# Cylinder Head

a computational fluid dynamics and structural mechanics challenge

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# Outline

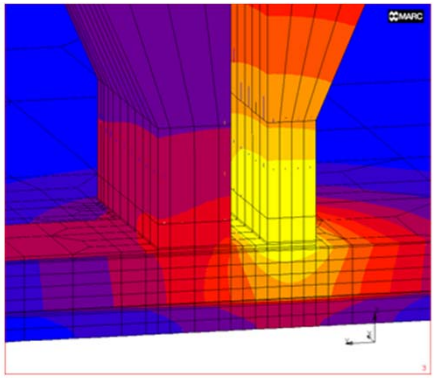
- PRETECH GmbH
- Temperature and pressure distribution with Autodesk Simulation CFD
- Forces and stresses with Creo Simulation
- Conclusions

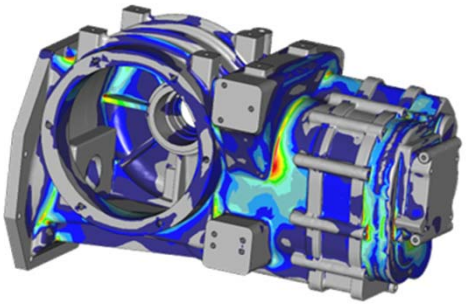
# PRETECH Predictive Design Technologies GmbH

- Managing Director: Dr.-Ing. Stefan Reul
- Foundation: End of 1992
- Internet: www.pretech.de
- Cooperations
  - **Reseller for PTC** (Parametric Technology), Needham, MA, USA
- Memberships:
  - **Hanse-Aerospace e.V.**
  - **CAE-Forum**
  - **Hanse Supplier**

# Our services for you !

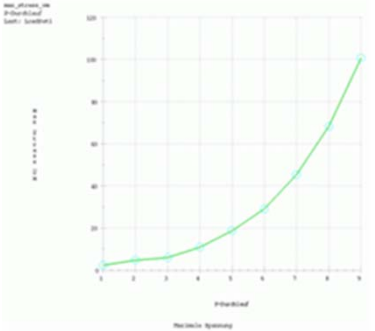
- **HighEnd Engineering** for e.g. Aerospace, Automotive, Medical, Mechanical Engineering, Electronics, etc.
- **Computations and Simulations** with Creo Simulate, Autodesk Simulation CFD, ABAQUS explicit and Creo Parametric MDO/MDX for static, thermal, dynamical, kinetic, fluid dynamics, etc. problems
- **Reseller for PTC** Simulation Codes: Creo Simulate, Fatigue Advisor, Plastic Advisor, MDX/MDO, etc.

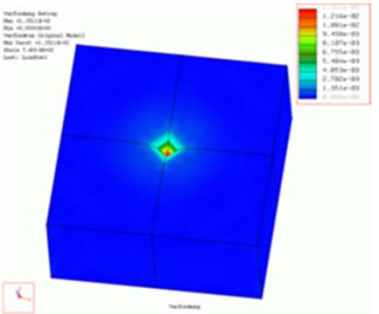




# Our services for you II

- **Trainings/consulting** (some courses also in english):
  - „**Virtual Mechanics**“
    (Basics of mechanics for future FEM users)
  - „**Validation of stresses** “
    (How must be FEM results validated eg. for endurance  strength ?, an introduction)
  - „**COMPOSITE|WORKS**“
    (Basiscs for the usage of laminates;, ‚design‘, ‚calculation‘, ‚production‘)
  - „**Trainings for Creo Simulate (MECHANICA)**“
    (also in cooperation with PTC)
  - „**Heat transfer**“
    (Opeartion with temperature fields and thermal strains)
  - „**MKS-System**“
    (Multi body-simulation with MDO/MDX)





# Cylinder Head

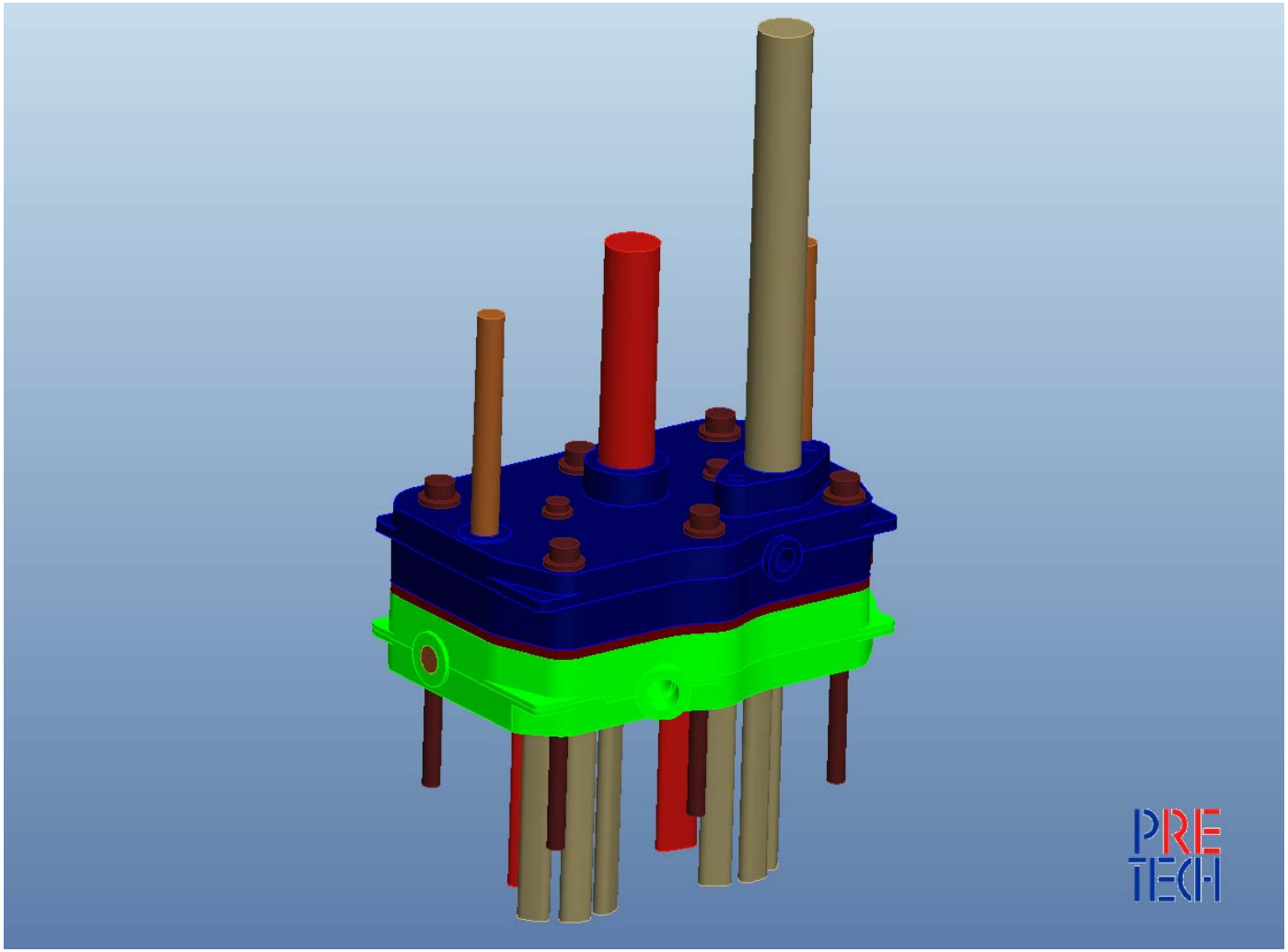
# Cylinder Head - Modeling

- Main objective: To determine the pressure distribution on the sealing surfaces of a compressor cylinder head with Autodesk Simulation CFD and Creo Simulate
- Additional objectives:
  - Details on the deformations and displacements of the cylinder head
  - Hits of potential problem areas
  - Informations about the influence of the initial load of the screws
  - Indications to the influence of pressure
  - Statements to the influence of temperature

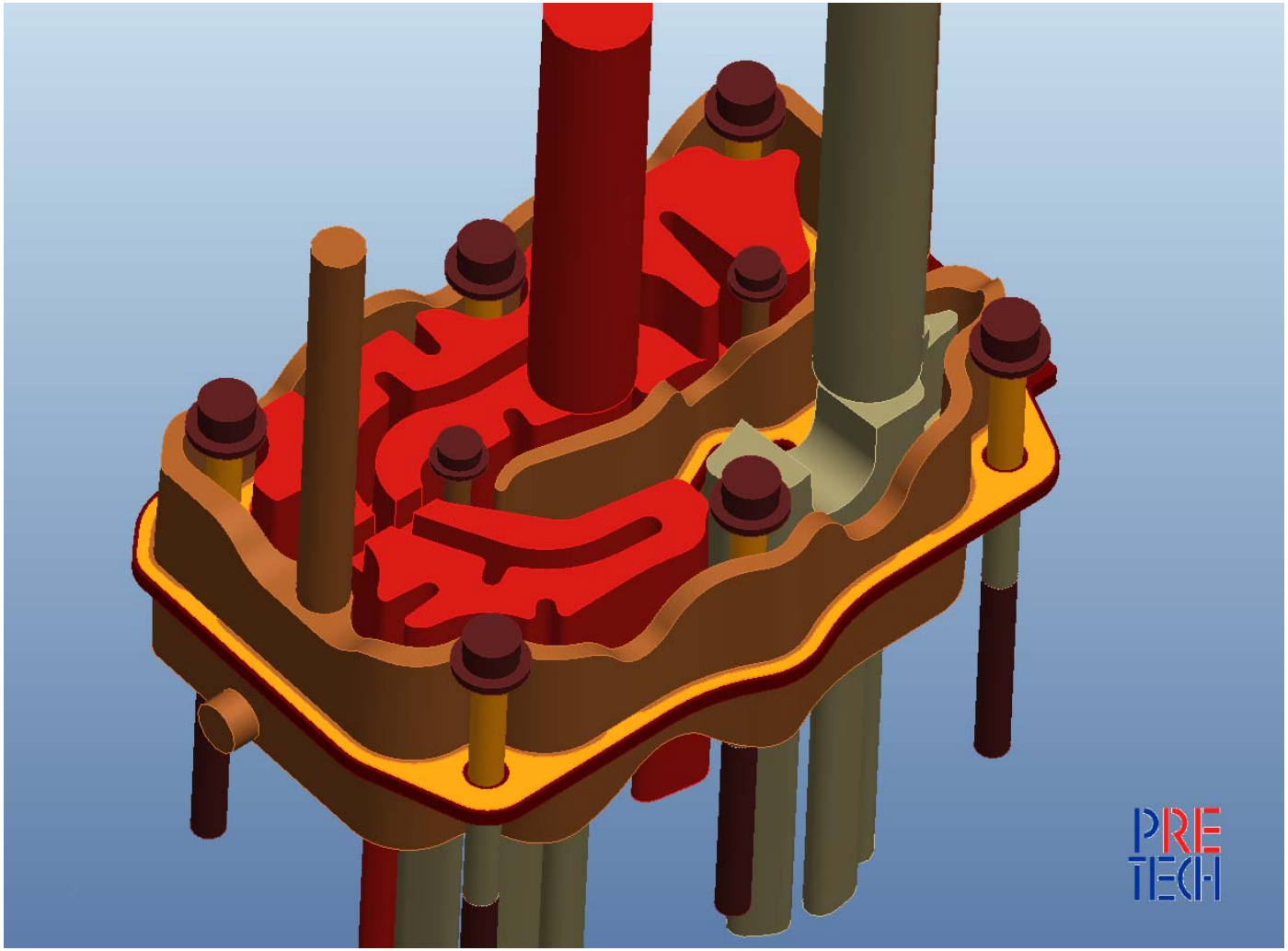
# Cylinder Head - Modeling

- Limitations:
  - "As simple as possible" start, closer examination only if necessary
  - The interface to the compressor housing is defined as completely flat
  - The heat generation inside the compressed air is simplified (heat source below the end plate, cooling with water)
  - Outer influences are neglected

