HEAT FLOW IN BRUSH SEALS

What happens when Bristles and Rotor are in contact?

Cortes, Fuchs, Ursprung | Institut für Test und Simulation für Gasturbinen | 27.05.2025

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1. Basics of brush seals
2. The planned experiments
   - Test stand design
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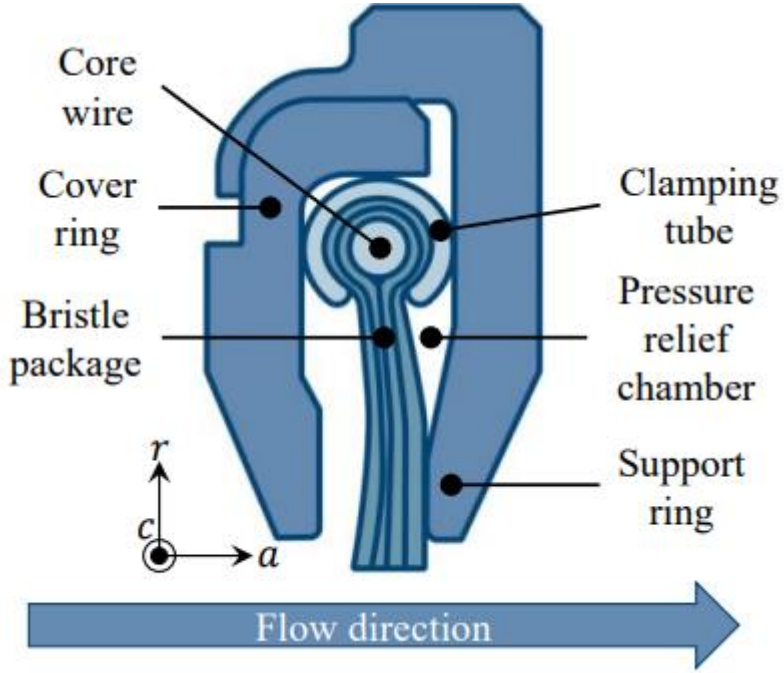
1. Brush seal basics

- Usage in airplane engines between rotating and static components
- Mainly in the SAS
- expansion of the operating area ongoing
  - Goal: closer to the main gas path
  - Challenges: temperature, surface speeds

Source: MTU Aero Engines



Advantages over labyrinth seals:

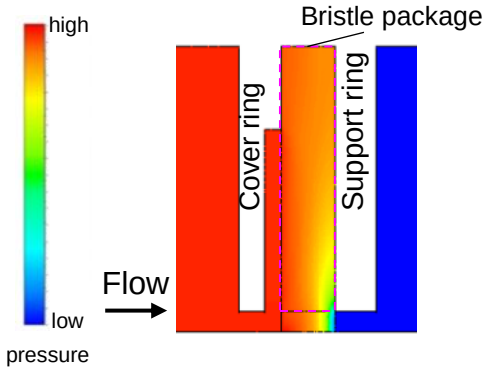
+ Lower leakage rate
+ Smaller seal gap
+ Tolerates seal contact
+ Easier to switch out
+ Smaller axial space requirement
+ Favourable influence on swirl flow

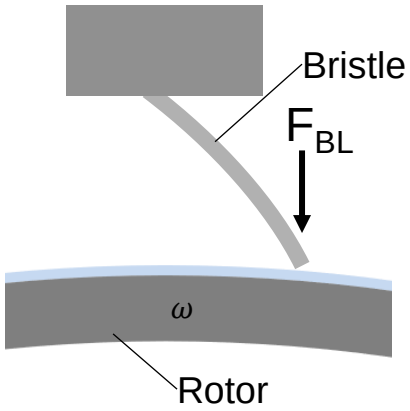
Disadvantages compared to labyrinth seals:

