UNIVERSITÄT SIEGEN

SIEMAG TECBERG

Analysis of the temperature development within a brake disk

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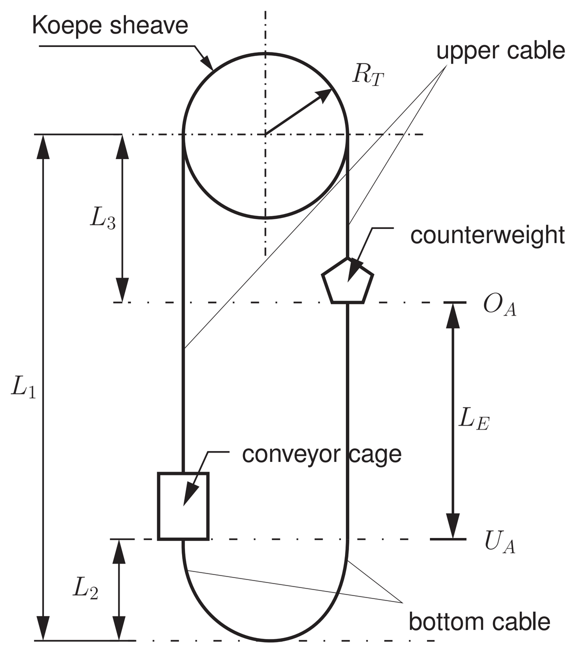
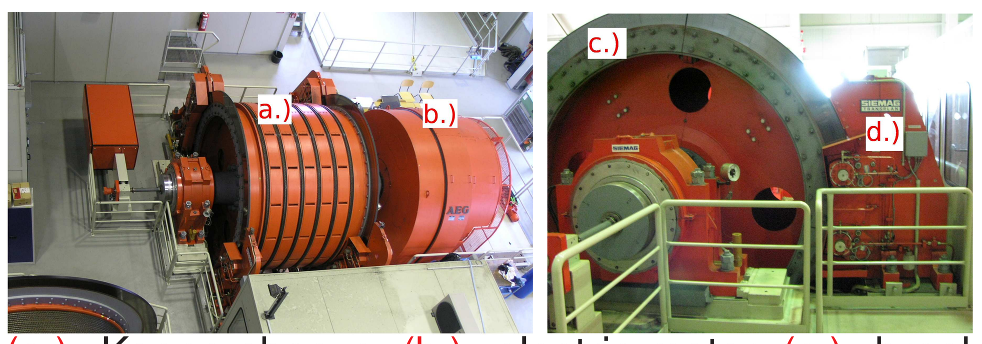
Motivation

- Determination of the peak temperature and the core temperature
- Distribution of thermal energy between the brake disc and brake pad
- Determination of the heat conduction and material parameters

Construction of the conveyor system





(a.): Koepe sheave, (b.): electric motor, (c.): break disc, (d.): brake frame

Derivation

- First law of thermodynamics

$$Q + P = \frac{d}{dt}[T + E]$$

- Heat energy is obtained from dissipated mechanicl energy

$$Q_{fric} = -P_{fric}$$

- Thermal balance equation (strong formulation)

$$c_p\,\rho\,\dot{\theta} - k\,\Delta\theta = 0$$

- Weak formulation

$$\int_{\Omega_0} \delta\theta\, c_p\, \rho\, \dot{\theta}\, \mathrm{d}V + \int_{\Omega_0} k\, \nabla(\delta\theta)\nabla\theta \mathrm{d}V - \int_{\partial\Omega_N} \delta\theta\, h\, \mathrm{d}A - \int_{\partial\Omega_R} \delta\theta\, \alpha\, (T_{flu} - \theta)\, \mathrm{d}A = 0 \quad (1)$$

- Discretization (spatial, semi-discrete)

$$\mathbf{C}\,\dot{\mathbf{\Theta}} + \mathbf{K}\,\mathbf{\Theta} - \mathbf{f} = \mathbf{0}$$