# Cylinder Head – CFD-Model

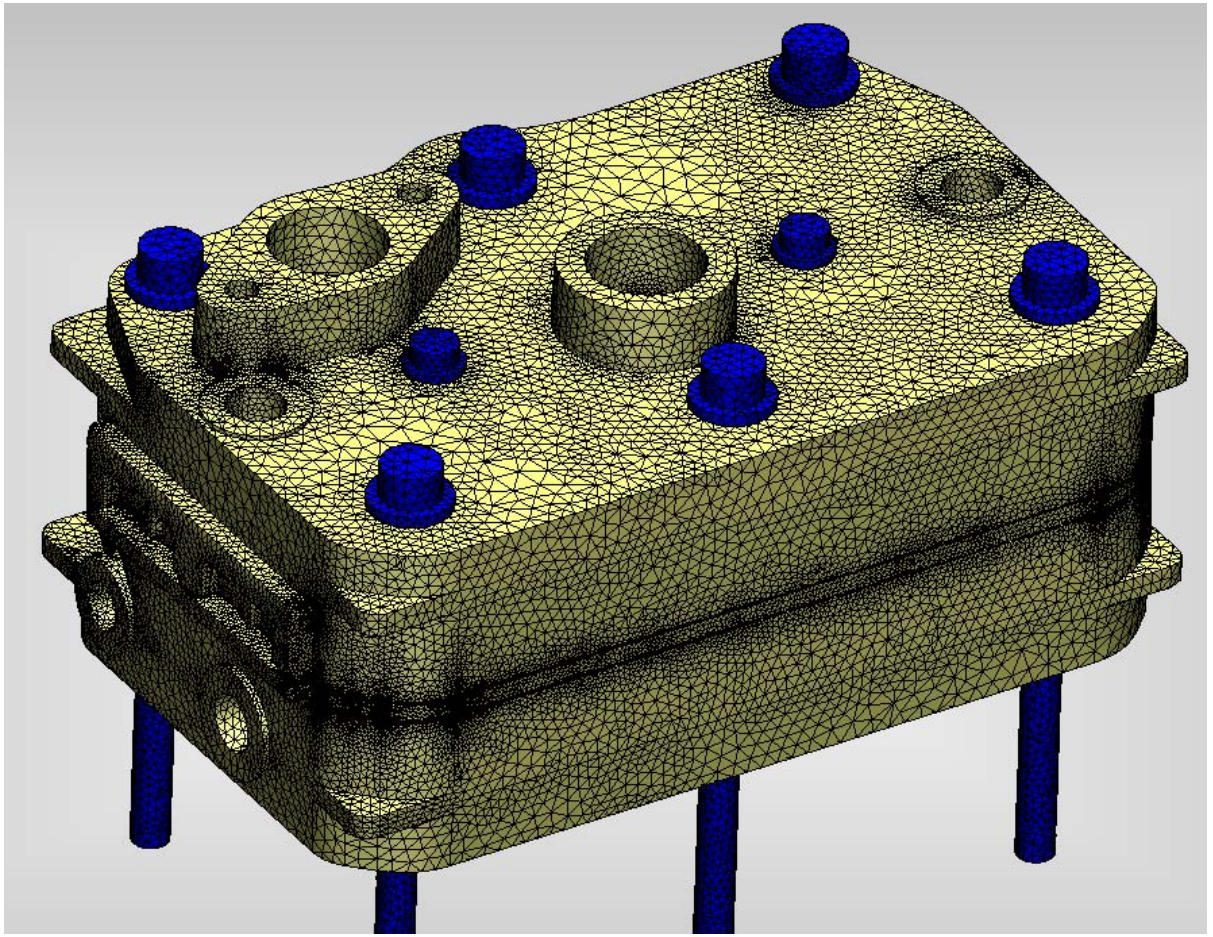


# Cylinder Head – CFD-Model



# Cylinder Head – CFD-Mesh

- CFD-Elements:
  - Solid: 11,069,154
  - Fluid: 8,762,587
  - Sum: 19,831,741



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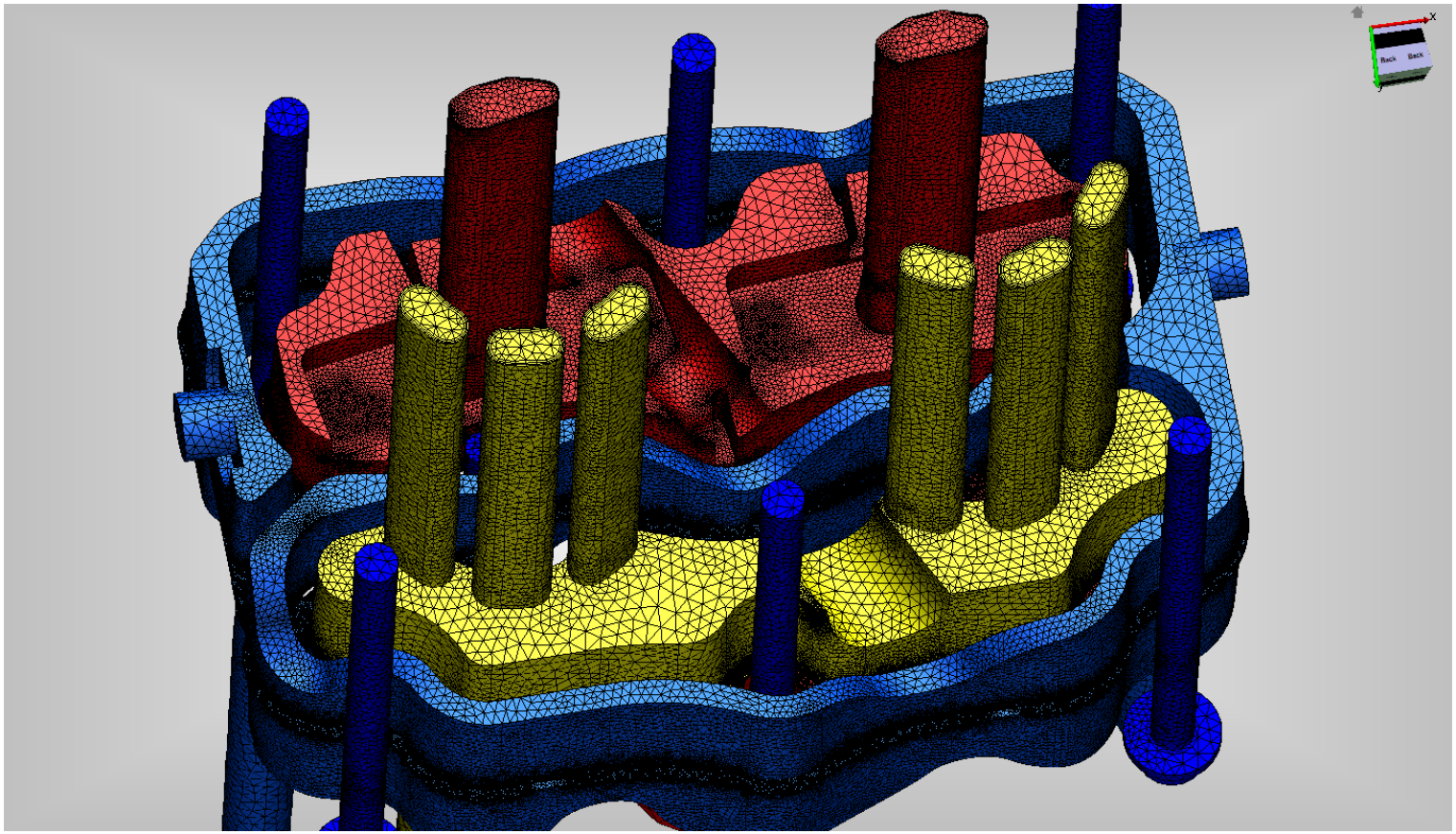

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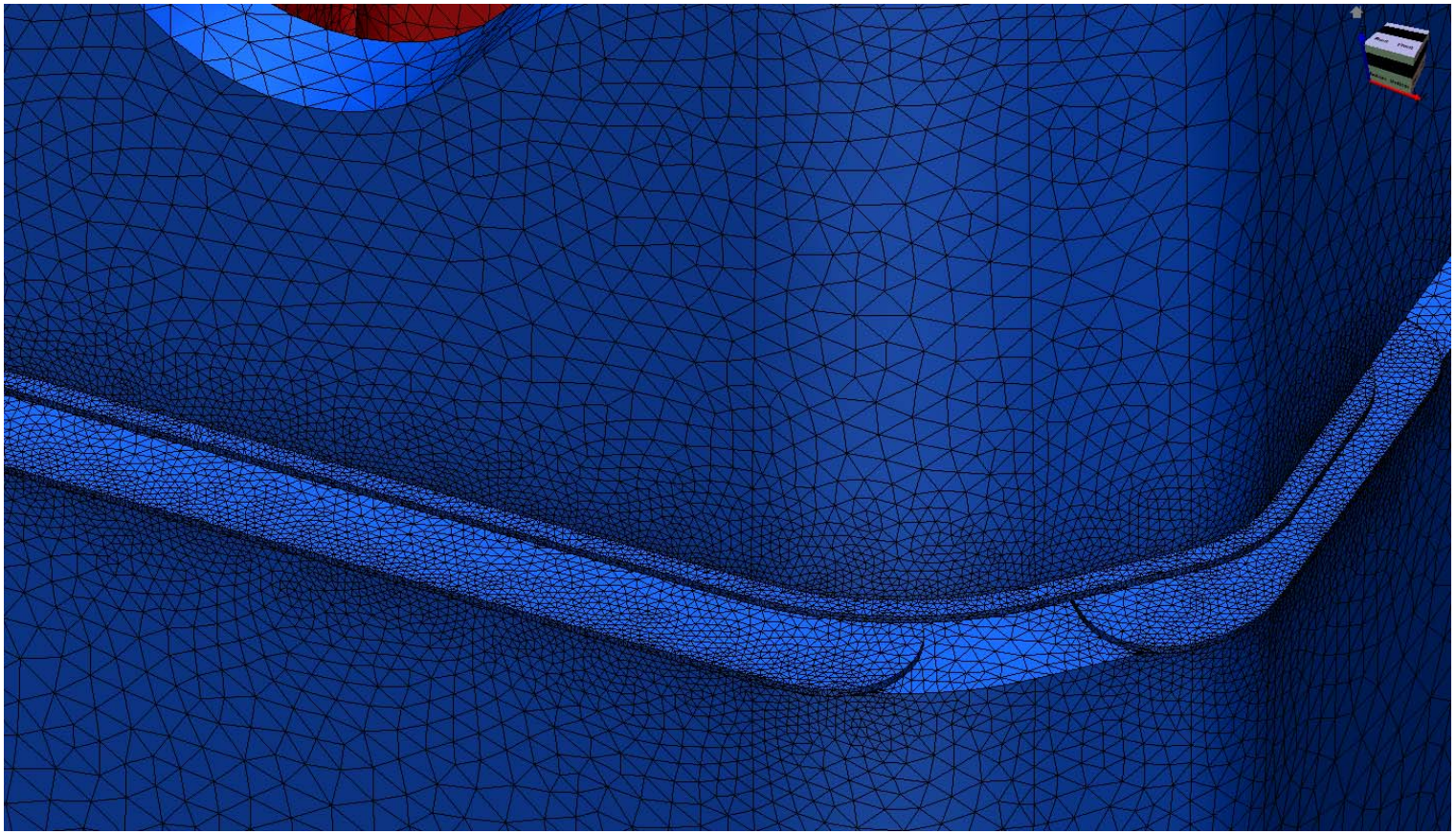
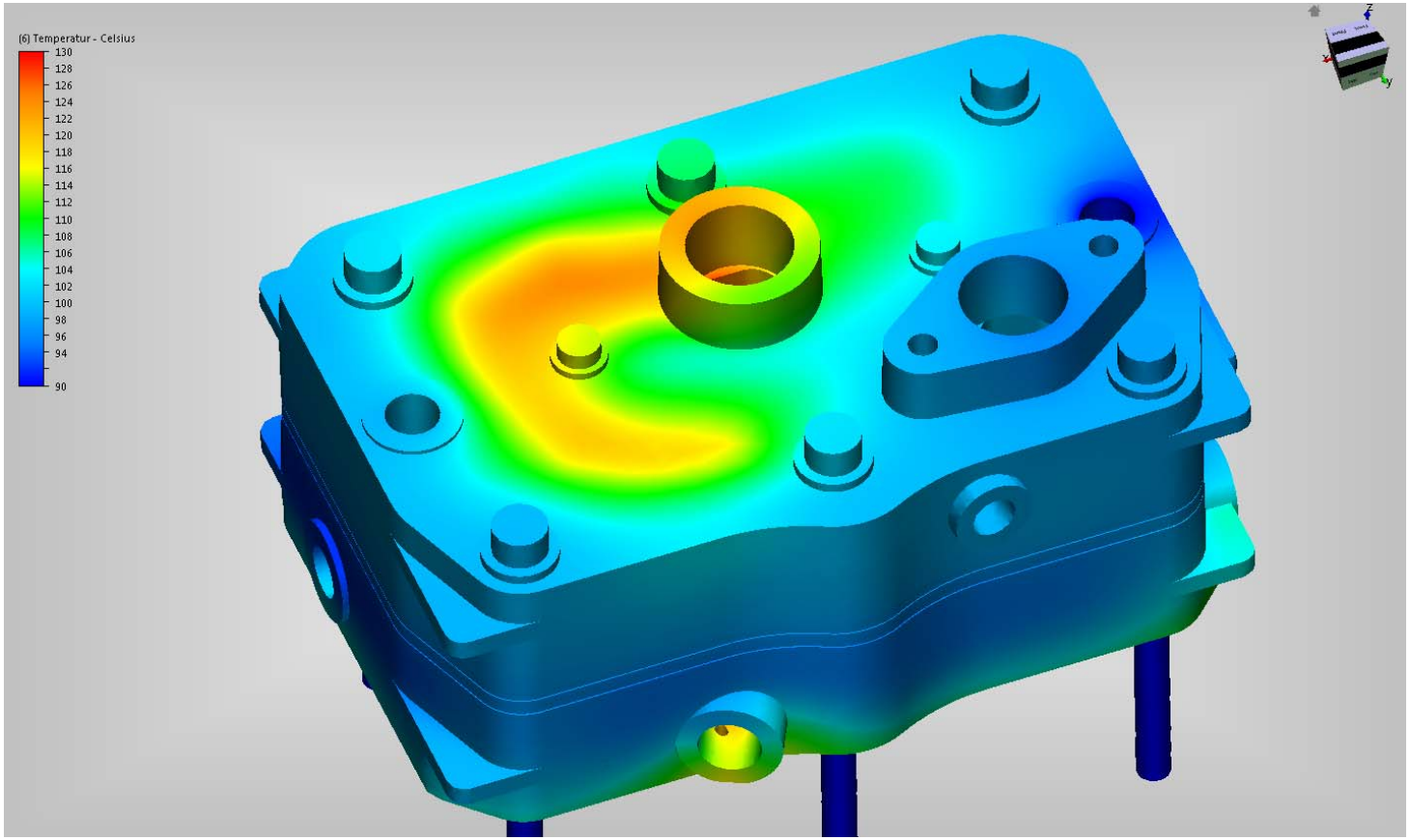


# Temperature distribution



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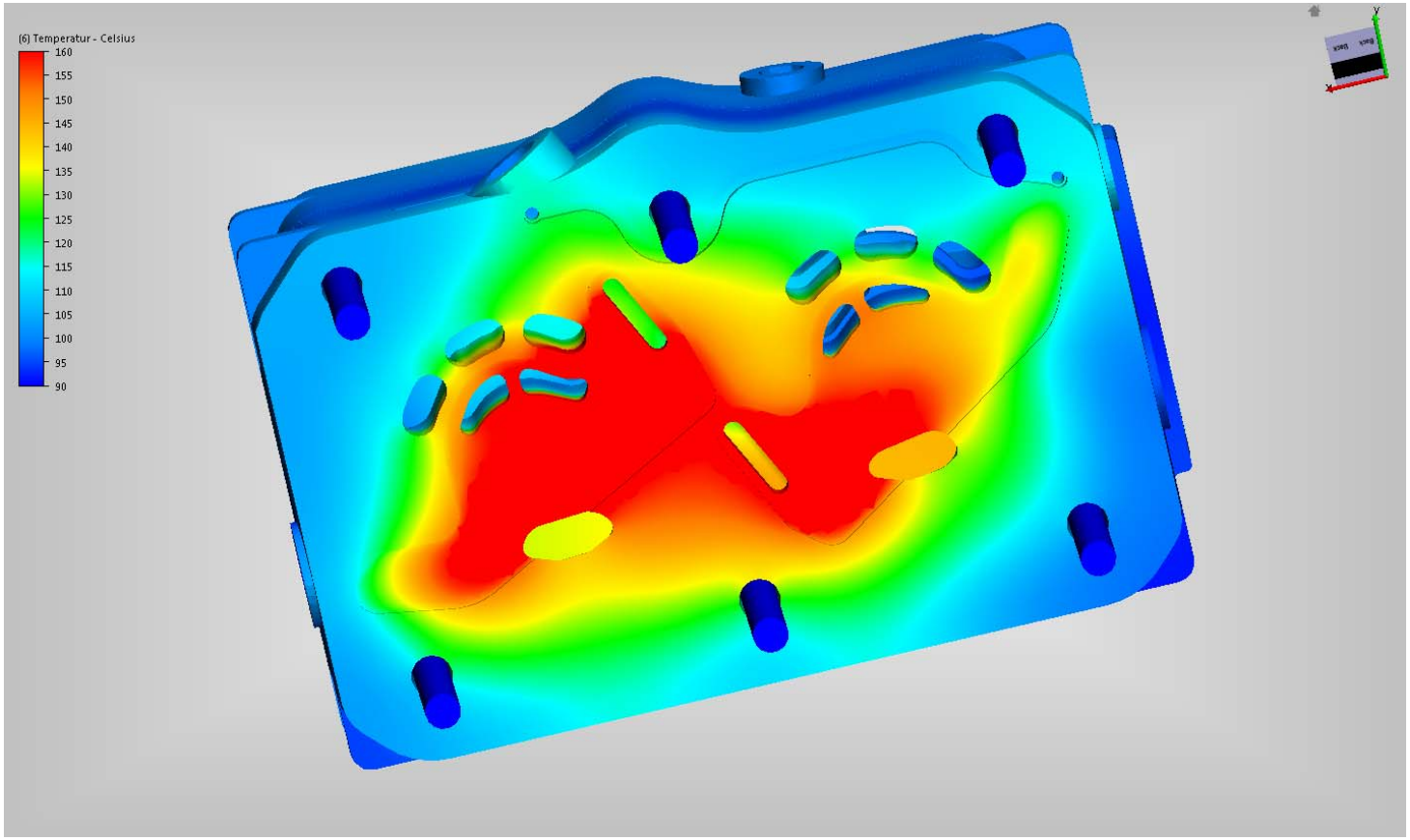