− Complexity
− Heat transfer to thin-walled rotor structures
− Wear

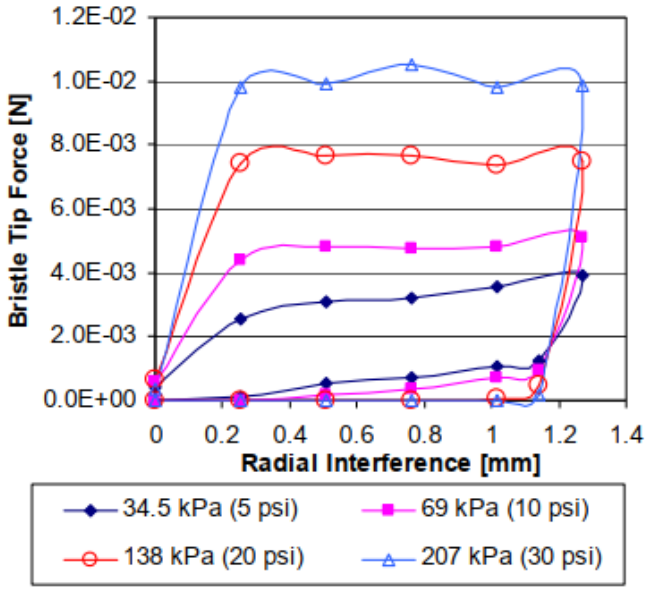
1. Brush seal basics

Blow down

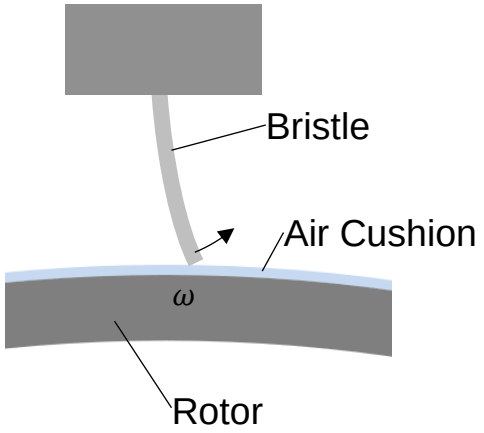




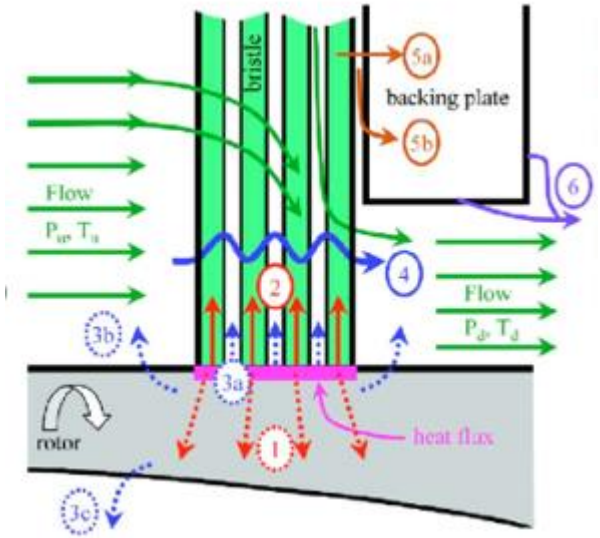
Hang Up



Lift Off



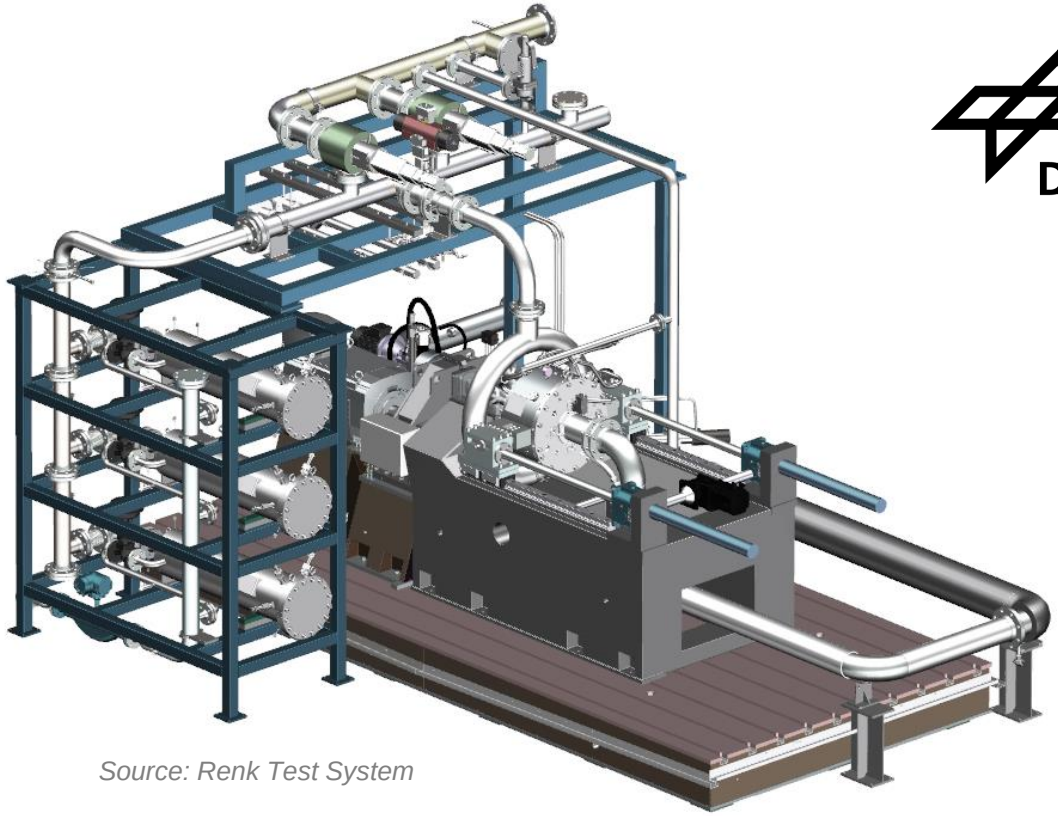
Heat Transfer



2. The planned experiments - the test facility -

