Karlsruhe Institute of Technology

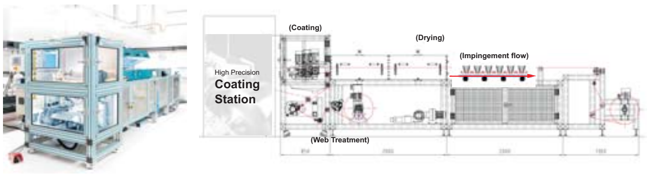
Institute of Thermal Process Engineering
Thin Film Technology
Dipl.-Ing. Lukas Wengeler
Phone: 0721/608-7152 | Fax: 0721/608-5319
Lukas.Wengeler@kit.edu | www.tft.kit.edu

# Local heat and mass transfer in impingement driers

L. Wengeler, P. Cavadini, P. Scharfer, W. Schabel

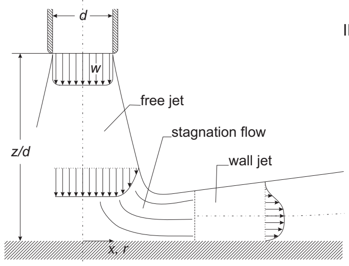
## Introduction

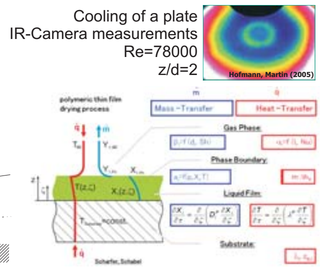
### Motivation




- Technical impingement driers show inhomogeneous drying conditions
- → Measurement of transfer coefficients using a portable sensor
- → Optimization of nozzle geometries:
  - Numerical simulation (CFD)
  - Heat transfer measurements based on thermochromic liquid crystal technology

### Heat transfer within impinging jets

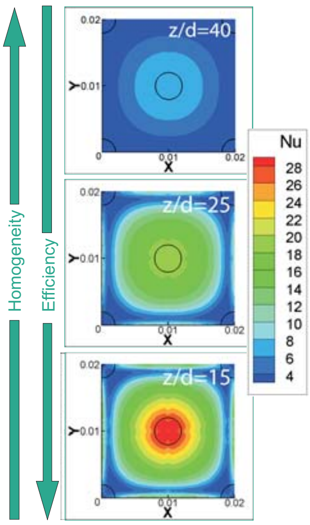


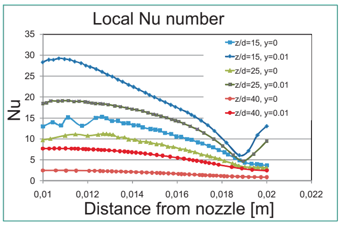




## Optimizing homogeniety in impingement driers

### Simulation of impingement flows

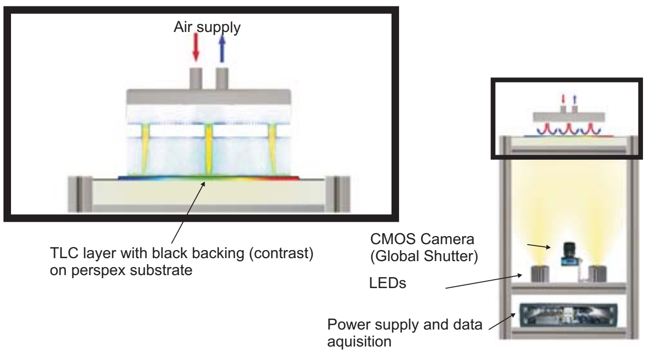
- IDEA:
  Optimization of transfer homogeneity by CFD
- CFD-Setup:
  Fluent, 3D, symmetric bocos, Re=2440
  RANS–realizable κ-ε with wall enhancement
- CONCEPT:
  - Staggered array of round nozzles with effusion holes to minimize x-flow effects
  - Each inlet nozzle is surrounded by 4 effusion holes and vice versa
- RESULTS:
  - Increasing separation distance:
    ↑Homogeneity, ↓ Efficiency
  - Although x-flow effect minimized, interaction between adjacent jets remains
- → Investigation of more complex configurations



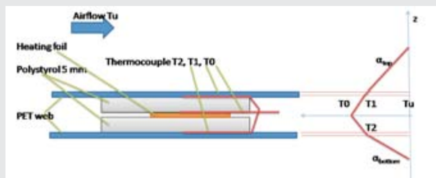

### Experimental setup for drier optimization

- TLCs indicate temperature by change of reflected wavelength (RGB)
- Recording of temperatue distribution at the wall during heating by air jets
- Assuming the substrate being a semi-infinte wall, analytical solutions for htc exist
- → High resolution measurement for local heat transfer




## On site measurement of local heat transfer

### Sensor design and application

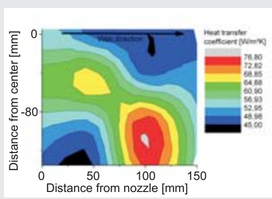


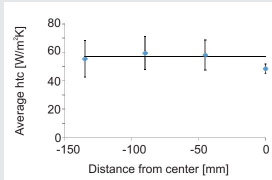

- Local heat transfer can be measured with a small portable sensor within technical driers
- Multi-point sensor os currently in the process of development

### Measurement Results

First measurements with the novel heat transfer sensor:

- Two dimensional plot of local heat transfer
- Local variation up to 180% at high flow rates
- Lower variation (~10%) after averaging in web direction
- Integral results are within 10% of the prediction by Schabel and Martin
- → An improved sensor with an array of measurement points is currently being tested




## Summary

- A novel sensor for local heat transfer in slot nozzle driers was designed and tested in a technical drier. The results were in good agreement with theory (Schabel and Martin, 2006) and experiments (Martin, 1973).
- Measurements revealed strong local variations for high air flow rates with peak values at the edge of the foil.
- Simulation of impinging jet was applied for different drier geometries also showing high inhomogenities.
- A Setup for detailed analysis of local heat transfer has been developed
- Optimized geometries can now be predicted by theory and validized by experiments.

## References

H. Martin, Heat and Mass Transfer between Impinging Gas Jets and Solid Surfaces. Adv.in Heat Transfer, vol. 13, pp. 1–60, 1977.
P.T. Ireland and T.V. Jones, Liquid crystal measurements of heat transfer and surface shear stress. Measurement Science and Technology, 11, pp. 969–986, 2000.
H. M. Hofmann, Wärmeübergang beim pulsierenden Prallstrahl. Dissertation Universität Karlsruhe (TH), Karlsruhe, Germany, 2005.