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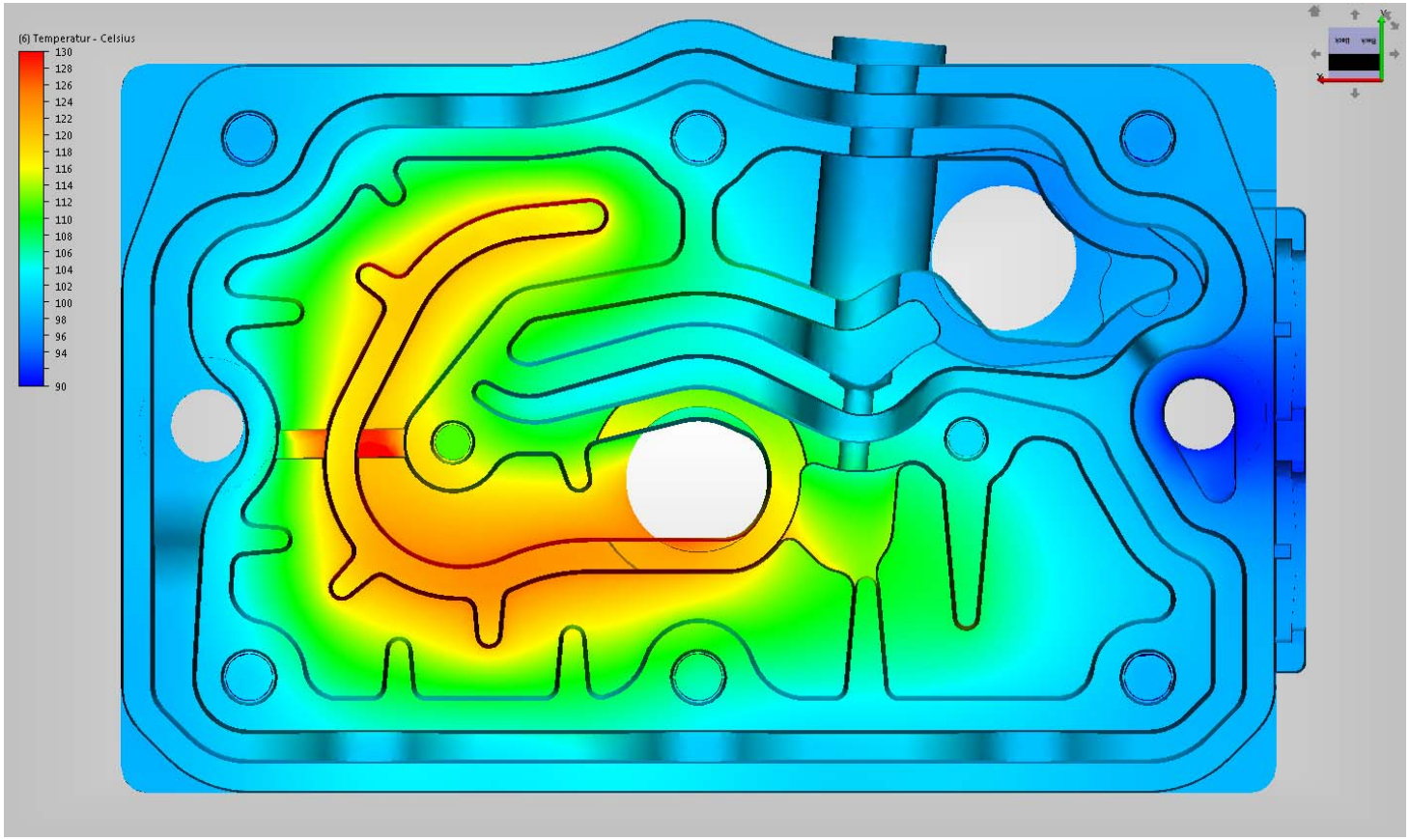

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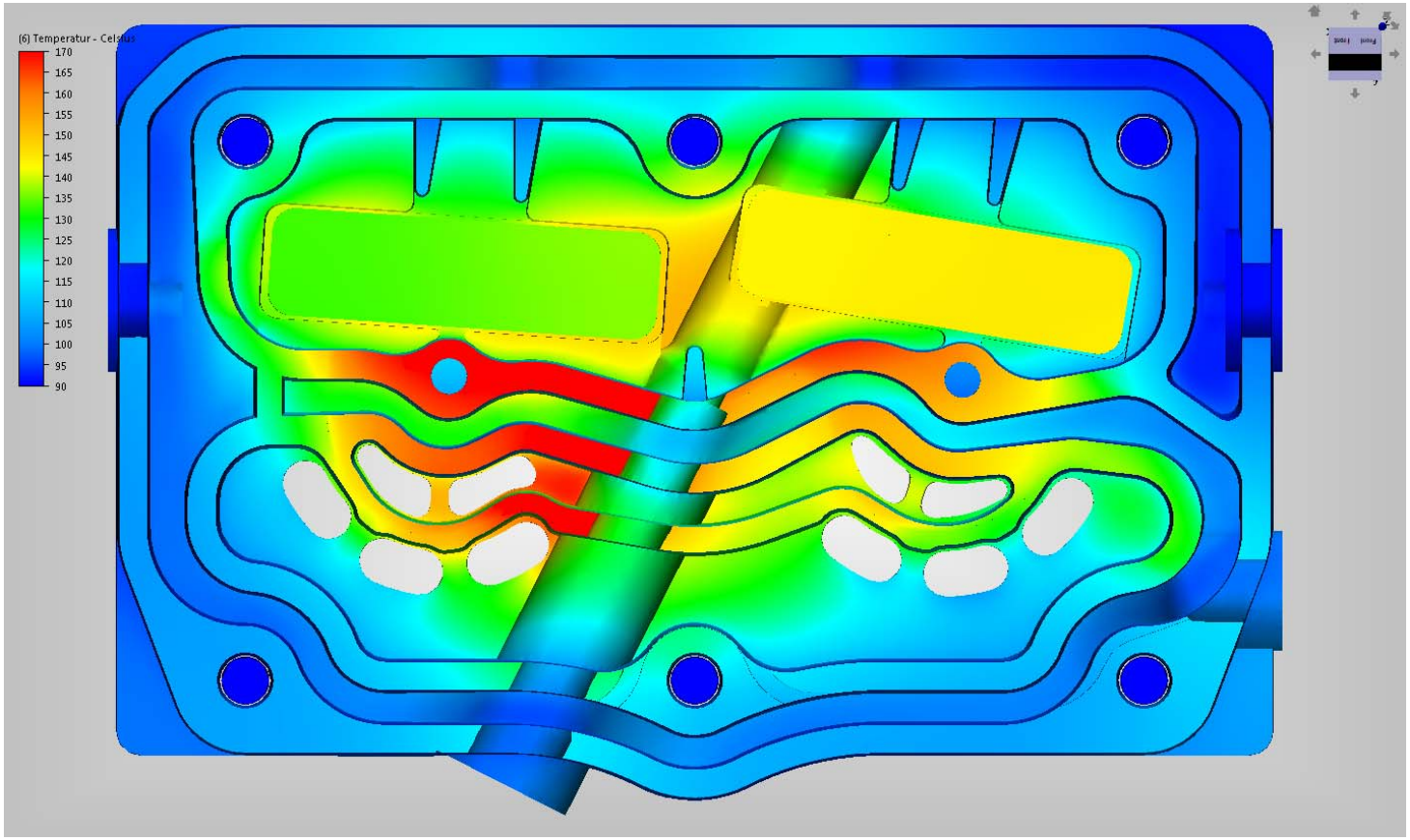

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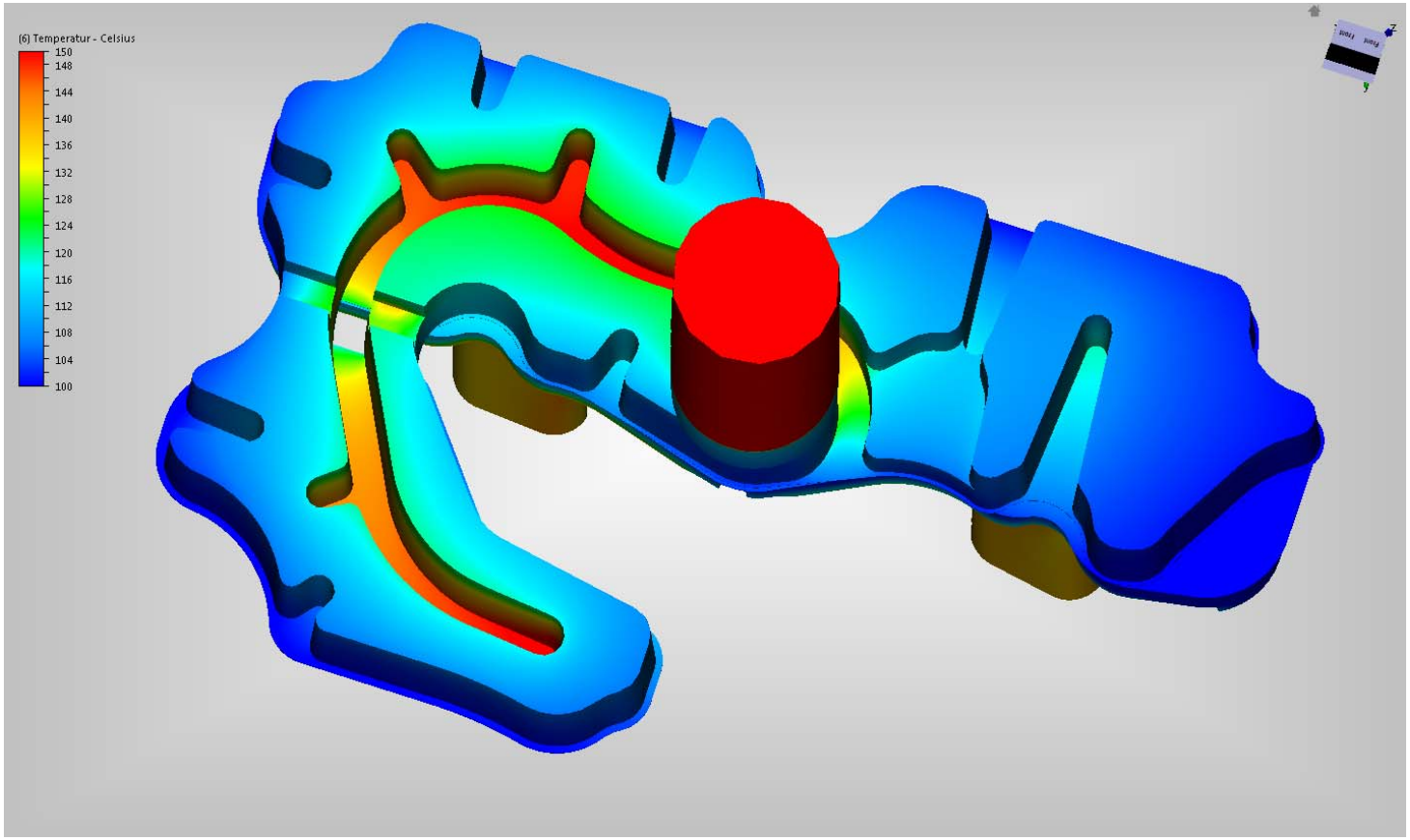

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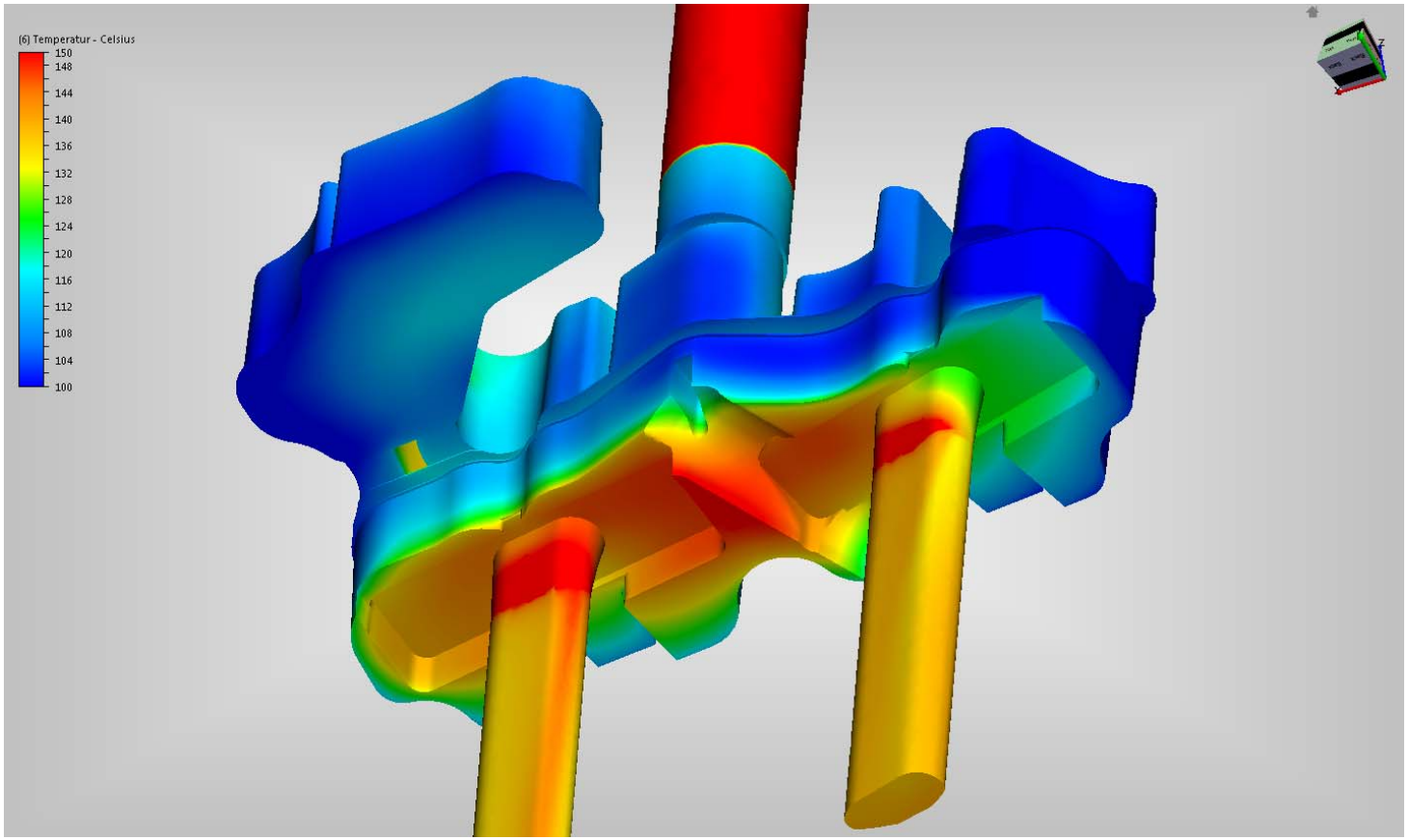

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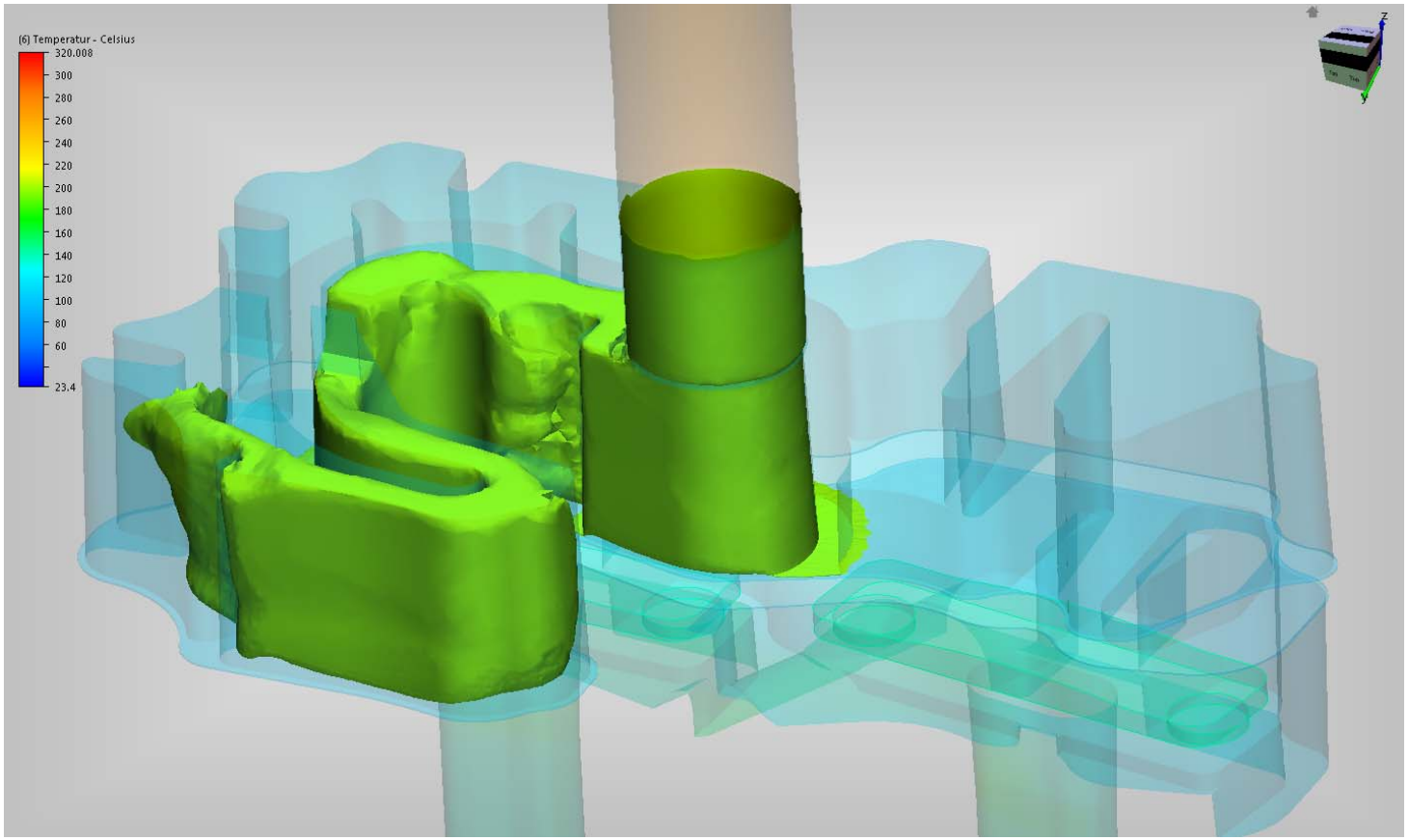

