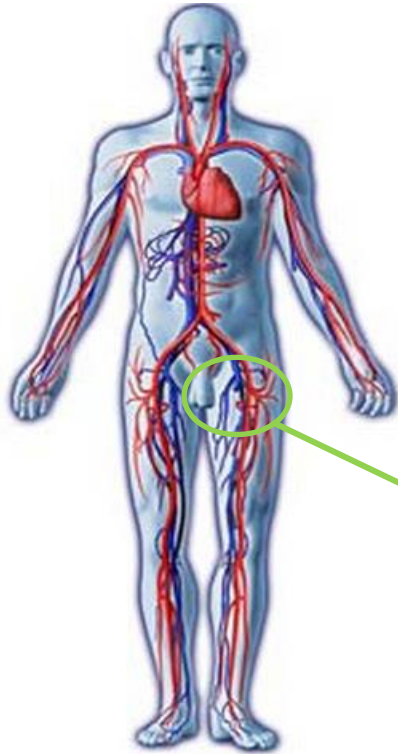


# Simulation and Verification of bionic heat exchangers with COMSOL Multiphysics

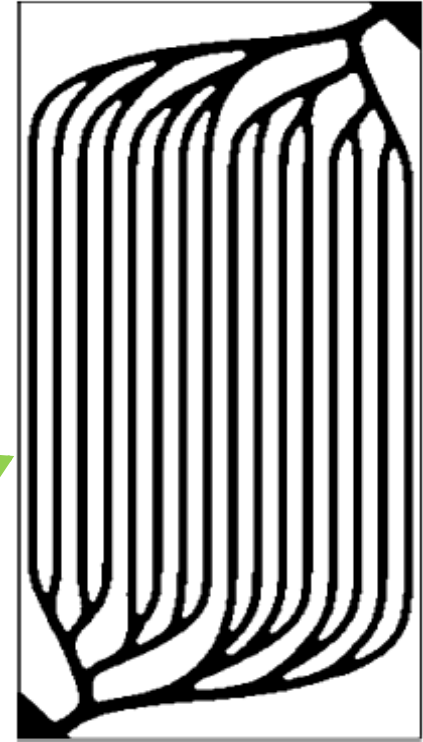
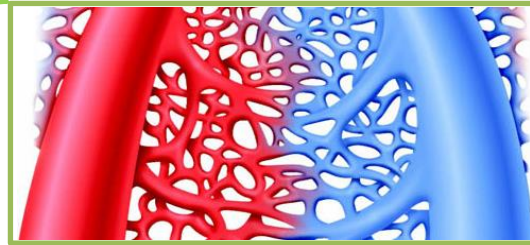
A. Kremers, M. Pieper



<http://m.tk.de/centaurus/servlet/Bild/34341>

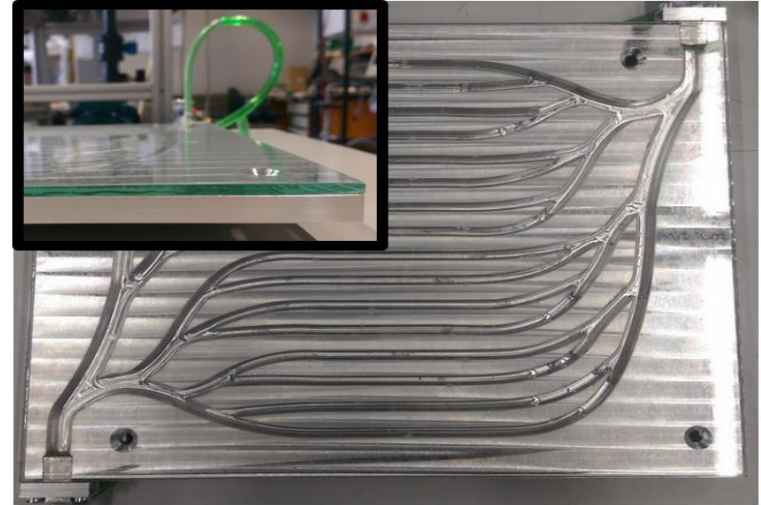
## Bionic heat exchanger

- Analogy to blood vessel system
- Low pressure losses
- Low energy consumption
- Optimized for fluid transport