Rotor test stand

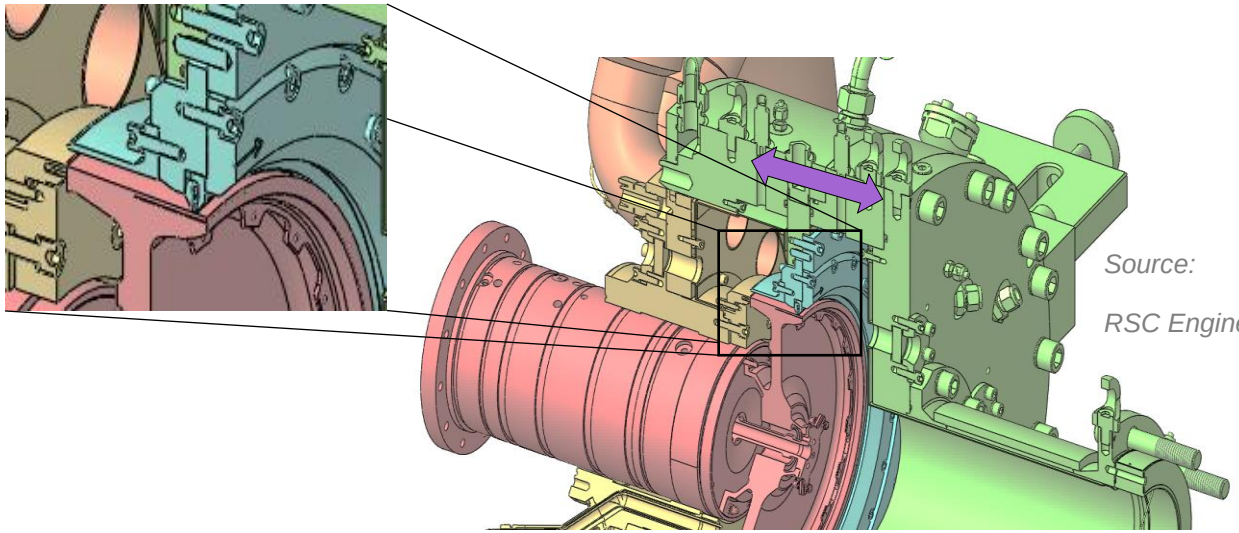
- Investigation of rotating hot gas cavities
- $\dot{m}_{max}$ = 1kg/s; T_{max} = 500°C; $T_{1kg/s} \approx$ 400°C p_{max} = 15bar;
- N_{max} = 27.000rpm; P_{max} = 170kW;



Source: Renk Test System

Brush seal rig

- Engine-like investigation of brush seals
- Adjustable pressure difference and sealing gap

