Measuring Optical and Thermal Properties of High Temperature Receivers

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Part I:

Thermal properties of receivers for

*SOLAR TOWER TECHNOLOGY*

→ Thomas Fend

Part II:

Optical and thermal properties of tube receivers for

*PARABOLIC TROUGH TECHNOLOGY*

→ Johannes Pernpeitner
Why Solar Tower Technology?

- Efficiency limited by thermal engine
- Higher temperatures – higher efficiencies
- Higher losses at higher temperatures
- Higher concentration ratio
Solar Tower Technology: Example
Receivers for Solar Tower Technology

- volumetric receivers
- tube receivers
- direct medium receivers
- ...
Tube Receivers

- absorption on outer tube surface
- transport of heat through tube wall to a medium
- **media:** liquid salt, liquid metal, water, air

  - thermal resistance
  - non homogeneous heating
  - tube surface temperature is higher than medium temperature
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Source: desertec UK
**Volumetric Receivers**

- Radiation absorbed in the porous volume of the receiver
- Front temperature lower than medium temperature

- **Medium**: air, pressurized air
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**Solar Tower Jülich**

- Tower: 60m
- 2153 Heliostats (8.2 m²)
- 22.7 m² receiver aperture
- 1 h thermal storage
- 500°C/ 30 bar
- 1.5 MWₐₑ turbine
Thermal Performance Prediction
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- Absorption
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- Absorption
- Conductive resistance in tube wall
Thermal Performance Prediction

- Absorption
- Conductive resistance in tube wall
- Convective resistance
Thermal Performance Prediction

- Absorption
- Conductive resistance in tube wall
- Convective resistance

→ tables
→ standard techniques
→ optimization of process by geometry and thermal properties of the employed material
Thermal Performance Prediction: Heat Transfer Enhancing Concepts

- Increased heat transfer surface
- Enhanced heat transfer by gradation in radial direction
- Thermal properties of porous material needed
- Proposed in Korean/Swiss/German project \textit{CMC4CSP}
Thermal Performance Prediction: Volumetric Receiver

- Conductive resistance and
- Convective resistance in porous volume

→ Advanced experimental techniques necessary if non-uniform pore geometries are used
Thermal Performance Prediction

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Thermal Conductivity of Porous Materials

- Transient Plane Source Technique
  - Measurement of characteristic volumes
  - Measurement yields
    - effective thermal conductivity
    - effective thermal diffusivity
    - heat capacity
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Effective Thermal Conductivity of Porous Materials: Metal Foams

Nickel base alloy

Thermal Conductivity (W/mK)

Temperature (°C)

model solid conductive
model conuctive + radiation
experimental data 2140
Convective Resistance in Porous Volume

- two phase approach in continuum model
- Additional term in energy equations of solid and fluid phase

\[ \lambda_{\text{eff}} \nabla^2 T_S - \alpha A_v (T_S - T_F) = 0 \]

\[ \dot{m} C_P \frac{dT_F}{dx} - \alpha A_v (T_S - T_F) = 0 \]

\( \alpha A_v \): volumetric convective heat transfer coefficient
Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient

$\alpha_{Av}$: AAF-method

- Air flow with alternating temperature profile induced
- Porous sample causes phase shift and amplitude attenuation
- $\alpha_{Av}$ determined

1) Alternating Air flow method after Younis and Viskanta
Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient

$\alpha_{Av}: AAF\text{-method}$
Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient

\( \alpha_Av: AAF\text{-}method \)
Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient

\( \alpha_{Av}: AAF\text{-}method \)

\[ \text{Nu} = 4.8 \cdot n_{PPI}^{-1.1} \cdot \text{Re}^{0.62} \]
Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient

\( \alpha_{Av}: \text{AlAv-method}^{1} \)

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1) AlphaAv-method after Brendelberger et al.
Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient

$\alpha_{Av}: AlAv\text{-}method$
The AlAv-method: Results on Metal Foams
Conclusions

• For the prediction of the thermal performance of high temperature components characteristic quantities are needed
• Transient plane Source Technique for thermal conductivity measurement
• AAF and AlAV method for volumetric convective heat transfer properties