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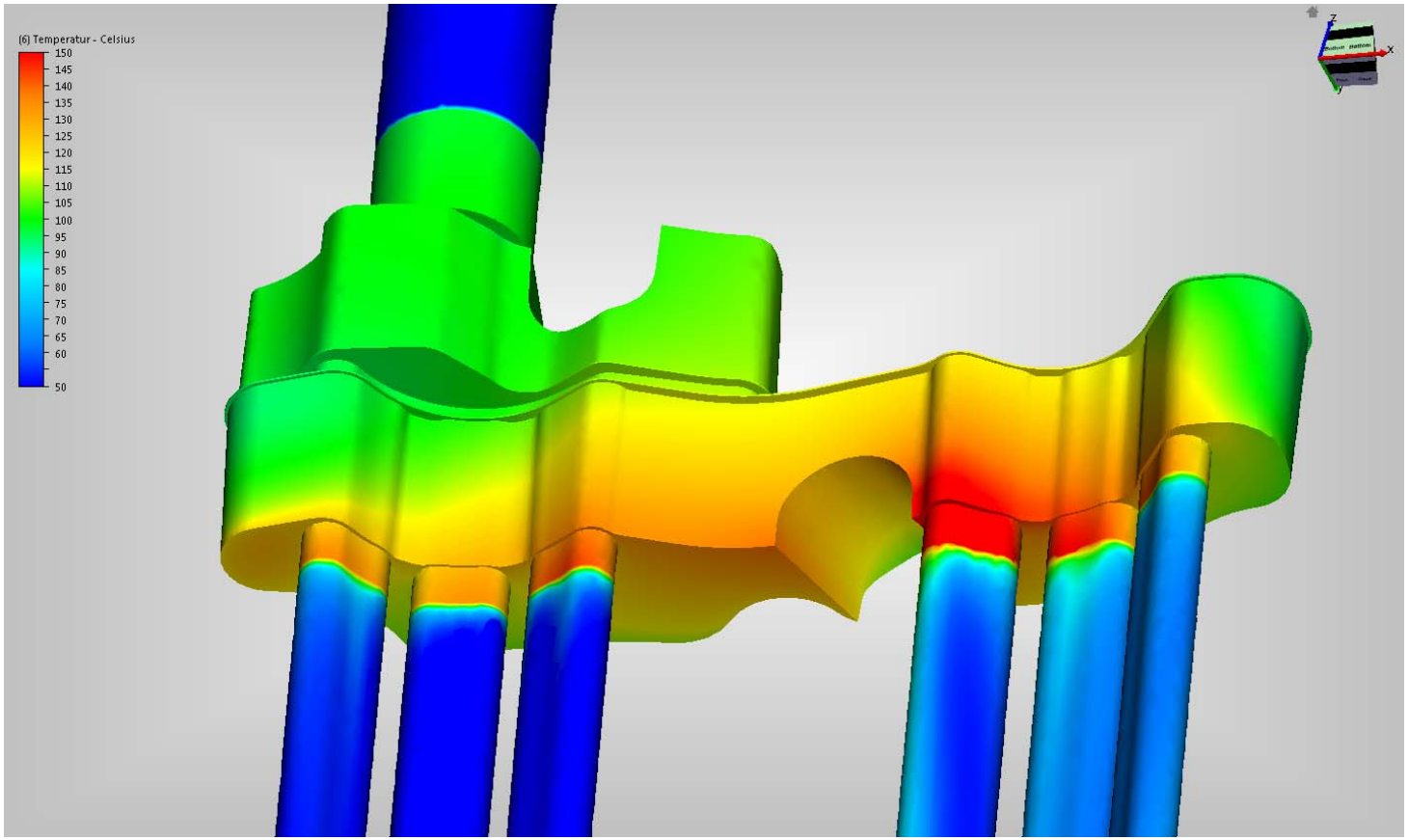

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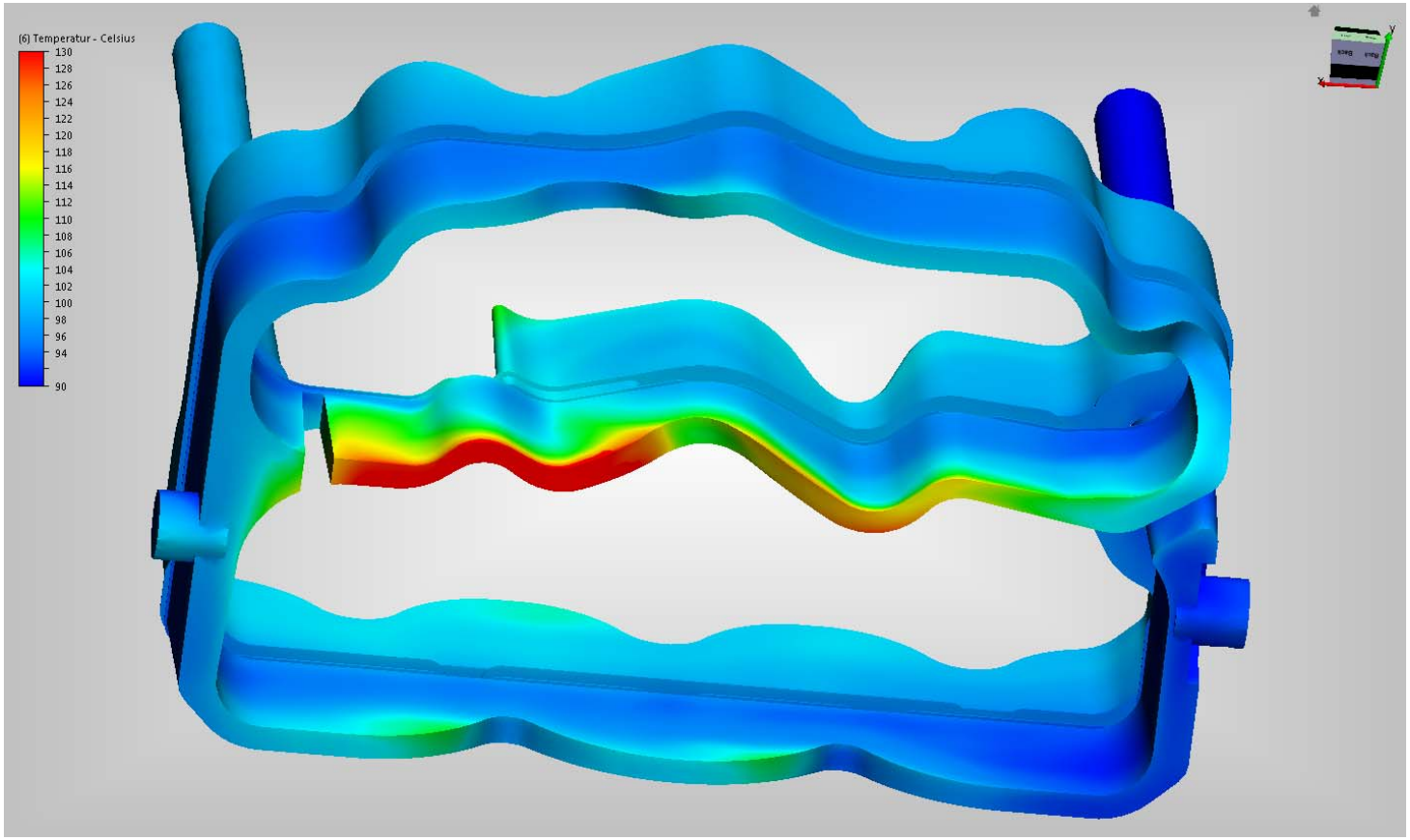
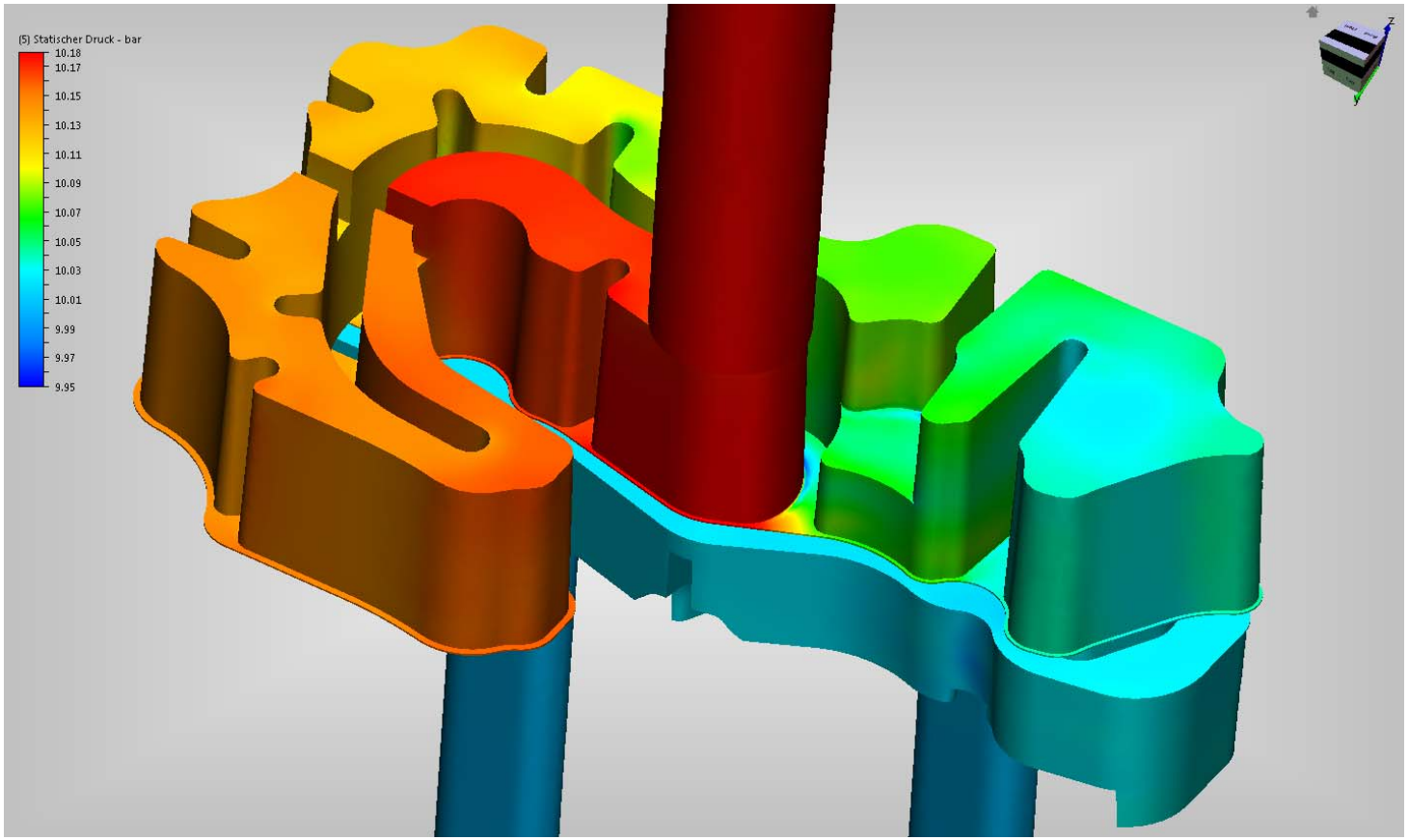


# Pressure distribution



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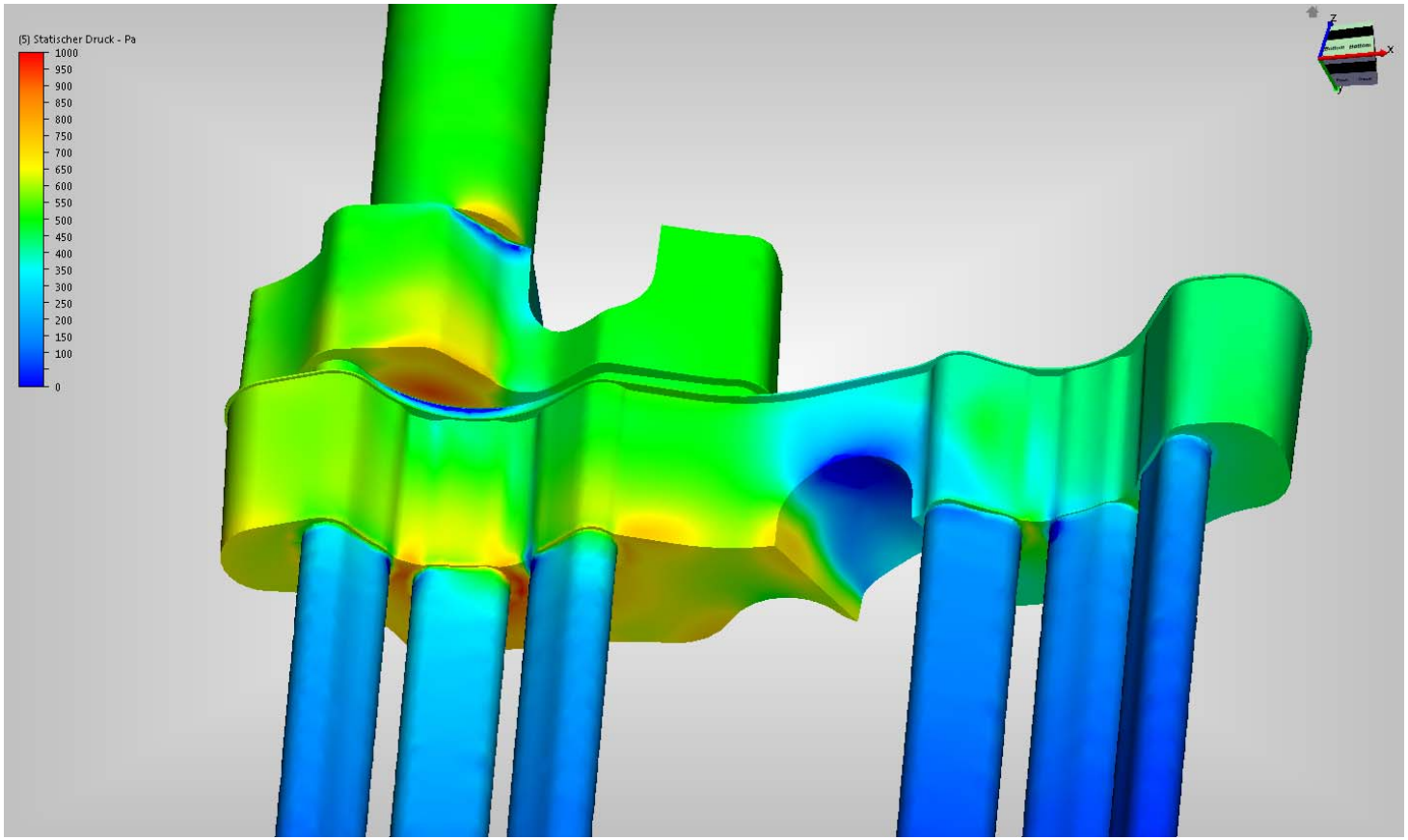