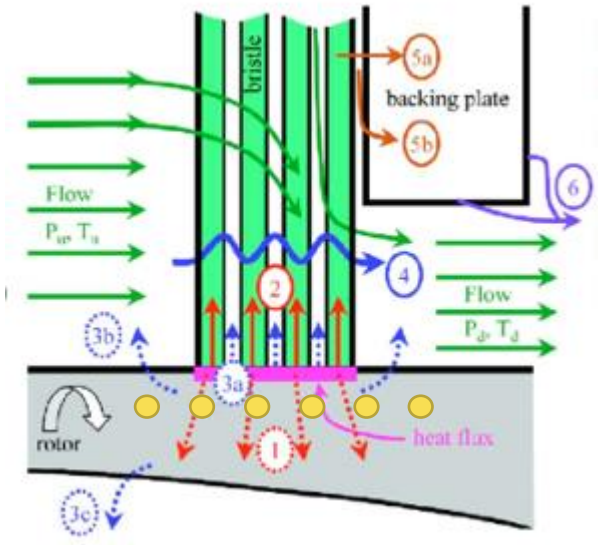


Source:

RSC Engineering

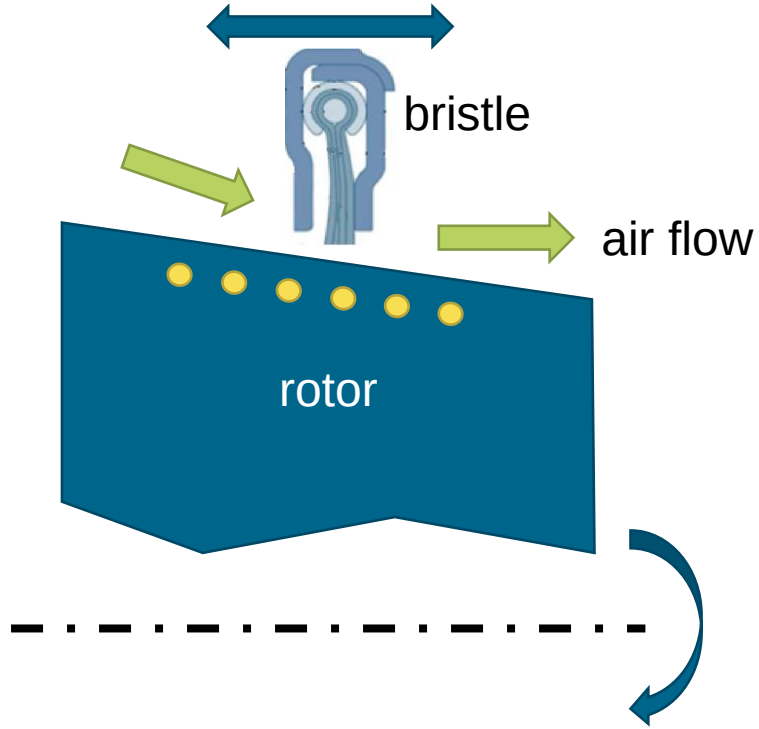
2. The planned experiments
- measuring techniques -

- Measurement of flow data:
  - Massflow through the seal using ultrasonic and dynamic pressure sensors
  - Pressure and temperature upstream and downstream of the seal
- Measurement of structural and mechanical data:
  - Local temperatures inside the rotor
  - Torque and rotational speed of the drive shaft
- Calculated results:
  - Heat flow into bristles calculated from the difference of power input and heat flow into rotor and air flow



2. The planned experiments - test conception -

- Typical test sequence:
  1. Stabilizing the boundary conditions for a positive sealing gap (rotational speed, flow and component temperatures, pressure difference across the seal)
  2. Closing the sealing gap up to an overlap (negative gap) while holding the boundary conditions constant
  3. Holding the closed gap for a few minutes (1-3min) and measuring local component temperatures
  4. Going back to the positive gap position and reversing the „hang-up“ with a special contact and pressure cycle (shaking the bristles)
  5. Starting the next sequence



