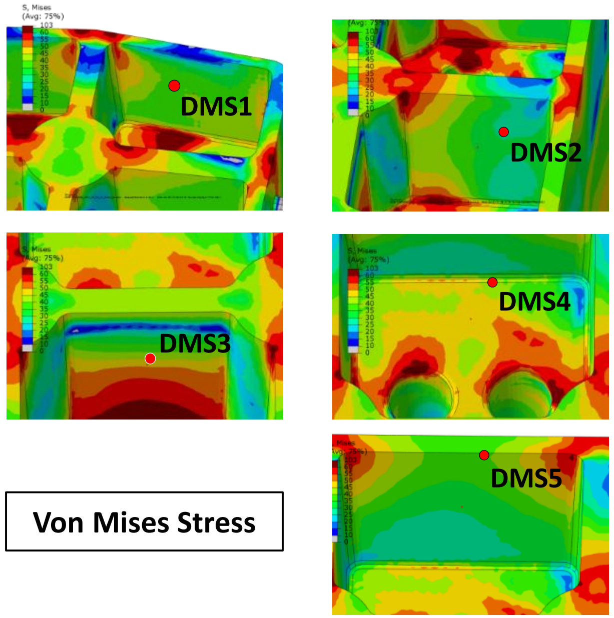
TRANSIENT SIMULATION RESULTS FROM FE-ANALYSIS