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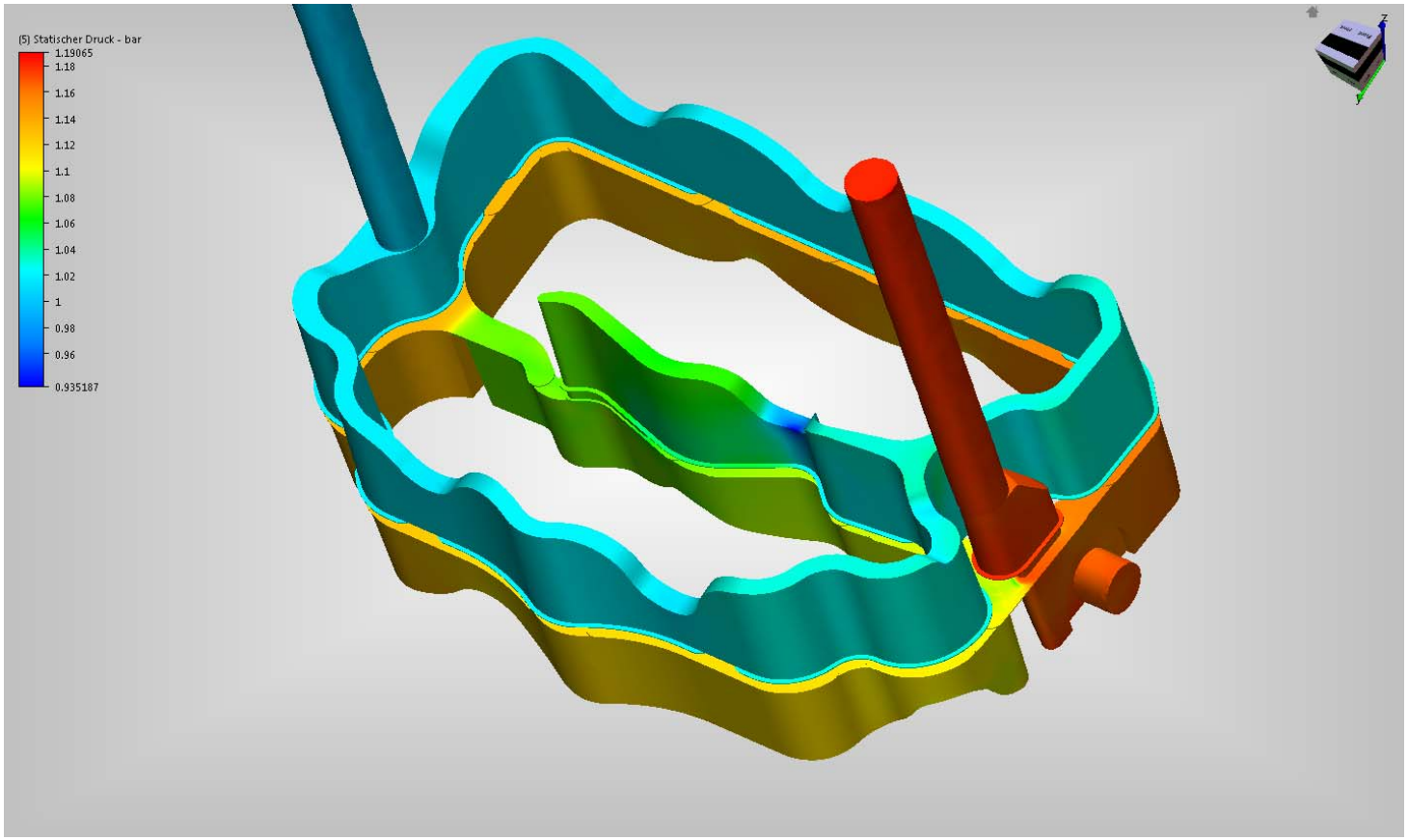
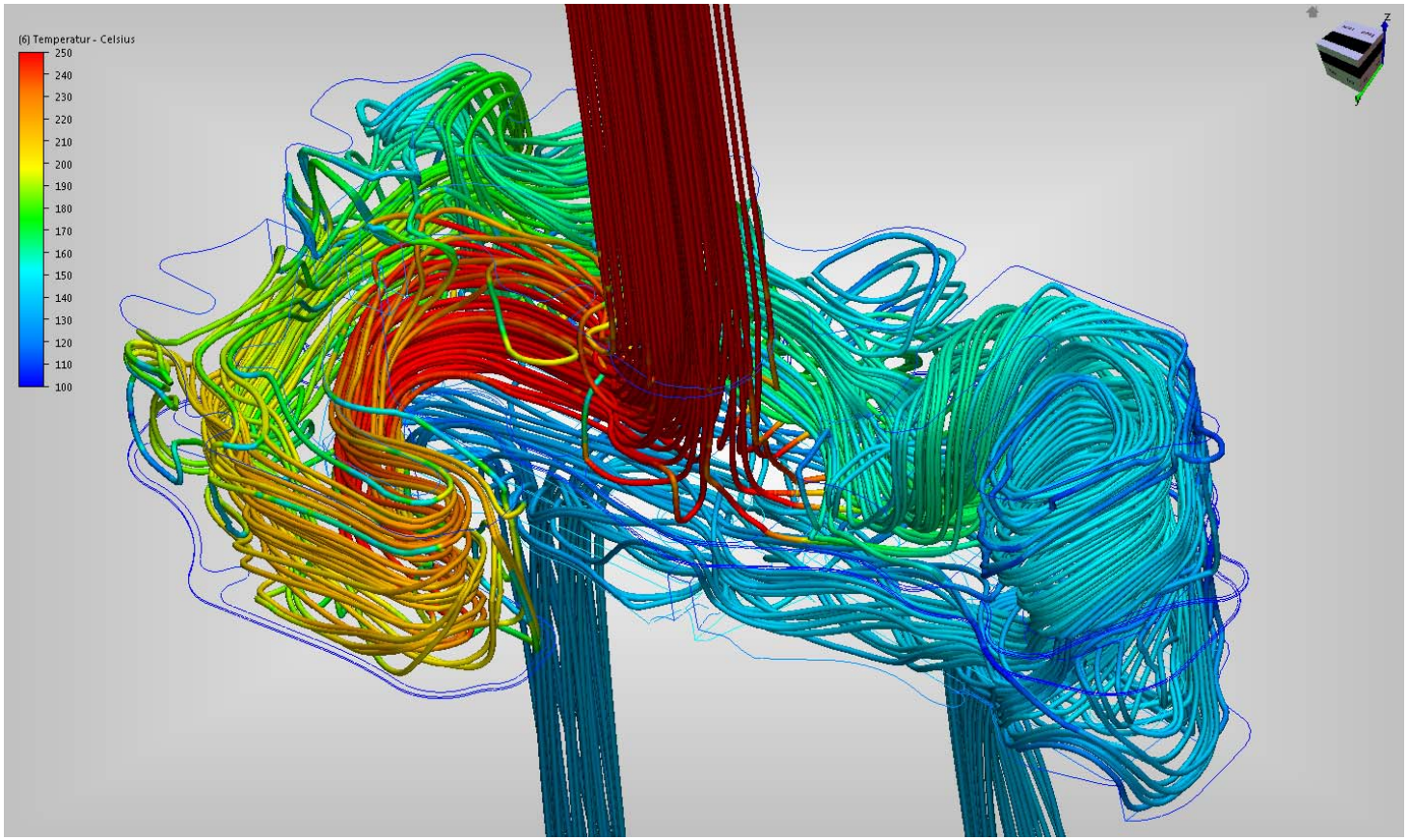


# Velocity/temperature of the compressed air



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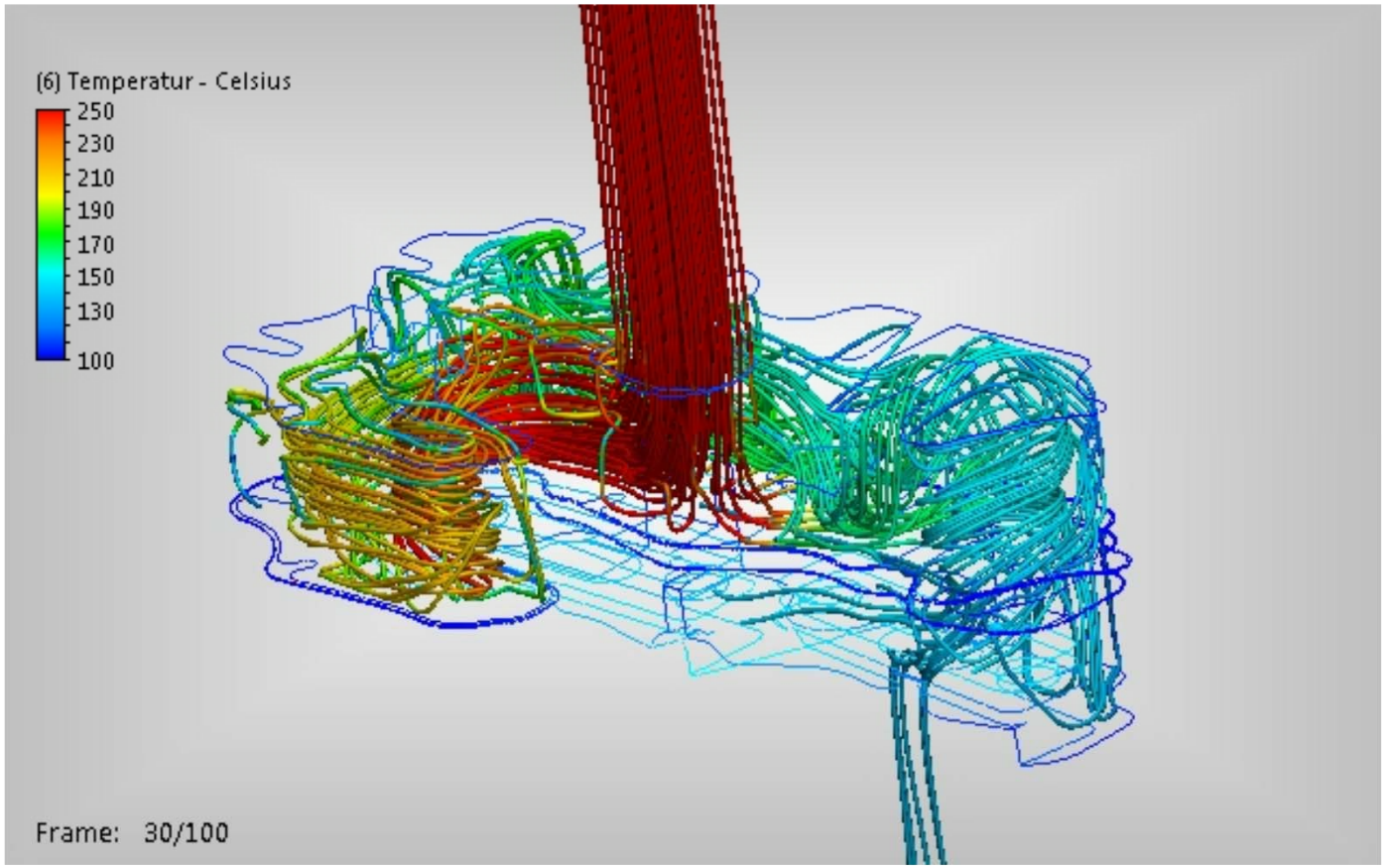


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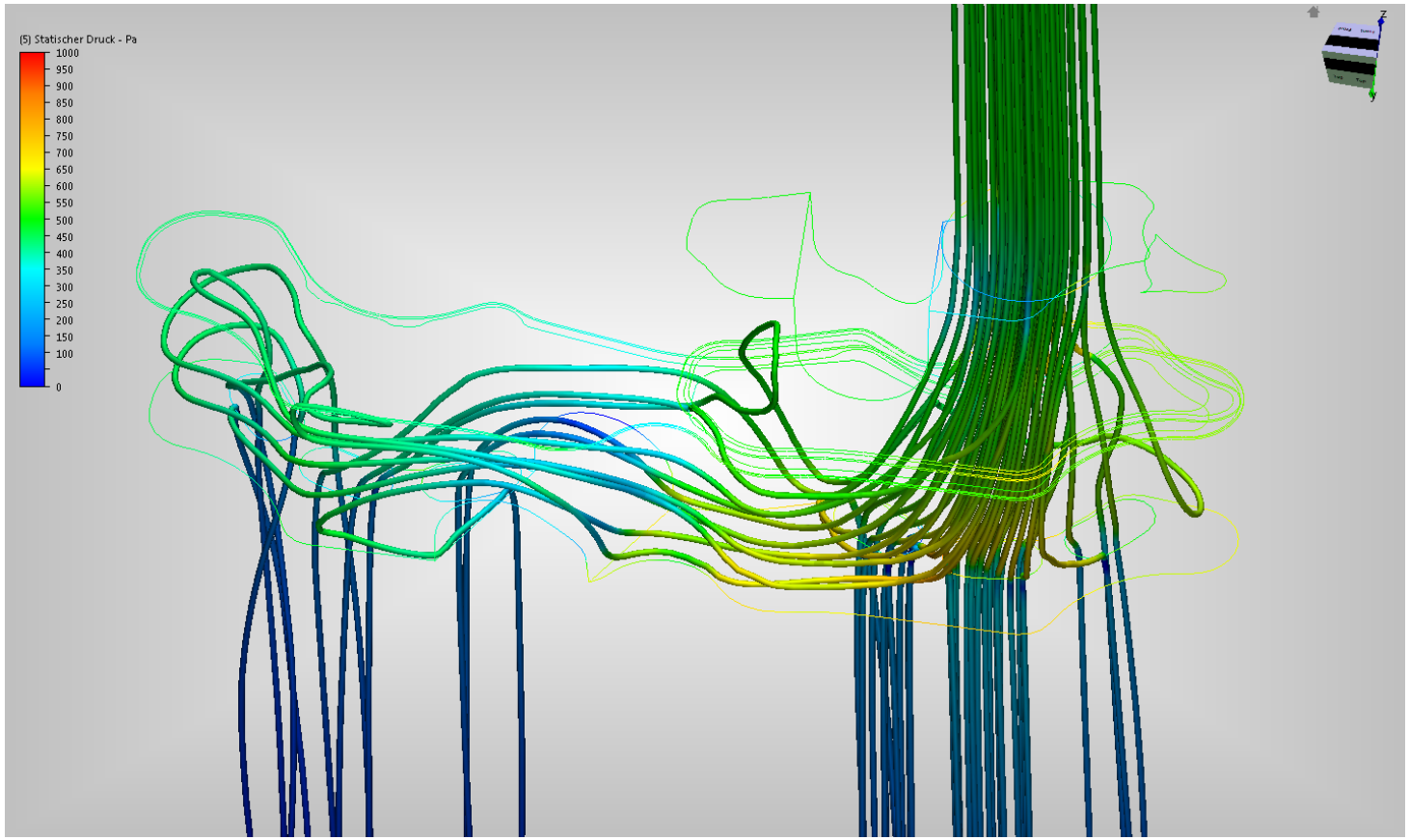