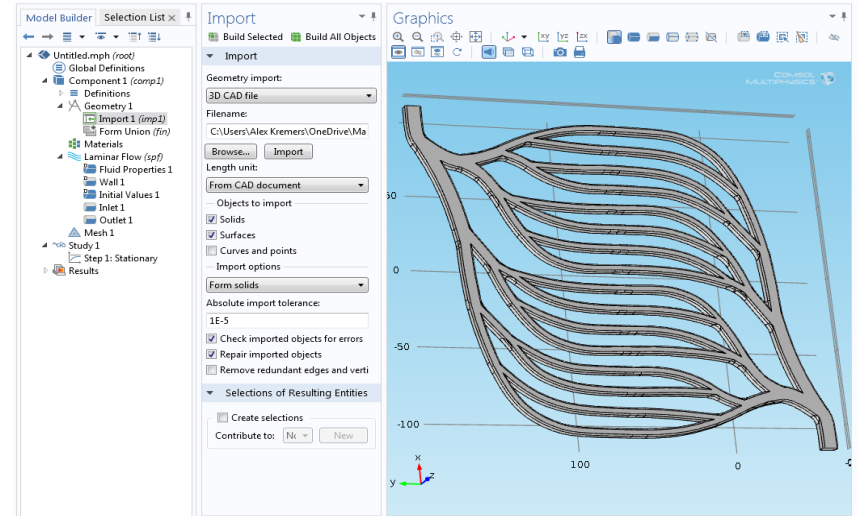


[1], [2]

- Production of 2 real heat exchangers
- Different cover plates for different experiments:
  1. *Pressure loss*: glass cover plate, tap water at room temp., pressure difference between in- and outlet
  2. *Temperature difference and behaviour*: aluminium cover plate, heated tap water, temperature difference between in- and outlet, thermographic camera
  3. *General flow behaviour*: glass cover plate, special fluid to visualize flow behaviour, high definition camera



- Same CAD model used for production of real heat exchangers and for simulations with COMSOL
- Flow velocities in laminar border zone  
→ Assumption: laminar flow
- Two simulation series:
  1. Laminar flow, stationary (pressure loss & flow behaviour)
  2. Non-isothermal flow, time dependent (temperature difference & temperature behaviour)
- Data from experiments as input data for simulations