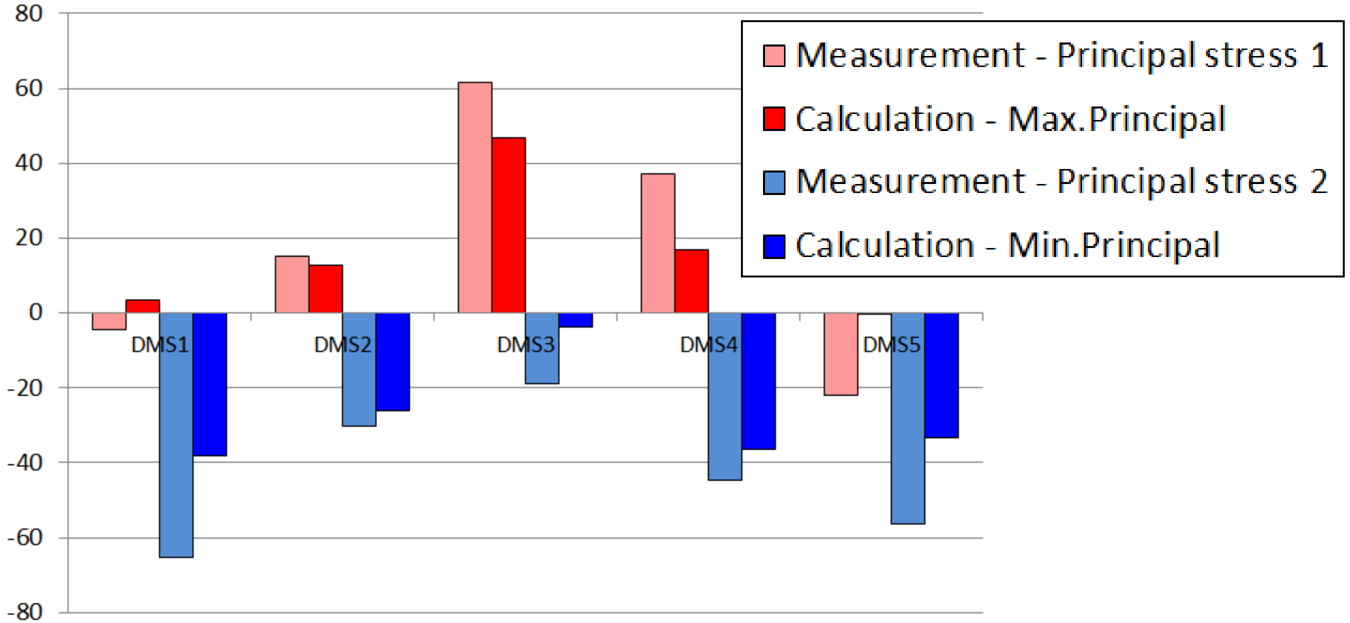




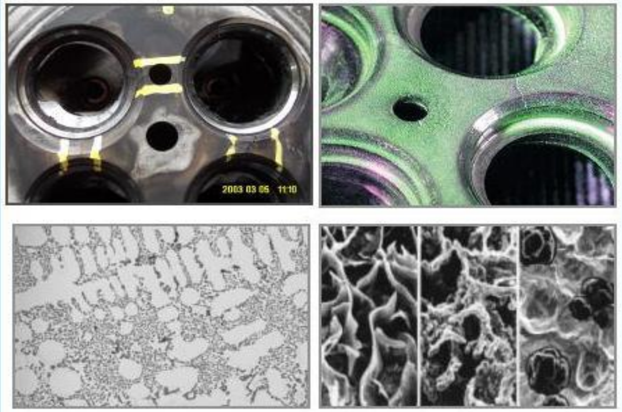
- Comparison with measurement for horizontal orientation