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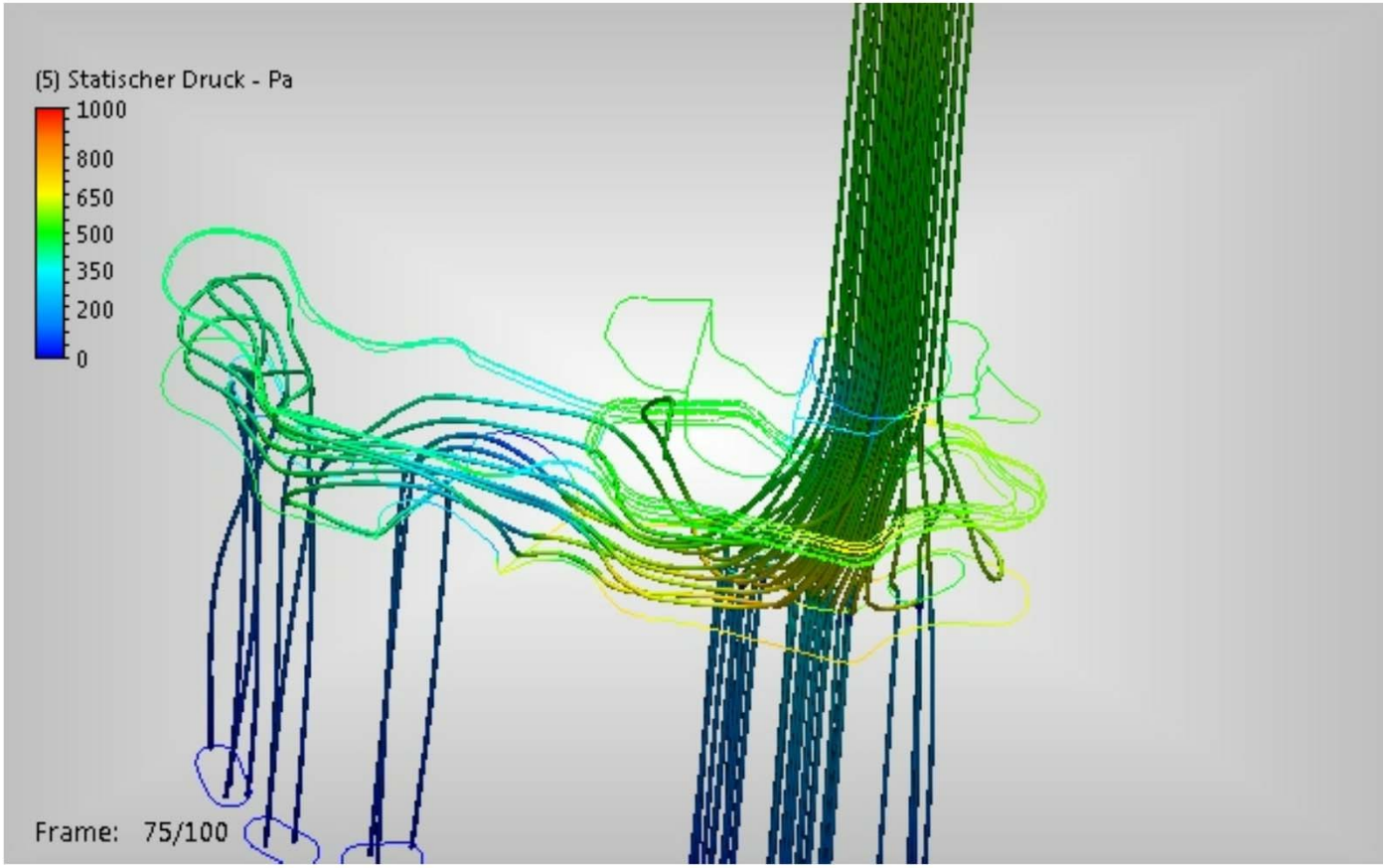
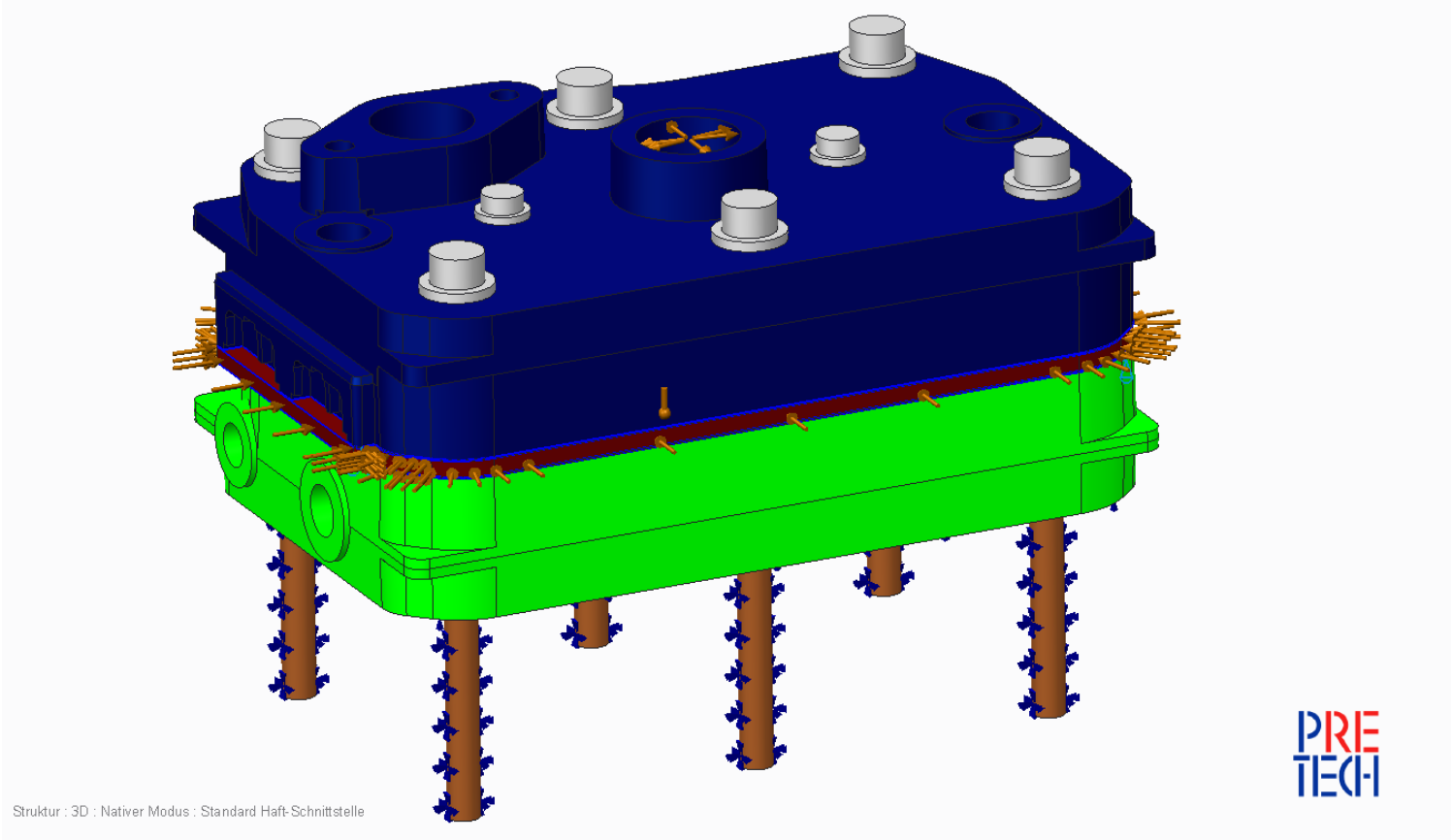


# CFD - Results

- Water: Outlet 99.5°C (Inlet: 89.9°C)
- Pressure chamber: Outlets: 134.6°C & 138.5°C (Inlet: 274°C)
- Air chamber: Outlets: 46.8°C , 38.2°C , 34°C ; 57.1°C , 62.2°C  & 63.7°C (Inlet: 23.4 °C)

# Cylinder head – CAE-Model



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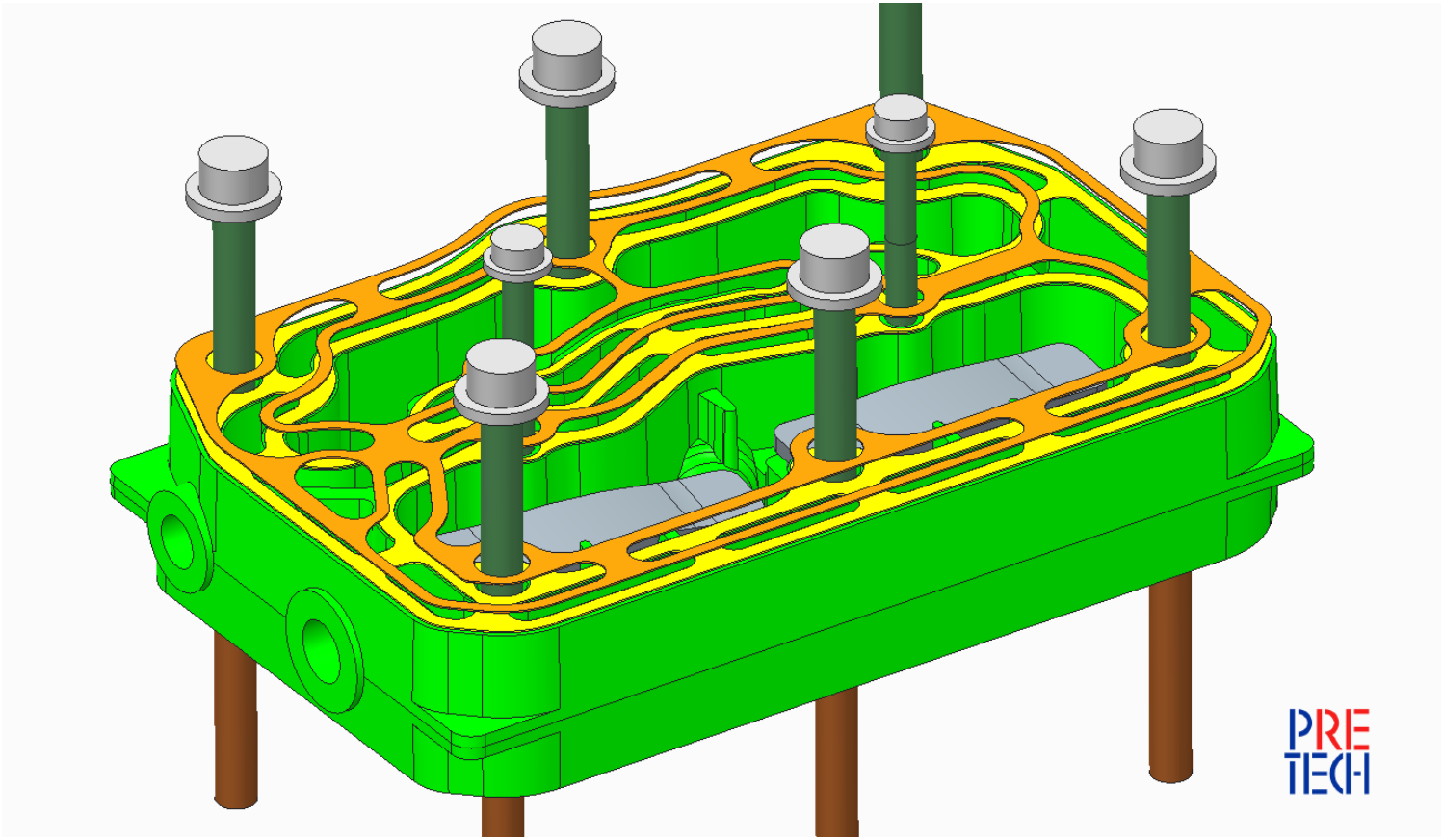

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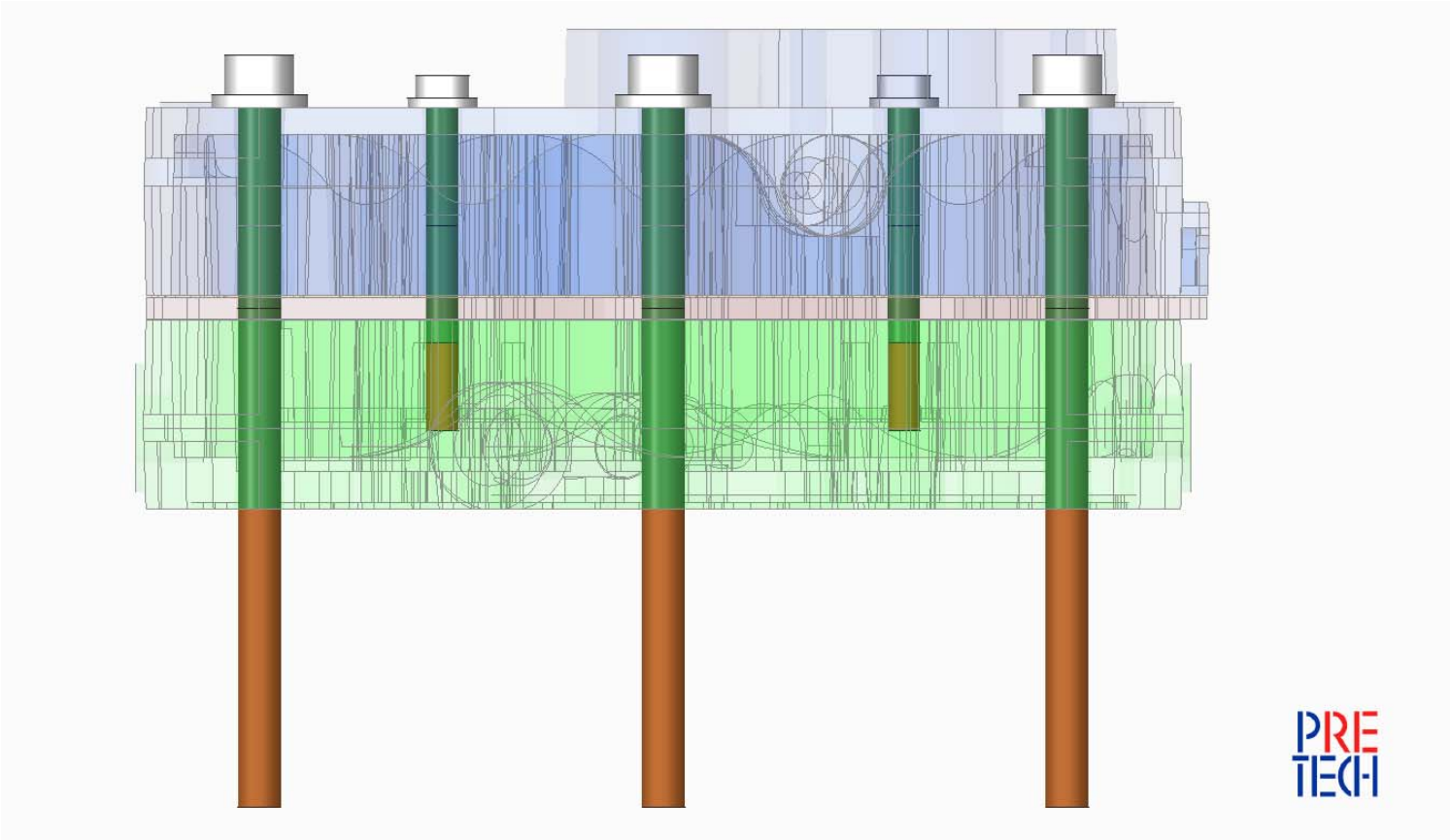
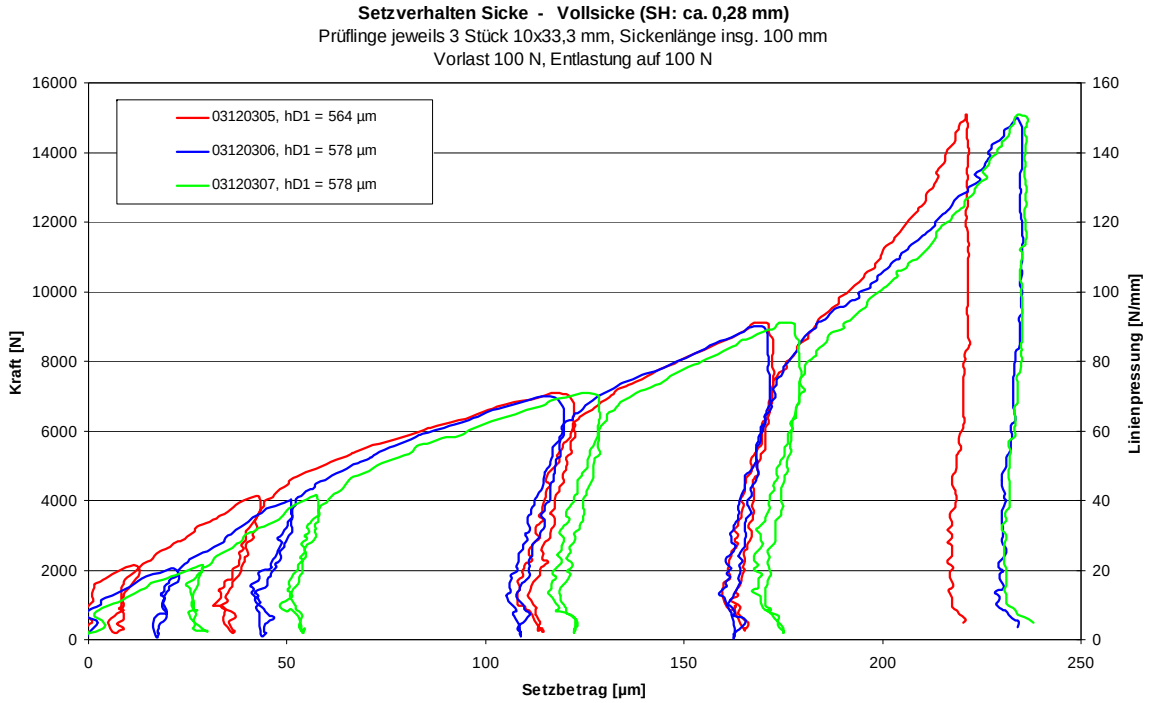