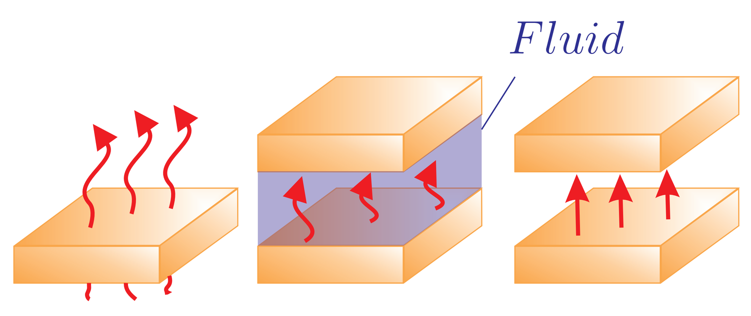
- Discretization in time: $\dot{\theta} = (\theta_{n+1} - \theta_n)/\Delta t$

$$\left[\frac{1}{\Delta t}\mathbf{C} + \mathbf{K}\right] \mathbf{\Theta}_{n+1} - \left[\mathbf{f}(t_{n+1}) + \frac{1}{\Delta t}\mathbf{C}\,\mathbf{\Theta}_n\right] = \mathbf{0}$$

Boundary conditions

- Overfall heat flux on boundary

$$Q = \gamma\, Q_{fric} + Q_{con}$$



Neumann boundary

- h is introduced across the surface of the brake pads