3. Thermal model of a brush-rotor-combination

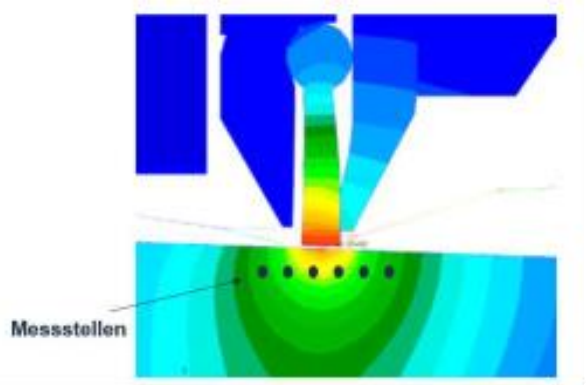
Heat Transfer

- Thin-walled component designs require a detailed understanding of heat flow
- Measurement of component temperatures during seal contact
- Implementation of an FEM thermal model of components involved
- Comparison of local temperatures with FEM thermal model
- Deduction of heat transfer into components as a function of
  - Contact pressure (frictional heat)
  - Surrounding temperatures
- Breakdown of heat flow into certain components

3. Thermal model of a brush-rotor-combination

Procedure

- Comparison of local temperatures from experiments and thermal model
- Calculation of friction between moving rotor and bristles in contact with rotor
  - Contact pressure from experiments
  - Determination of friction coefficient
- Coupling with CFD model including convection
- How warm do bristles and rotor get?
  - Where does the heat flow?
  - Comparison of results with experimental data