# Seal behavior

- The manufacturer supplied the measuring data of the force-deformation curve
- Relevant is the elastic behavior from 120 and 170 $\mu$m



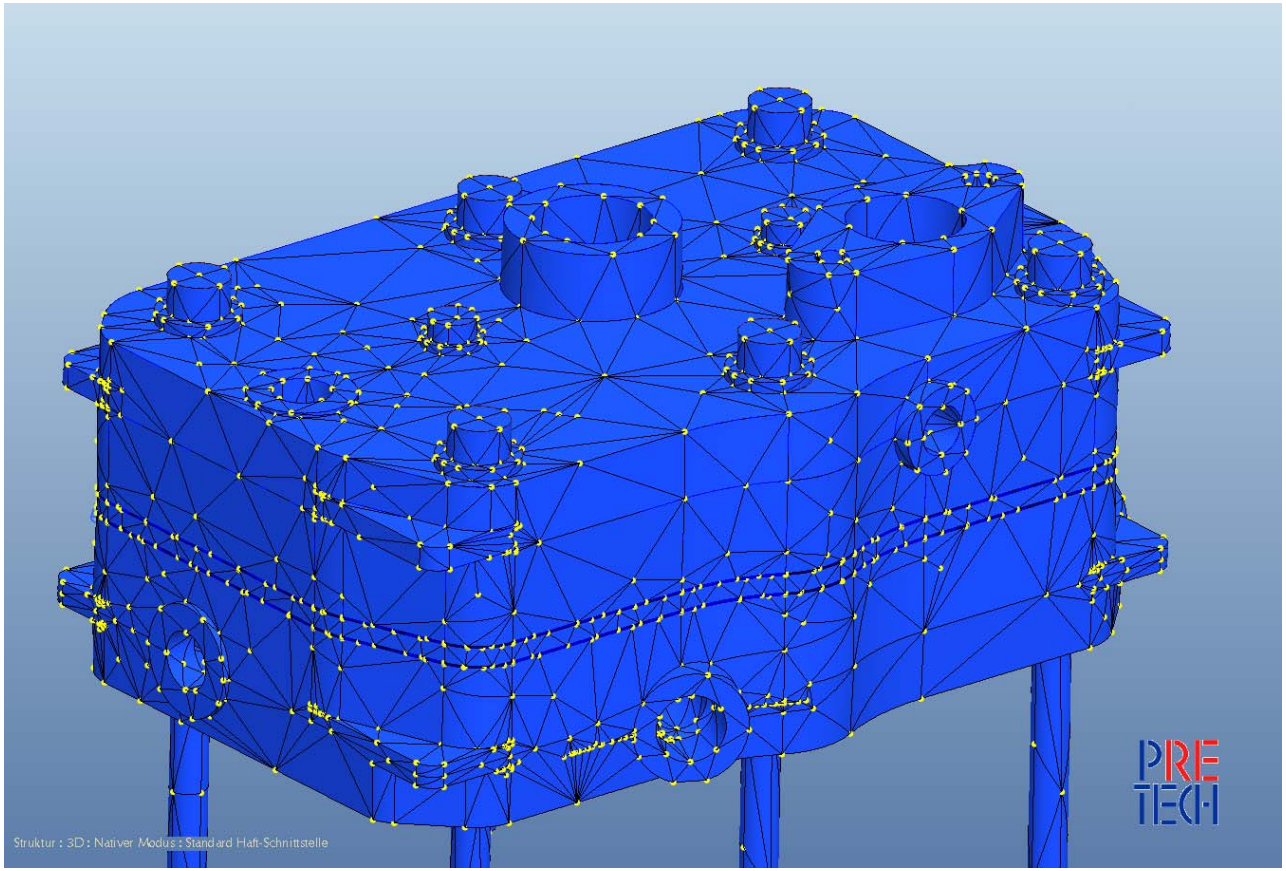
# Creo Simulate - Model

- Seal modeling:
  - Linear elastic behavior like in the measurements (loading/unloading)
  - Orthotropic definition of stiffness (high modulus of elasticity perpendicular to the seal level, low modulus and shear modulus in the sealing surface)
  - It can be assumed that the seal always covers the whole sealing surface
  - For the static analysis, the seal is defined as rigidly connected with all parts (except for the contact analysis), therefore no friction must be considered
  - The seal section is simplified as a rectangle

# Creo Simulate - Model

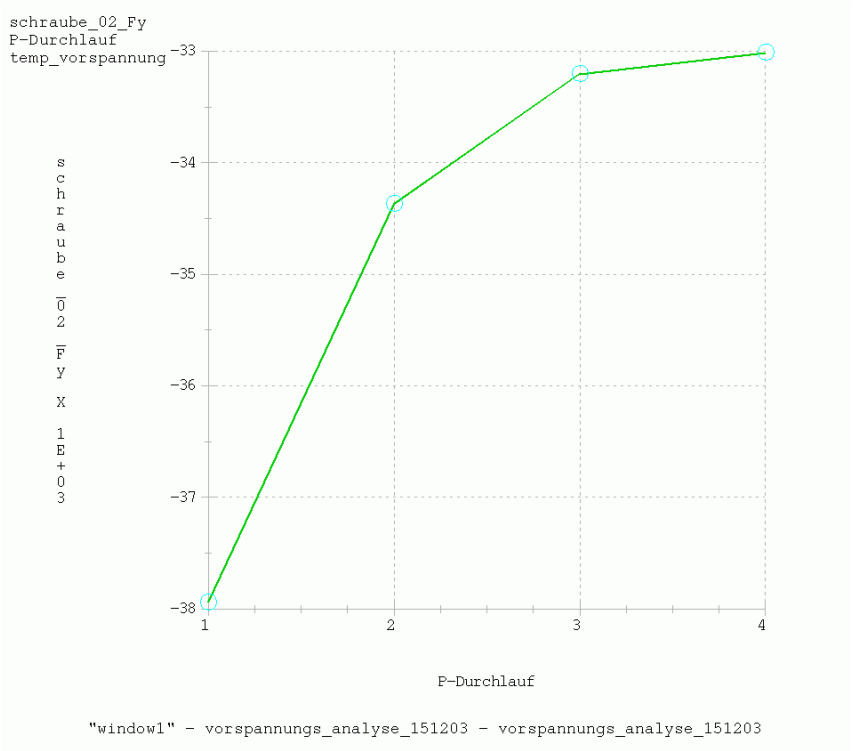
- Boundary conditions: temperature & pressure distribution computed by Autodesk Simulation CFD
- Initial screw loads are generated with a temperature difference of 100 K; the thermal expansion coefficient is adapted to the screw forces
- Element count: 53,560 p-elements
- DOF: at final pass: 3,051,645

# CAE - Mesh



# Contact - Analysis

» Typical convergence of the screw force



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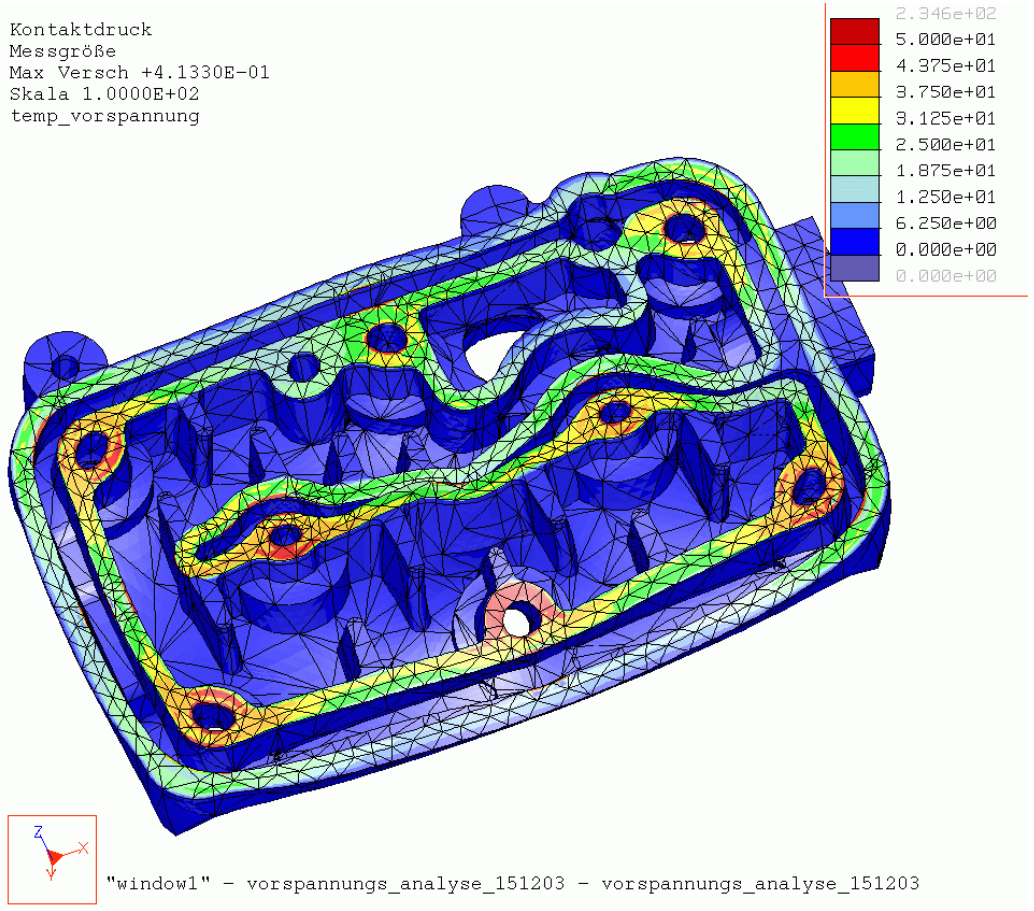

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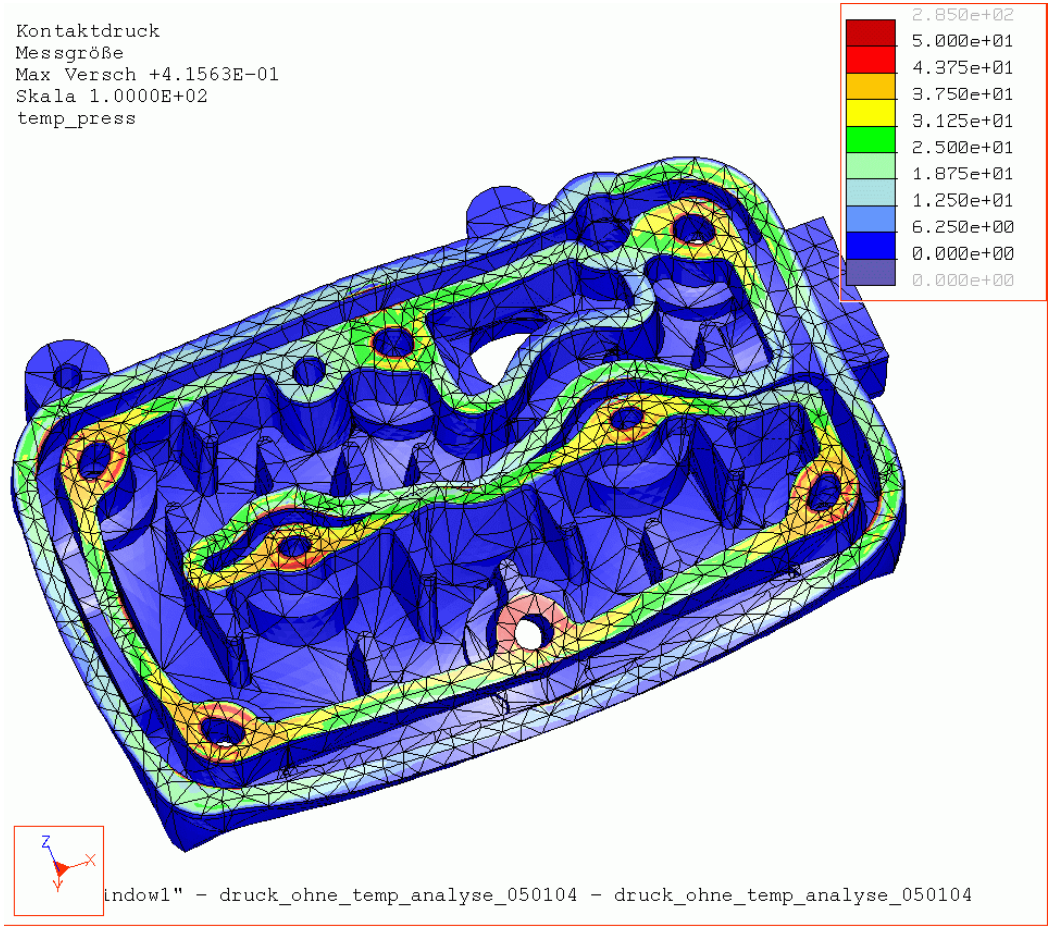
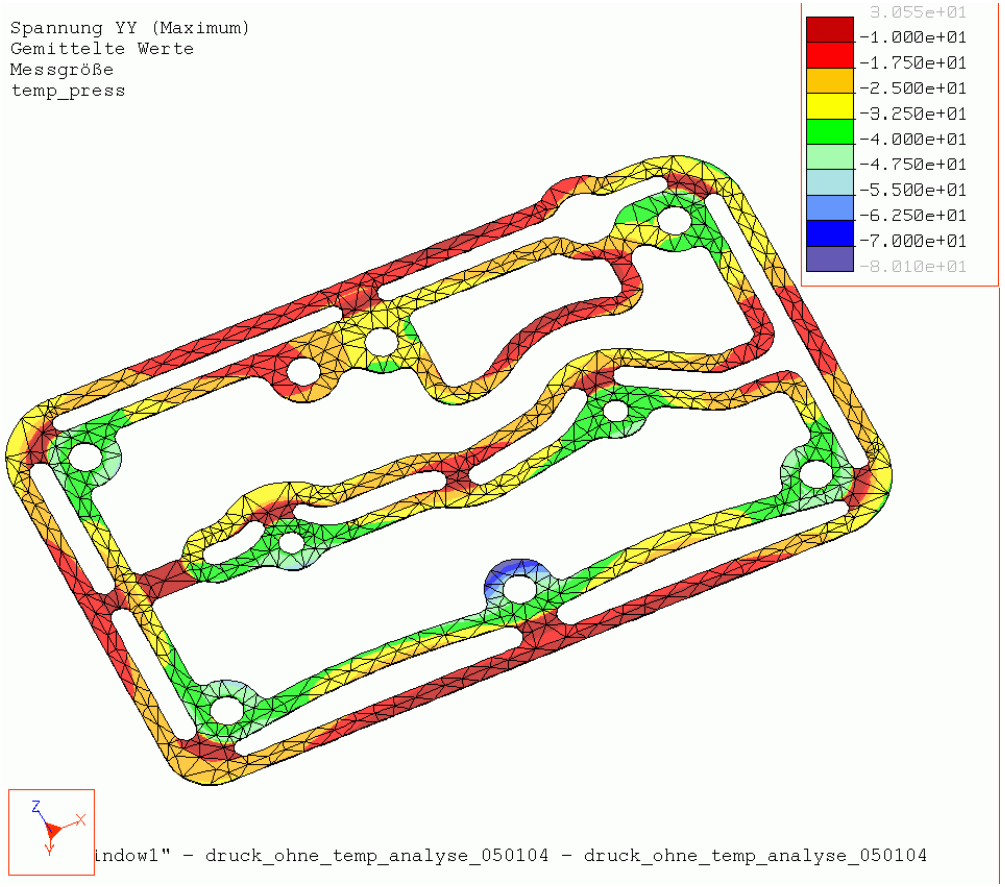