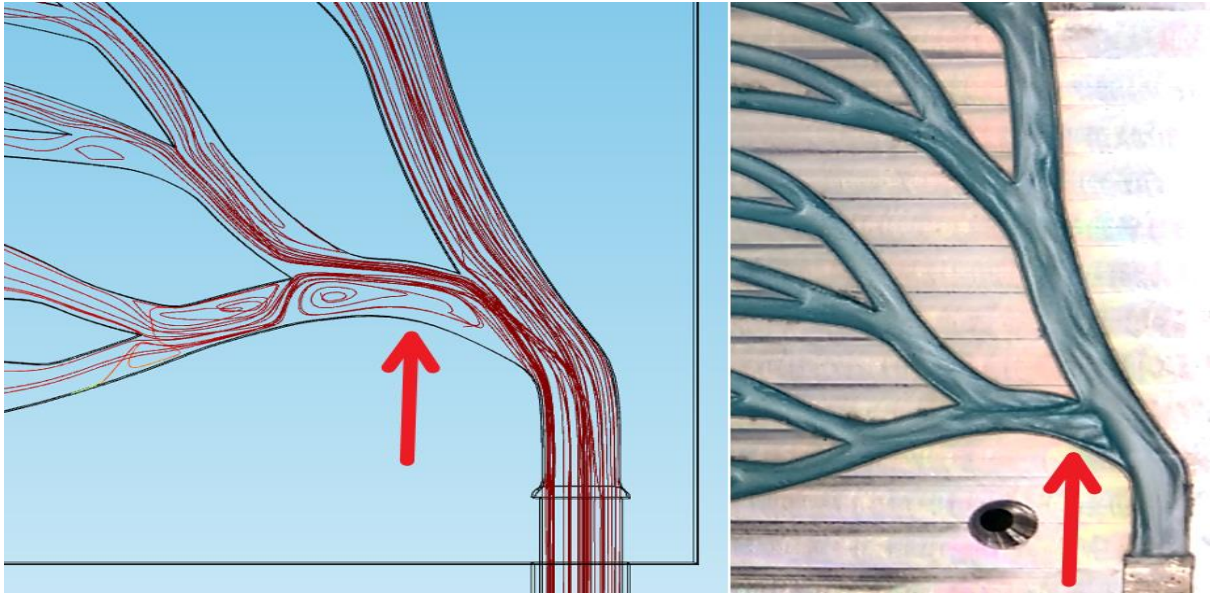
## 1. Pressure loss

Inlet velocity [m/s]	Differential pressure experiment [mbar]	Differential pressure simulation [mbar]	Error [%]
0.55	3.95	3.63	8,1
0.91	9,95	8.82	11,3
1.27	19.22	16.65	13,7

- Pressure difference was measured at different inlet velocities
- A simulation was done for every inlet velocity
- Average error between simulation and experimental results: **11%**
- Higher inlet velocity → higher error  
    ➡ Flow velocities more and more in turbulent flow zone
- Good results of comparison between simulation and experiment

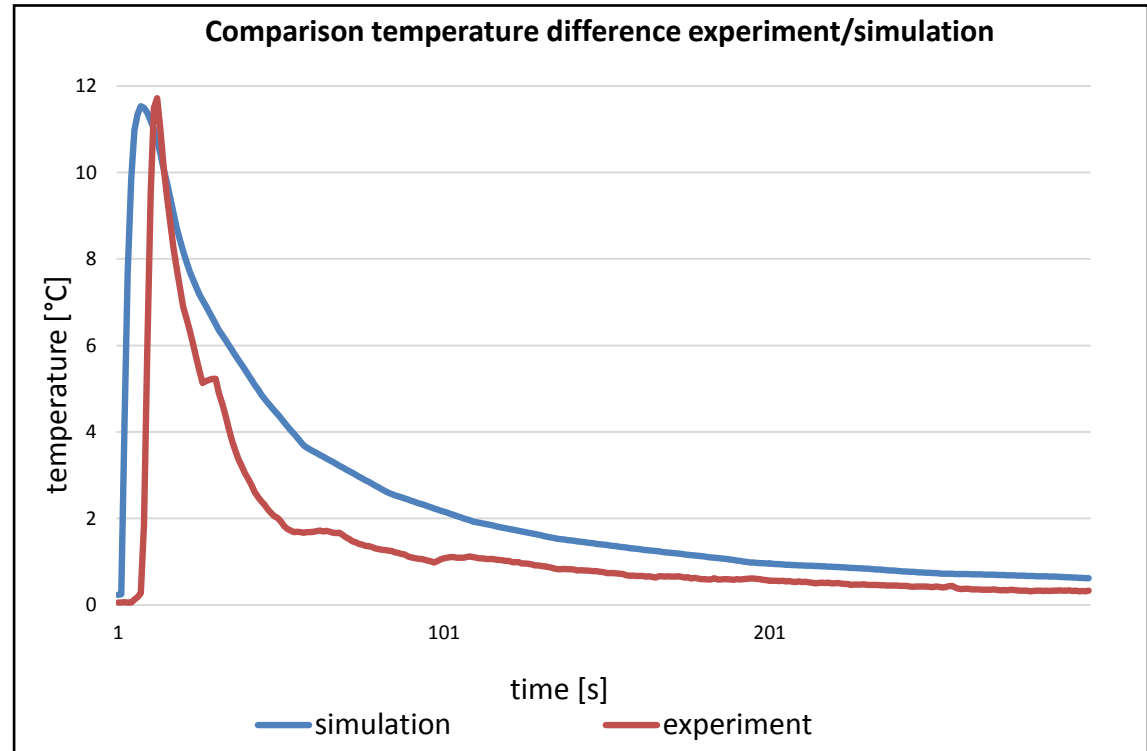
## 2. General flow behaviour

- Very good results
- Good correspondence with respect to flow behavior
- COMSOL calculates swirls of same size and position