$$\gamma Q_{fric} = \int_{\partial\Omega_N} h\, \mathrm{d}A$$

Robin boundary

- Heat transfer

$$Q_{con} = \int_{\partial\Omega_R} \alpha\, (T_{flu} - \Theta)\, \mathrm{d}A$$

- Forced convection

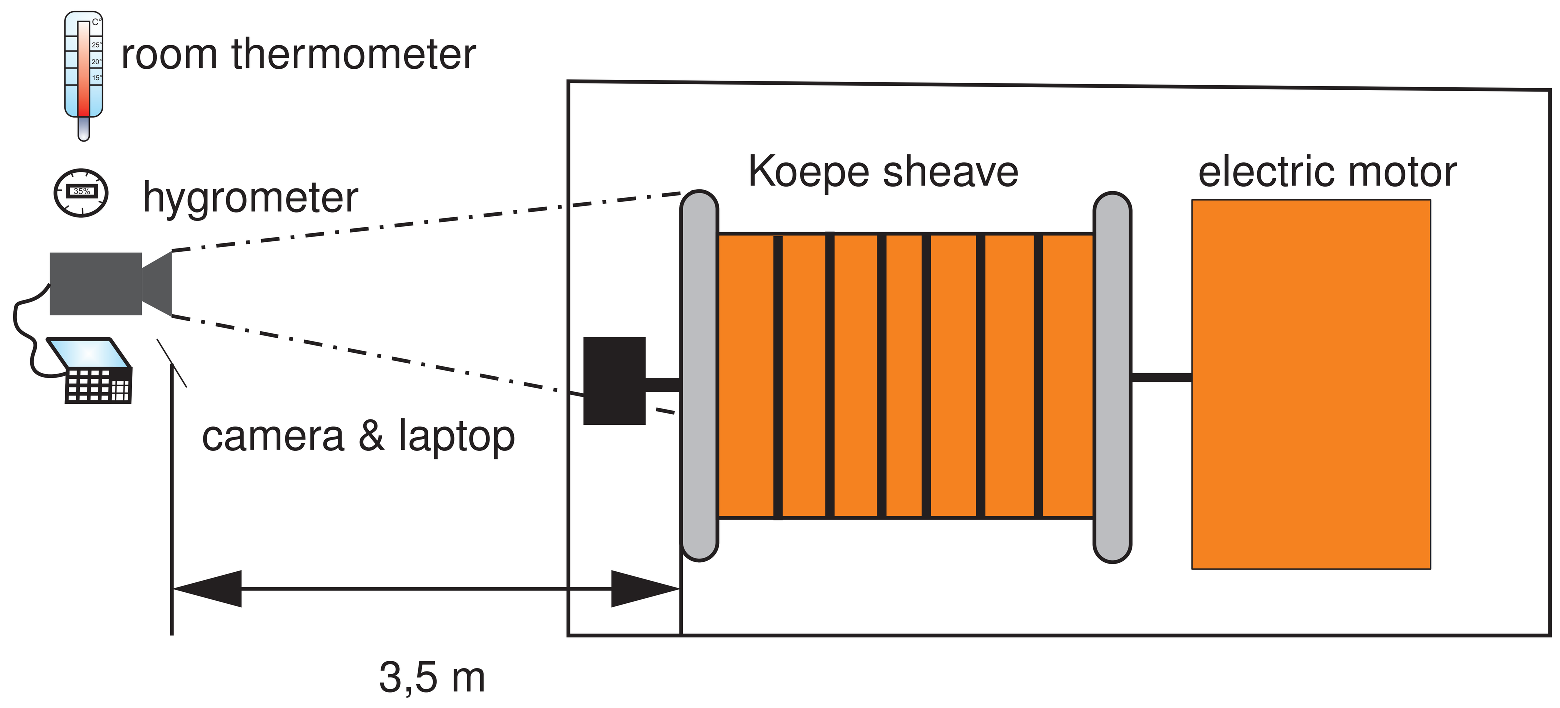
$$\alpha = \frac{Nu(Re, Pr)\, k}{L}$$

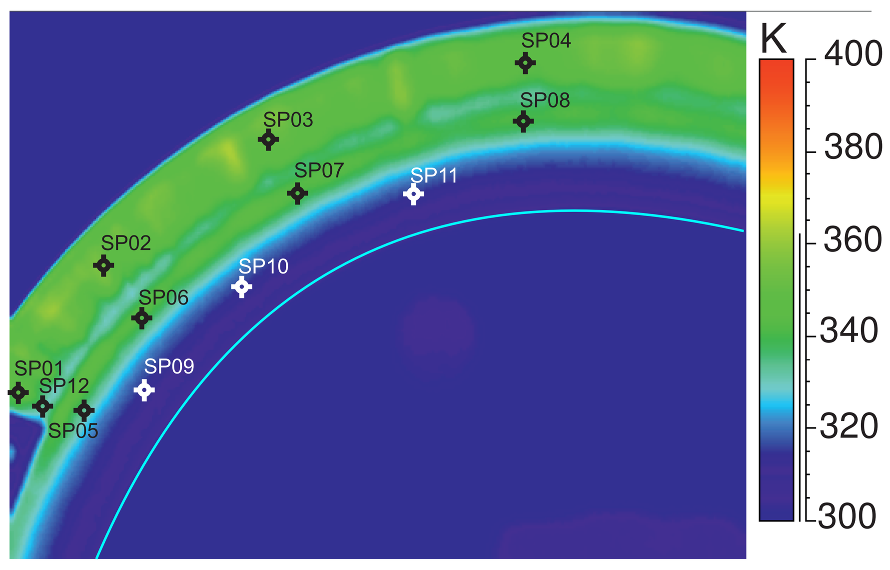
- Free convection

$$\alpha = \frac{Nu(Gr, Pr)\, k}{L}$$

Measurement

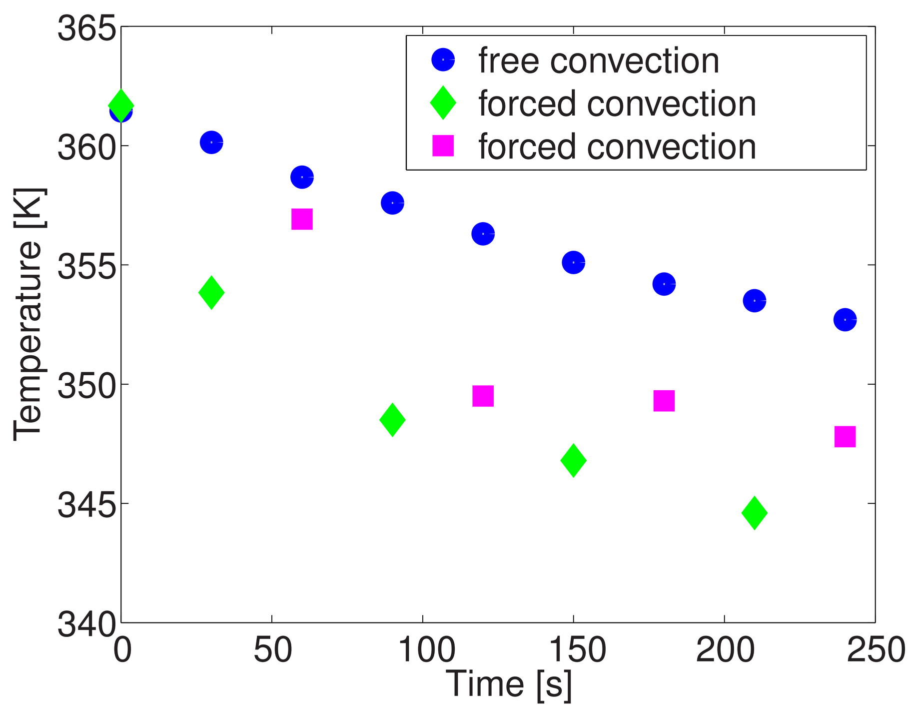