Qualitative good agreement

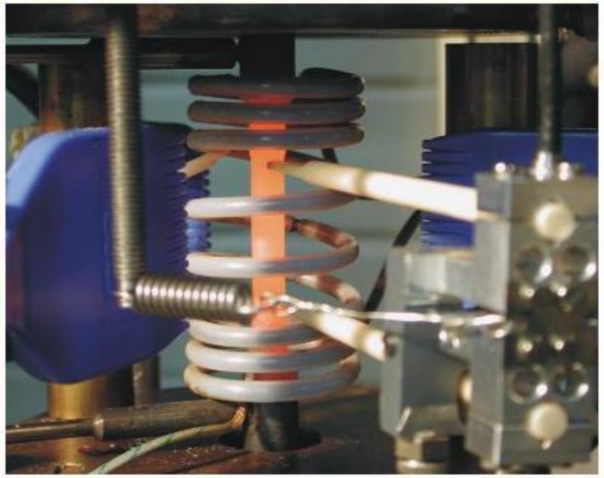




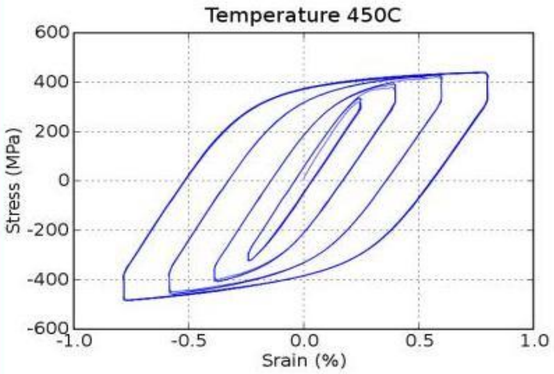
MATERIAL MODEL PARAMETER IDENTIFICATION



Input / Model



Analysis



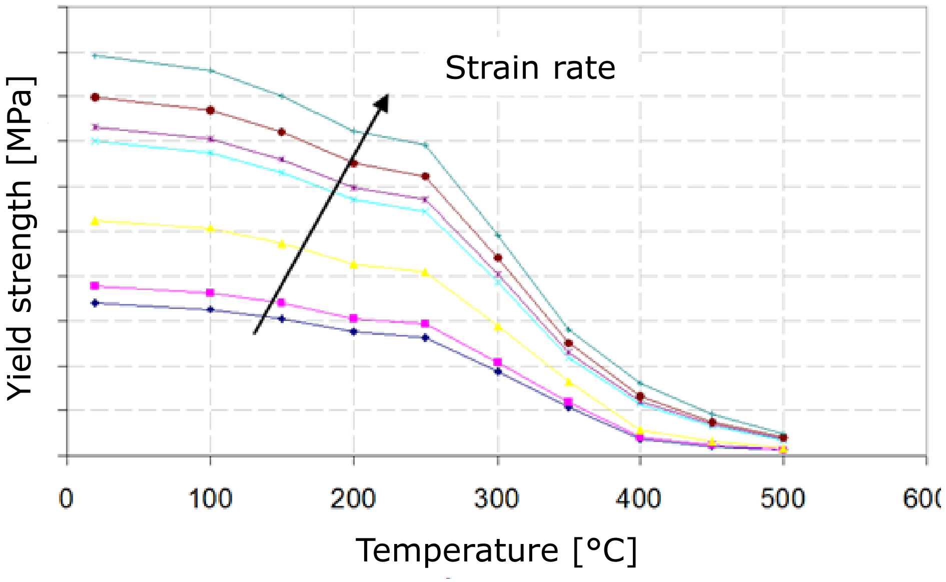
Results

Development value

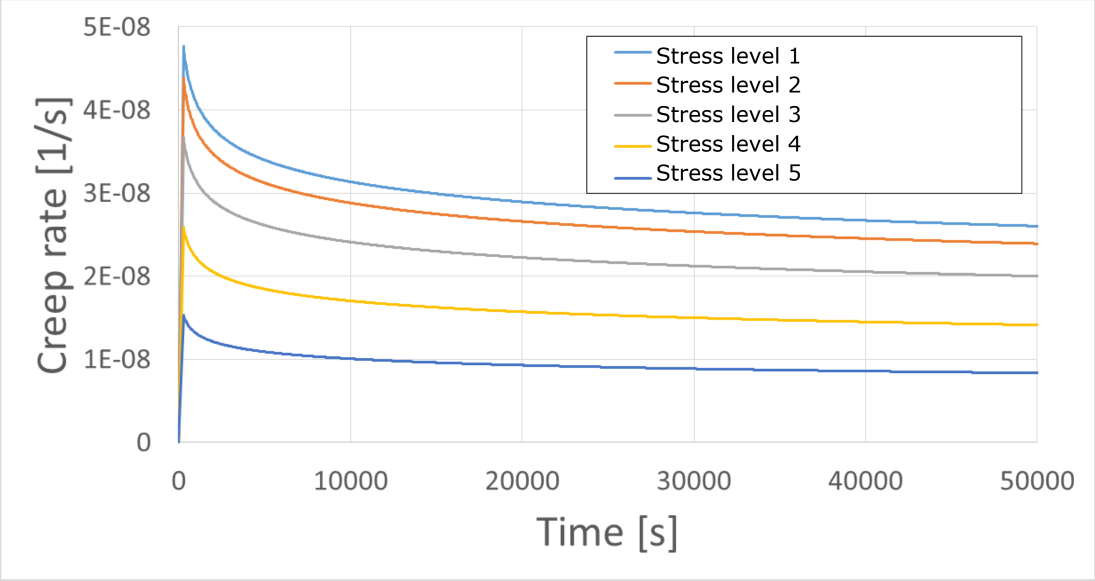
- ❑ Database with detailed test results from hardening and creep for quenching available.
- ❑ Experience with external partners to measure new materials.
- ❑ Experts to implement new materials / material models.