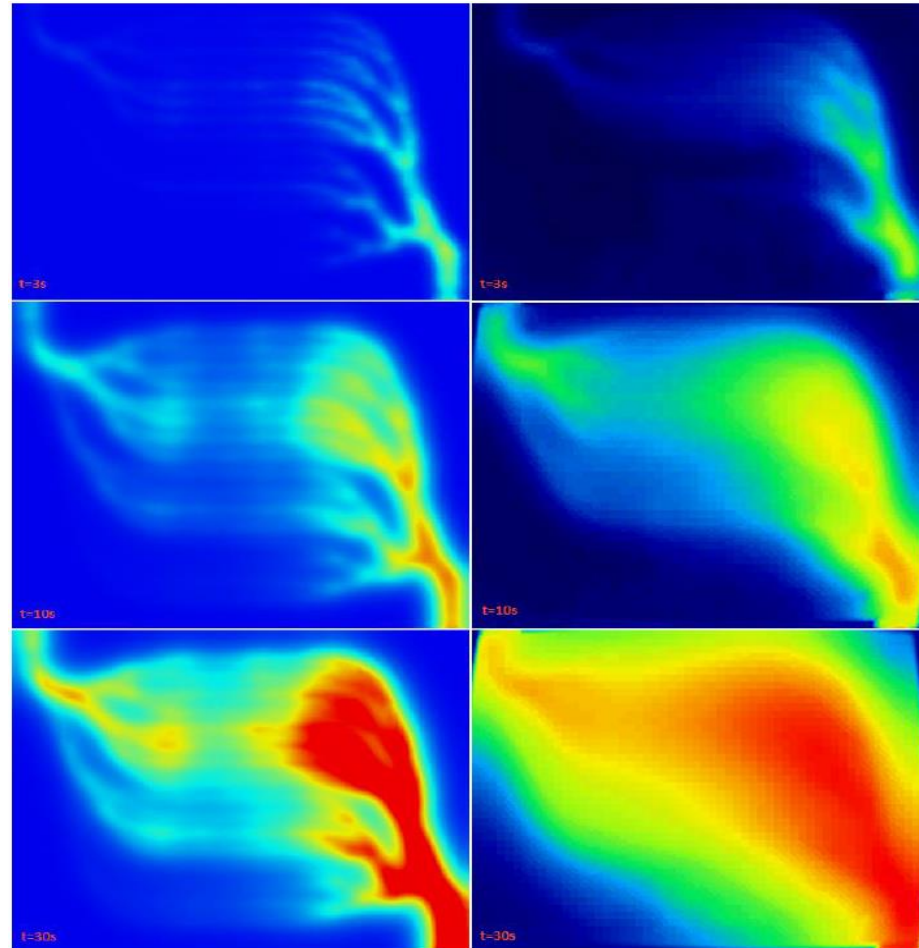
## 3. Temperature difference and behaviour

- Graphs do have similar trend, but are not congruent to each other
  - Reasons:
    - Laminar flow model was used, but actually turbulent flow behaviour in some spots
    - Material data of aluminum of real heat exchangers was not exactly known
- Material data of COMSOL material library was used



## 3. Temperature difference and behaviour

- Left: COMSOL
- Right: Thermographic camera
- Nearly equal pictures at the same time
- Very good correspondence





## Conclusion:

- The comparison between simulations and experiments shows positive results
- The error between simulation and experiment results is dependent on the particular physical parameter
- Pressure loss: Average error: 11%
- General flow behaviour: COMSOL results are equal to experiment results
- Temperature difference and behaviour: Temperature differences show a similar trend, but are not congruent. The pictures of the thermographic camera are nearly equal to the simulation results