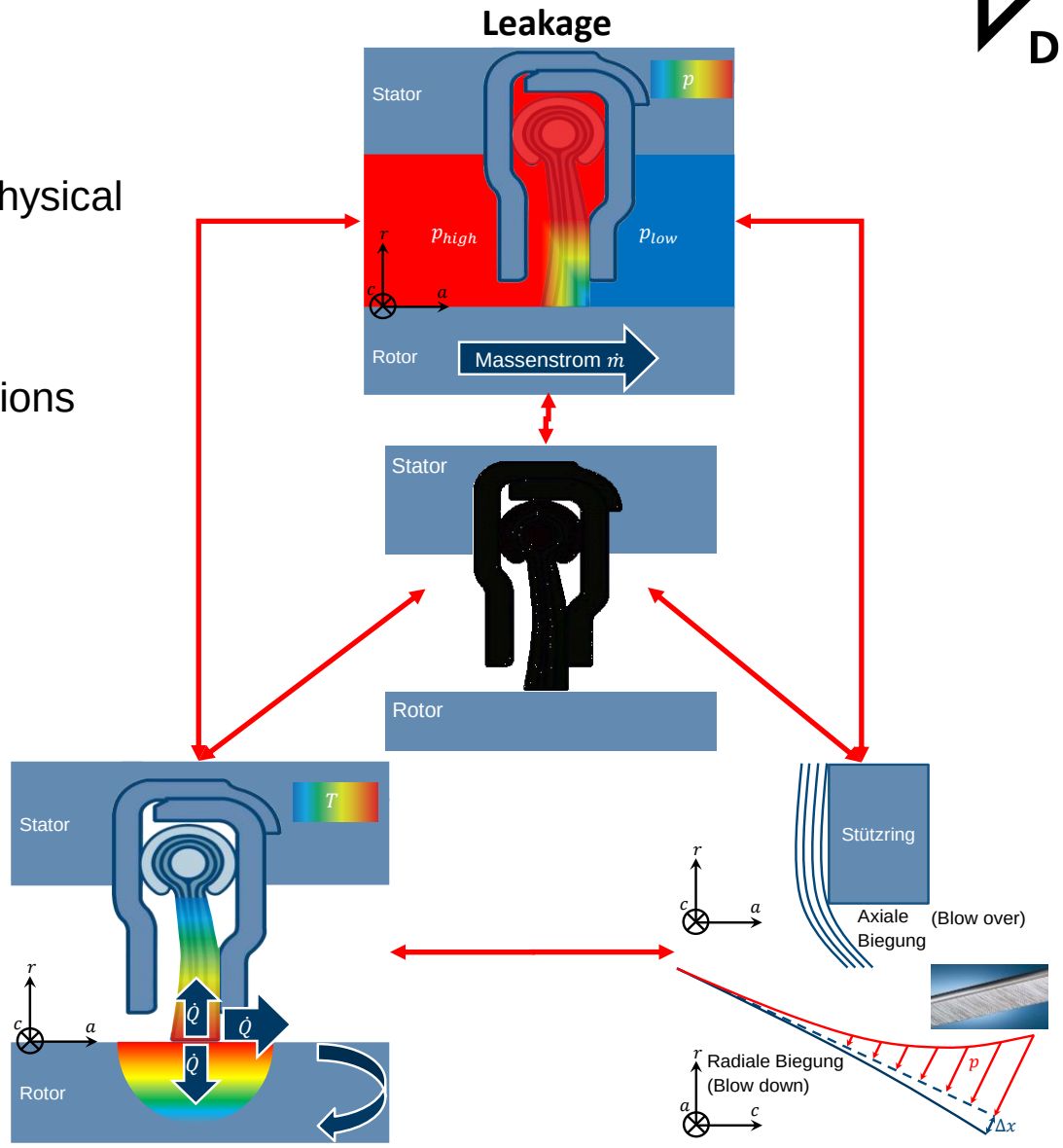


Source: MTU Aero Engines

4. FSI – Model setup and what we hope to learn from it

Objective: „Comprehensive Model“ to describe the complete physical behaviour of a brush seal

- Better understanding of individual aspects and phenomena
- Better understanding of correlations, dependencies, interactions
- Reduced need for testing thanks to simulation
- Evaluation of parameter adjustments
  (material, bristle diameter, laying angle, bristle length, …)
- Optimization of configurations for specific applications
- Initial evaluation of new concepts / ideas
- Creation of a simplified tool for real-world application



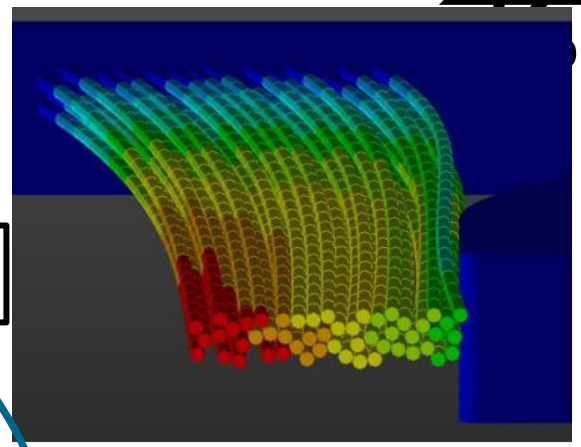
4. FSI – Model setup and what we hope to learn from it

FSI

Deformation

CFD 1

FEM 1



Forces

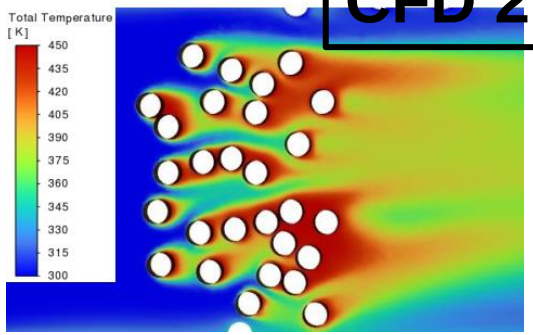
Deformed geometry

Forces

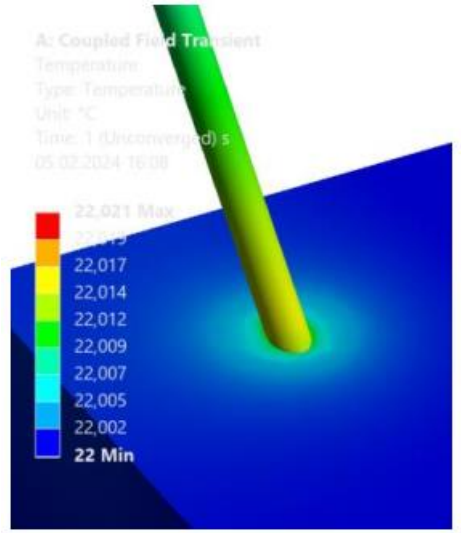
Heat Transfer Coupling

Convection from leakage

CFD 2



FEM 2
(static)



Wall temperatures

Contact:
Institut für Test und Simulation für Gasturbinen
Prof. Dr. Sabine Ardey
Forschungsallee 1
86159 Augsburg
Sabine.Ardey@dlr.de

THANK YOU

Impressum

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Datum:	2025-05-27
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