# Comparision contact vs. static analysis



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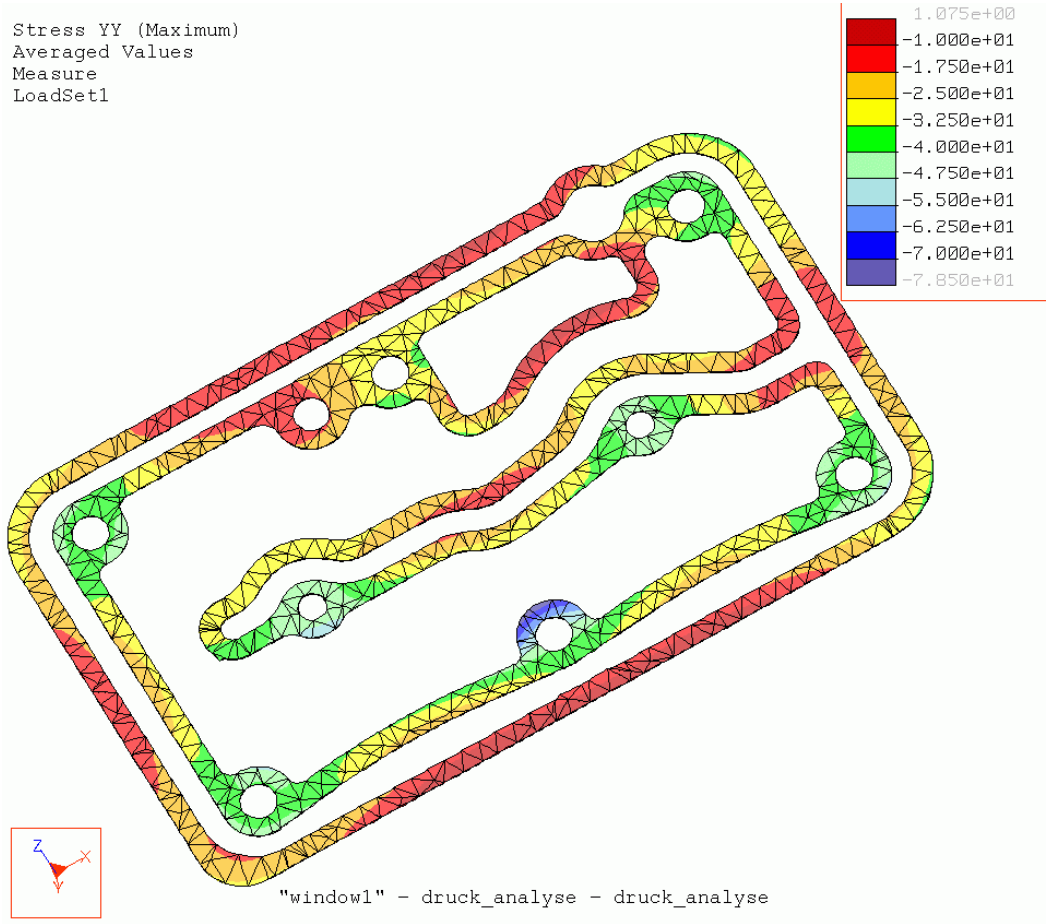
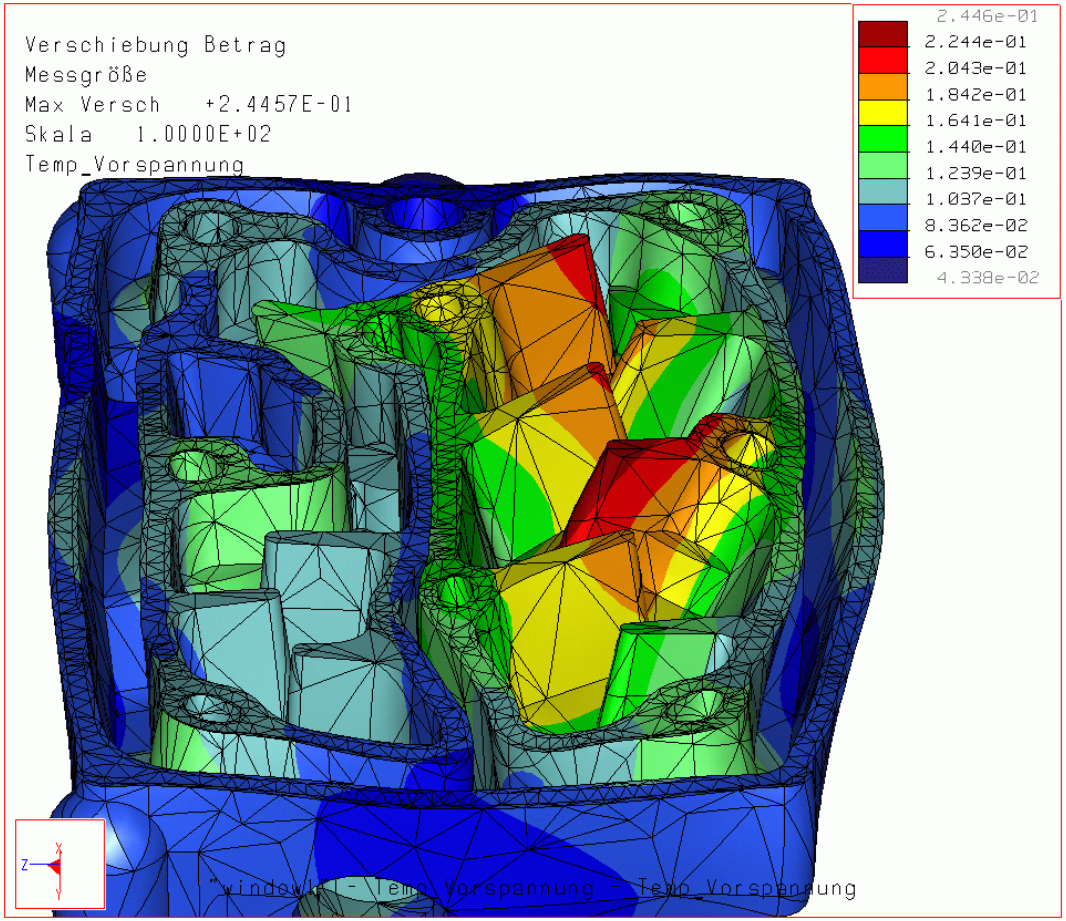


# Temperatureinfluences



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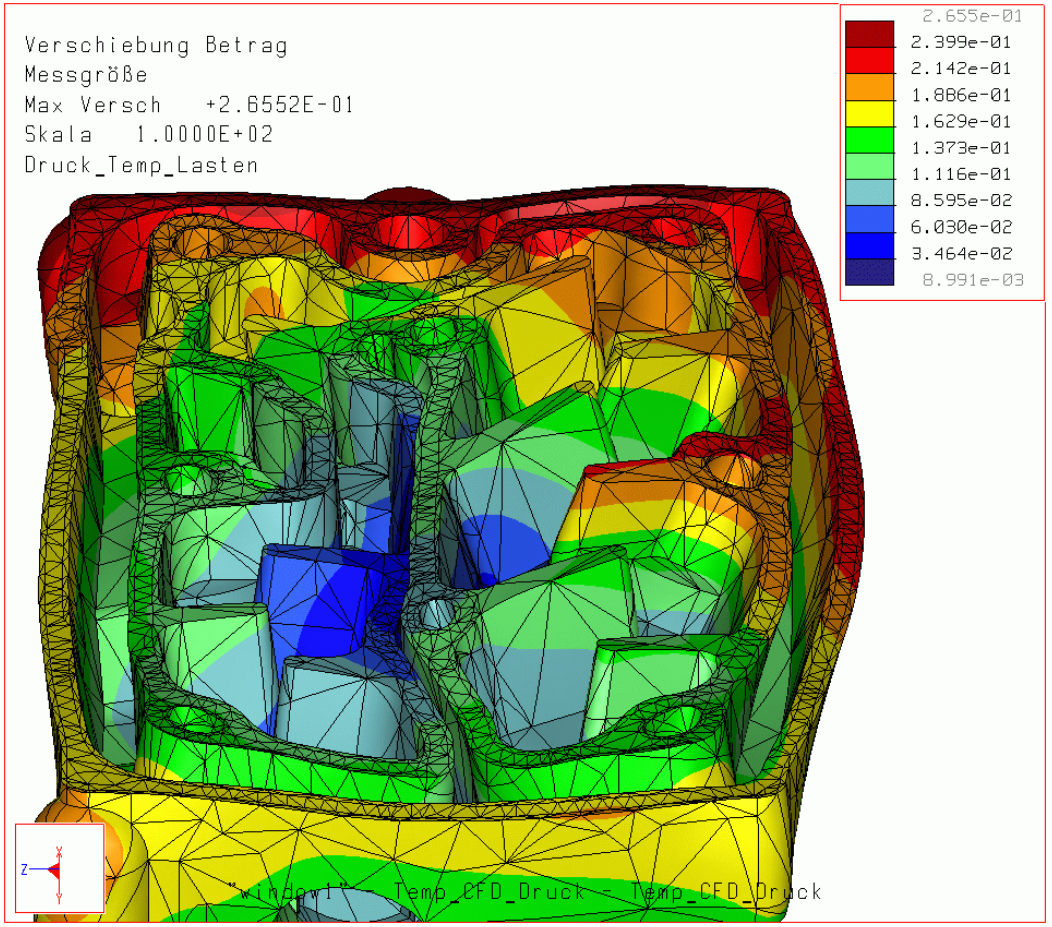
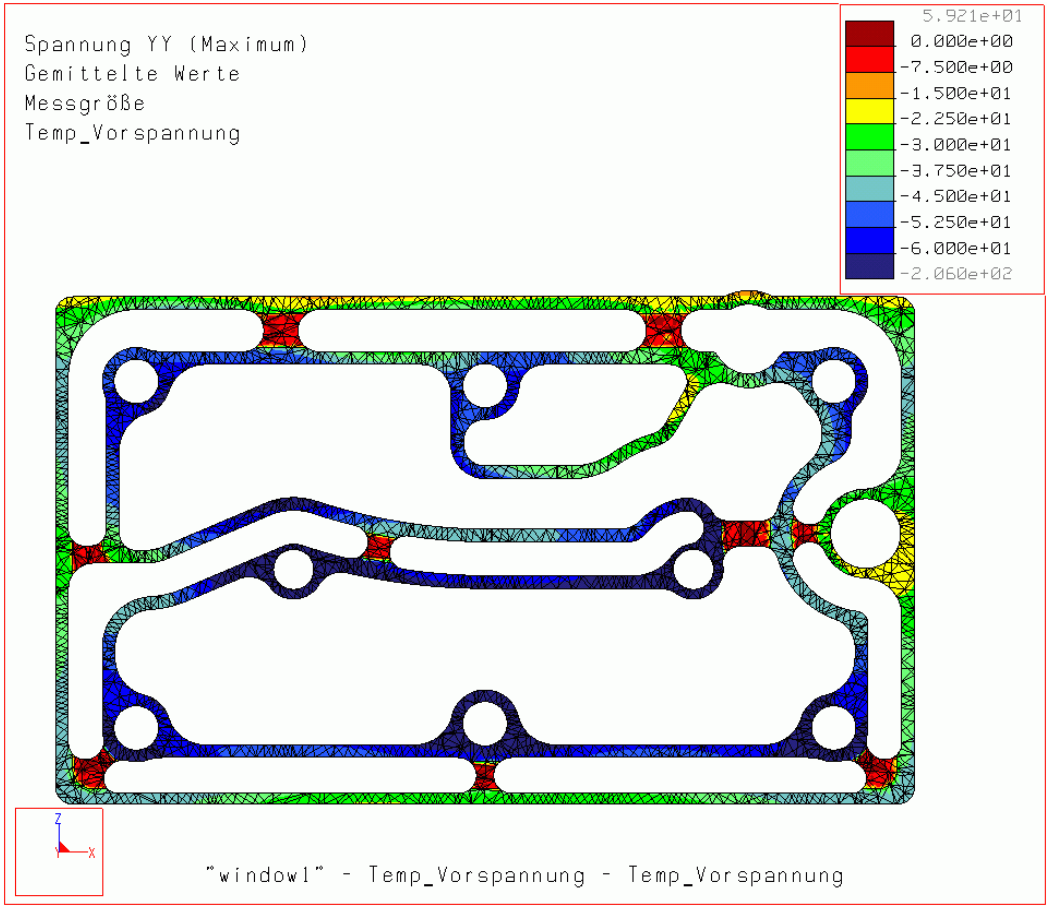
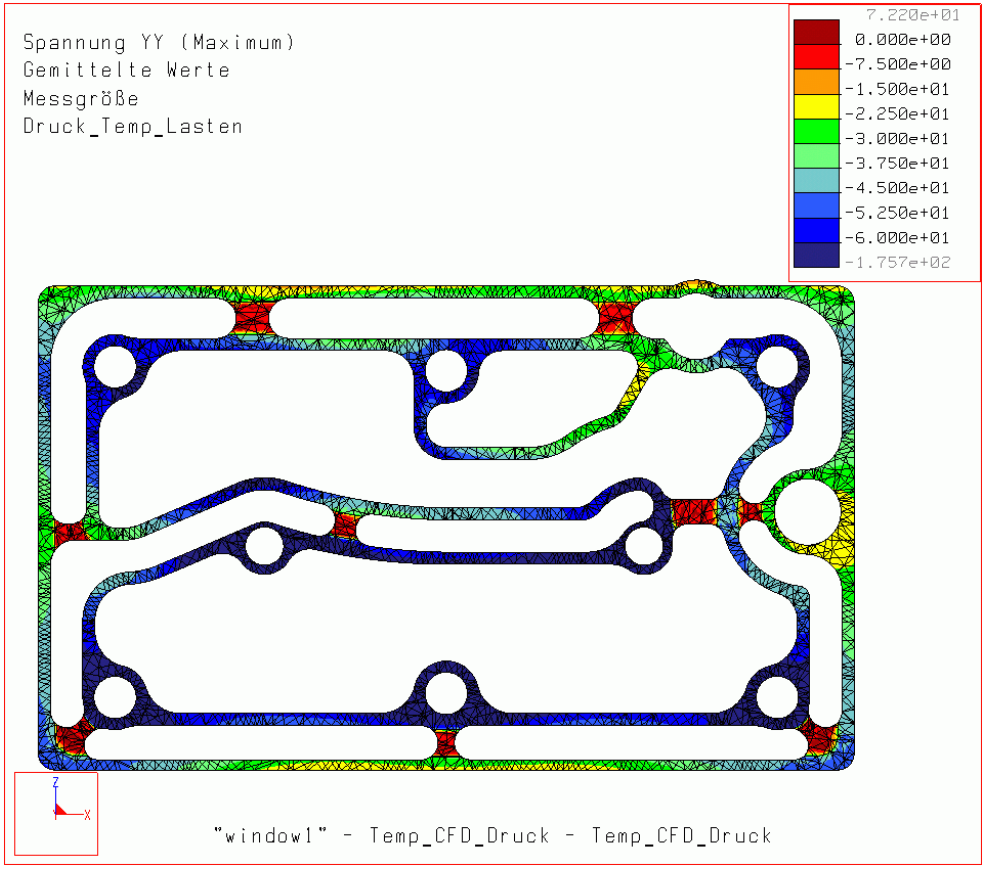


# Comparision of seal pressures



# Comparision seal pressure



# Conclusion

- Autodesk Simulate CFD computes the pressure and temperature distribution
- Creo Simulate can calculate the strains and stresses within the cylinder head screws in the light of preload, external temperature field and pressure loads
- It is not necessary to consider friction
- It is not necessary to compute a contact-analysis

# Conclusion

- The main results are:
  - The most dominant parameters are the screw forces
  - A second critical parameter is the temperature
  - A third critical parameter is the pressure distribution
  - Increased stiffness of all parts drastically increases the reliability of seals (thigtness; confirmed by tests)
  - All calculation results strongly promote the understanding of the mechanical and thermal behavior of the cylinder head

# Thanks for your attention
# Questions ?