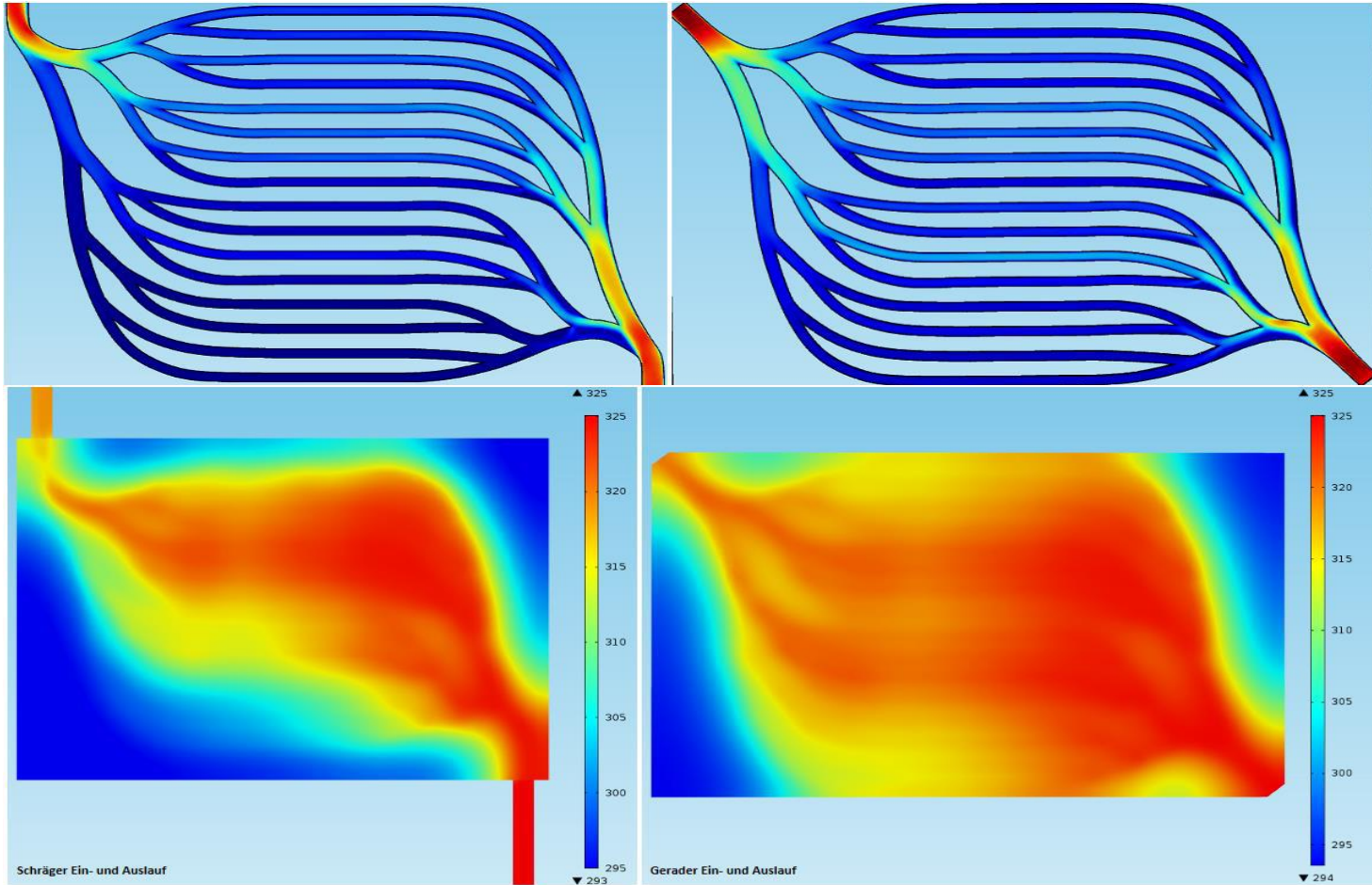
**Comsol Multiphysics® can be verified as an extremely useful tool to design and test physical and technical processes**

## Sources:

[1]: M. Pieper, P. Klein: A simple and accurate numerical network flow model for bionic micro heat exchanger

[2]: M. Herrmann: „Bionische ansätze zur Entwicklung energieeffizienter Fluidsysteme für den Wärmetransport“, PhD-Thesis, University of Karlsruhe, 2005

# Improvement of the bionic heat exchanger design



## 3D CAD structure

- Development of 3D-CAD model according to an optimized 2D model
  - Channels become smaller after every branching
  - Mirroring of structure for perfect symmetry
  - Optimizing CAD model for simulation reasons
  - Simulation with optimized CAD model runs fast and without any problems
- Simplifying the CAD model can speed up your simulation