INFLUENCING PARAMETERS FOR MATERIAL MODELING WITH FOCUS ON QUENCHING

Strain rate dependency on yield

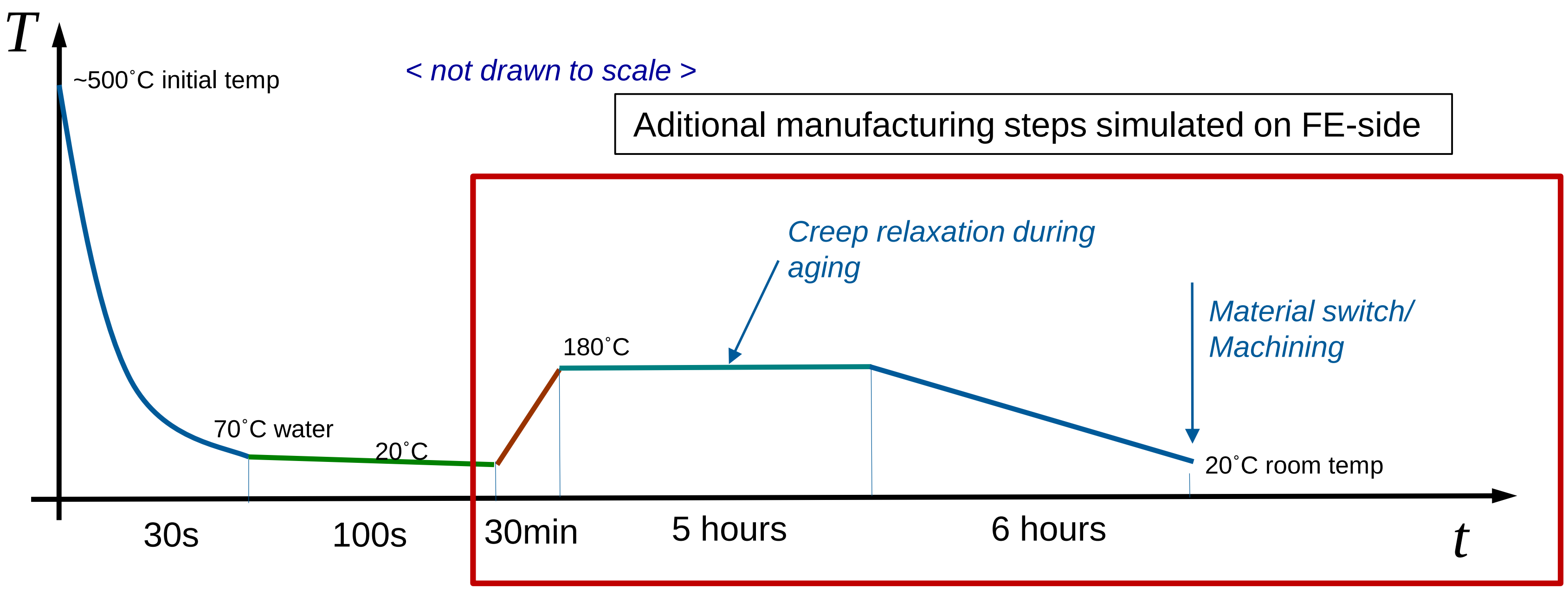


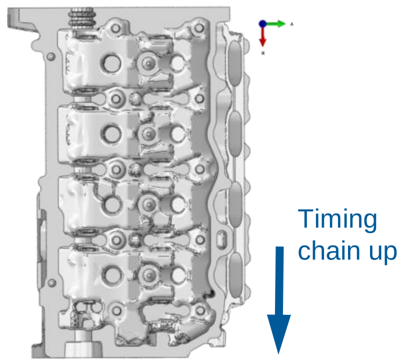
Creep relaxation during aging



TIME HISTORY OF HEAT TREATMENT WITH MACHINING STEP AT END

Temperature time history plot for a aluminum cylinder head

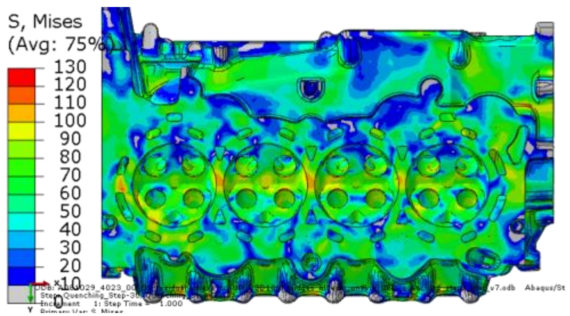