Measurement setup



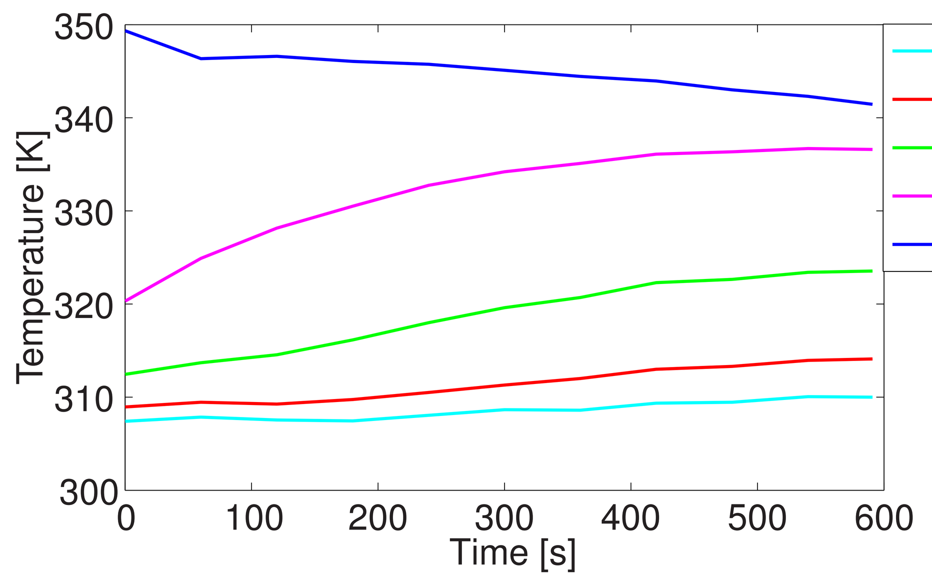


- Thermographic camera from FLIR
- Evaluation software *Researcher Pro 2.10*

Measurement results

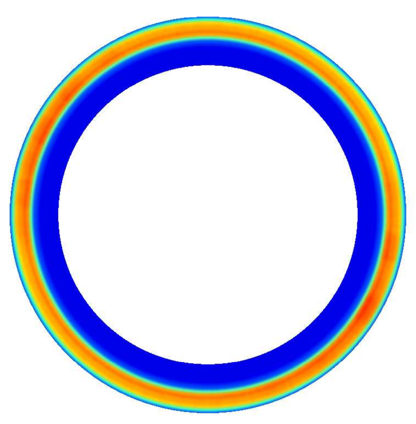


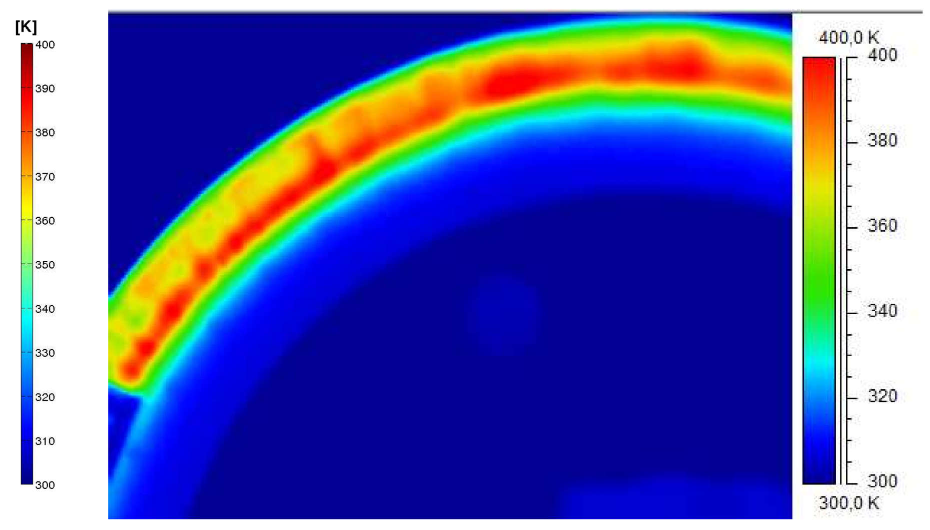
- Cooling curves for free and forced convection



- Heat conduction in the radial direction

Simulation





	Temperature in Kelvin [K]
Measurement	376,4-390,3
Simulation	383,5