INFLUENCE OF DIPPING DIRECTION AND MATERIAL ON THE STRESS AND DEFORMATION

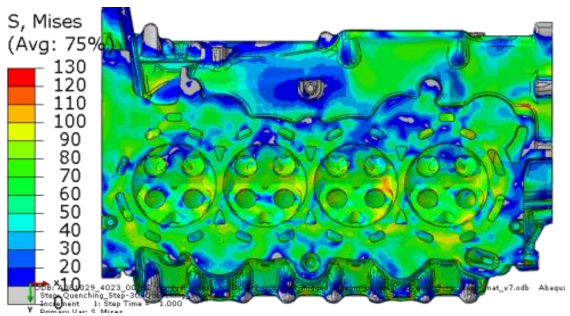
Dipping direction TC up

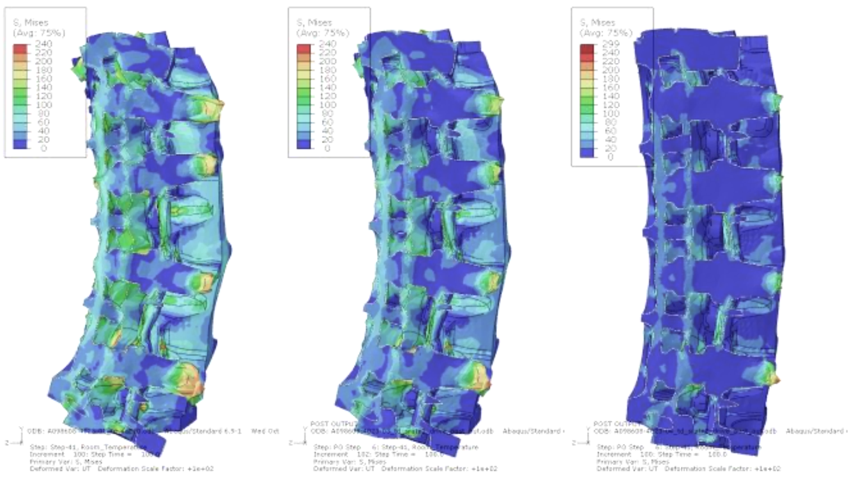
Time = 30 s



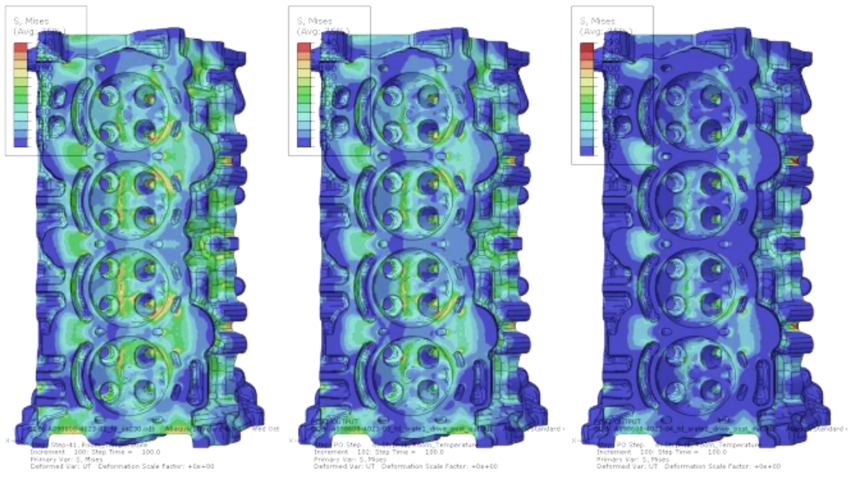
Dipping direction TC down

Time = 30 s





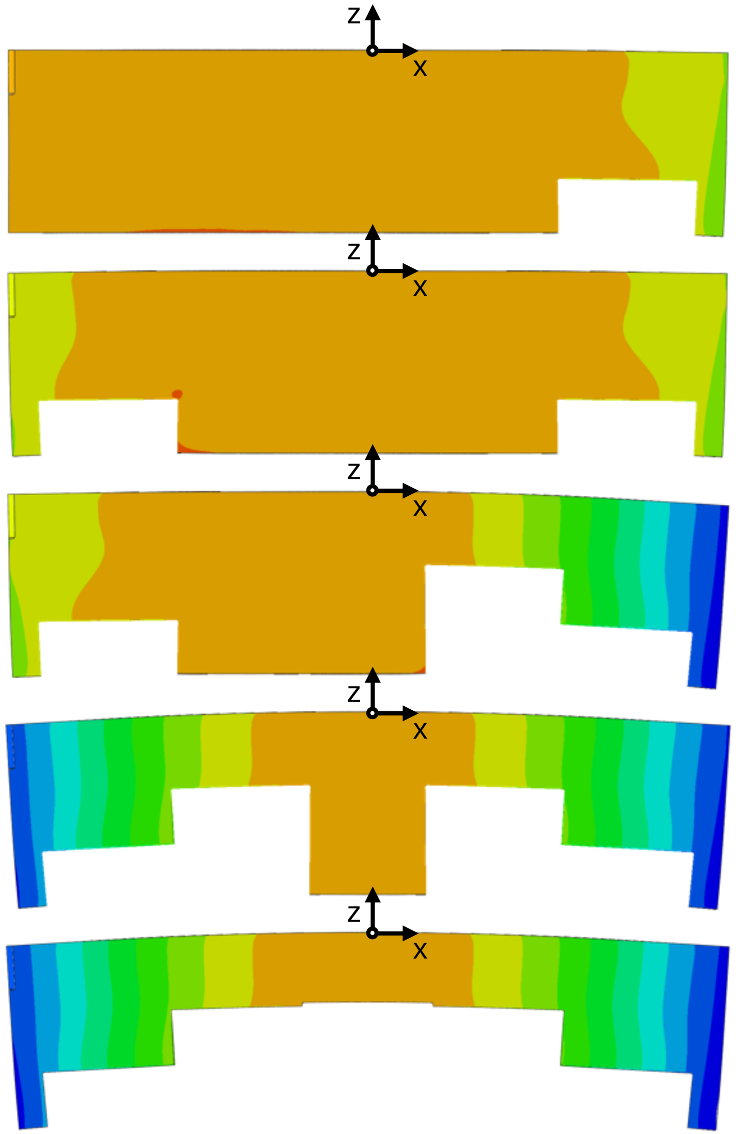
Basic material | material 1 | material 2



Basic material | material 1 | material 2

INFLUENCE OF MACHINING AND MACHINING ORDER ON THE DEFORMATIONS

AVL



1. Machining step

2. Machining step

3. Machining step

4. Machining step

5. Machining step

SUMMARY

- AVL offers a unique single-shot quenching simulation approach
- Simulation of any quenched metal parts is possible
- Direct, air and spray quenching can be considered
- Prediction of residual stresses and deformations for design and optimization of the thermal treatment process

The methodology has matured and has been proven!

ANY QUESTIONS?

Please do not hesitate to contact us:

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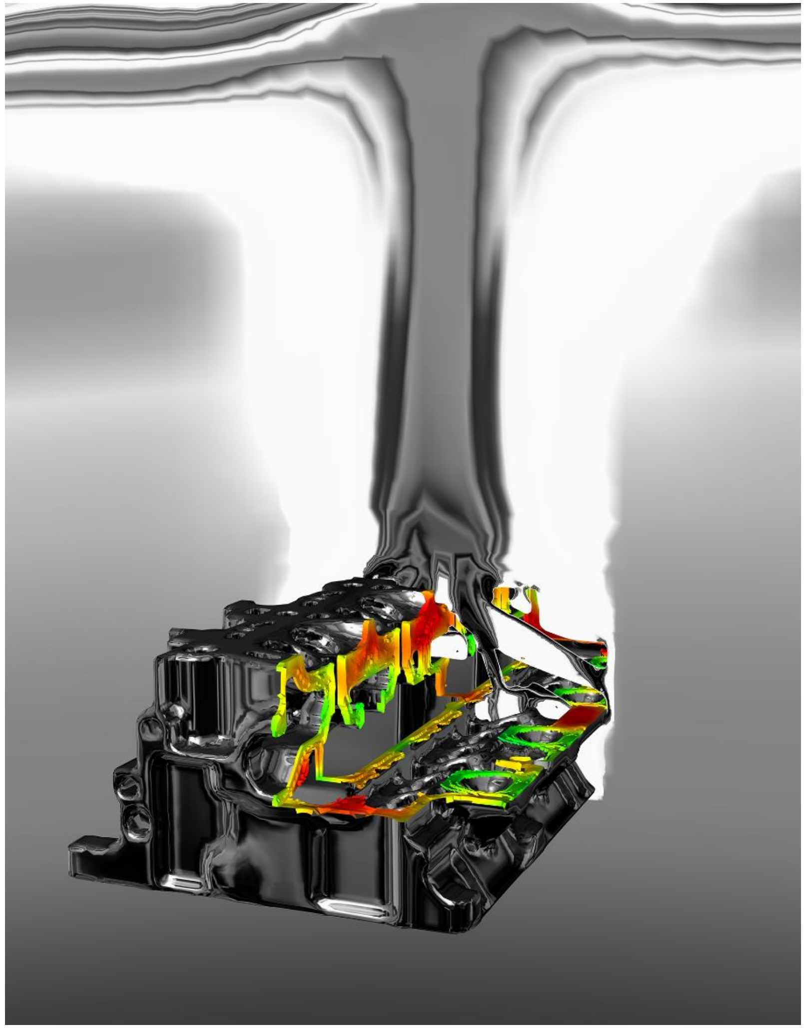


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