Simulation of Heat Transfer on Periodic Microstructured Surfaces for Evaporation Cooling

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Microstructures for Evaporation Cooling

- In high power density applications evaporative cooling is a promising method for dissipating high heat fluxes
- Using micro structured evaporator surface enhances heat transfer
- FEM Simulations enable preselecting promising microstructures for experiments

Results

- Fluid dynamics: (**Fig. 1** and **2**)
  - Cubic pin arrangement: Fluid flows from pin tops to structure bottom
  - Hexagonal pin arrangement: Fluid flows from structure bottom up over pin tops → Advantage for evaporative cooling: Emerged bubbles are removed quickly from cooler surface
  - In hexagonal pin arrangement stronger fluid stirring occurs
  - In hexagonal pin arrangement fluid reaches higher velocities after being close to solid body surface
- Thermodynamics:
  - Total heat flux density stream lines concentrate in pins in both pin arrangements (**Fig. 3** and **4**)
  - In hexagonal pin arrangement total heat flux density stream lines reach higher norm and distances to solid body (**Fig. 4**)
  - Lowest averaged solid body surface temperatures occur in hexagonal pin arrangement (**Fig. 5**)
  - Thermodynamic advantage of microstructures rises with inflow velocity
  - Highest heat transfer coefficient achieved with hexagonal pin arrangement (up to 230% related to plane cooler surface)

Non-Isothermal Flow Model

- Investigating flow profiles as well as conductive and convective components of heat transfer
- Exploiting stable and symmetric flow conditions in periodic microstructures → Periodic geometry (**Fig. 6**)
- Using stationary compressible form of Navier-Stokes and energy equations
- Investigated microstructure arrangements shown in **Fig. 7** and **8** (pin diameter: 100 µm; pin height: 50 µm, horizontal and vertical center distance: 200 µm)

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ZIM Zentrales Innovationsprogramm Mittelstand

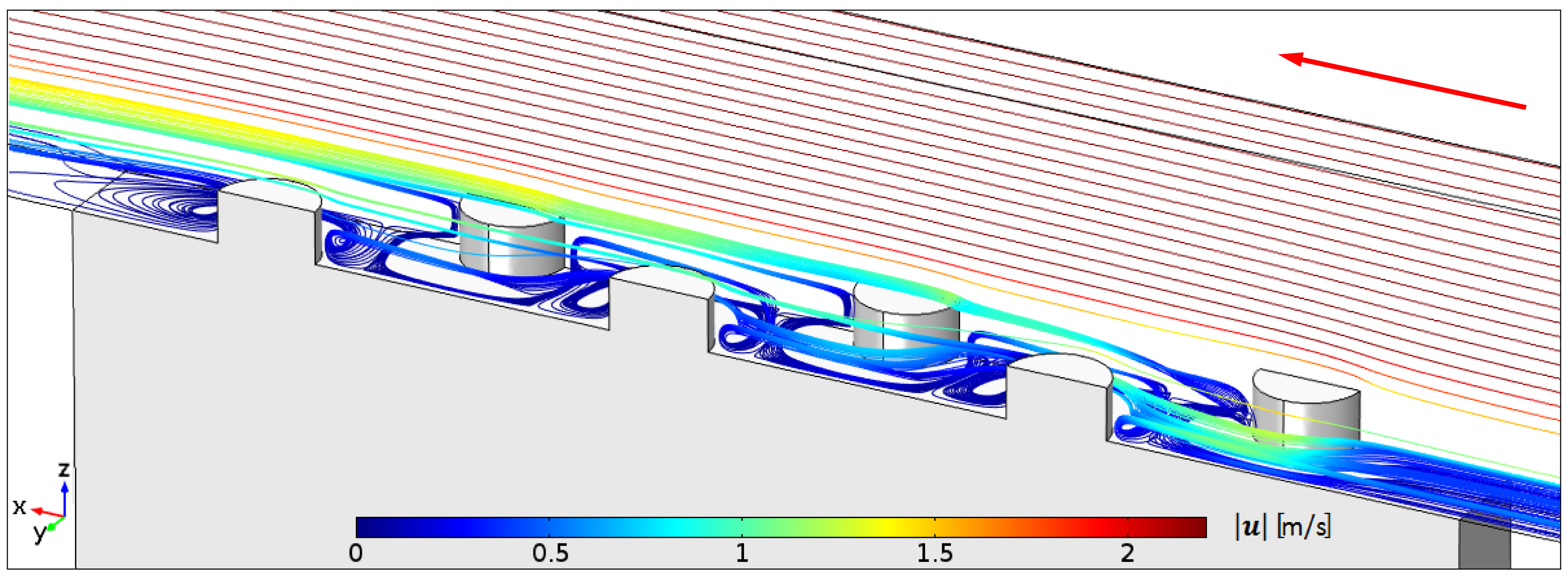

Fig. 1: Streamlines of the velocity field (hexagonal pin arrangement; U_0 = 2 m/s)

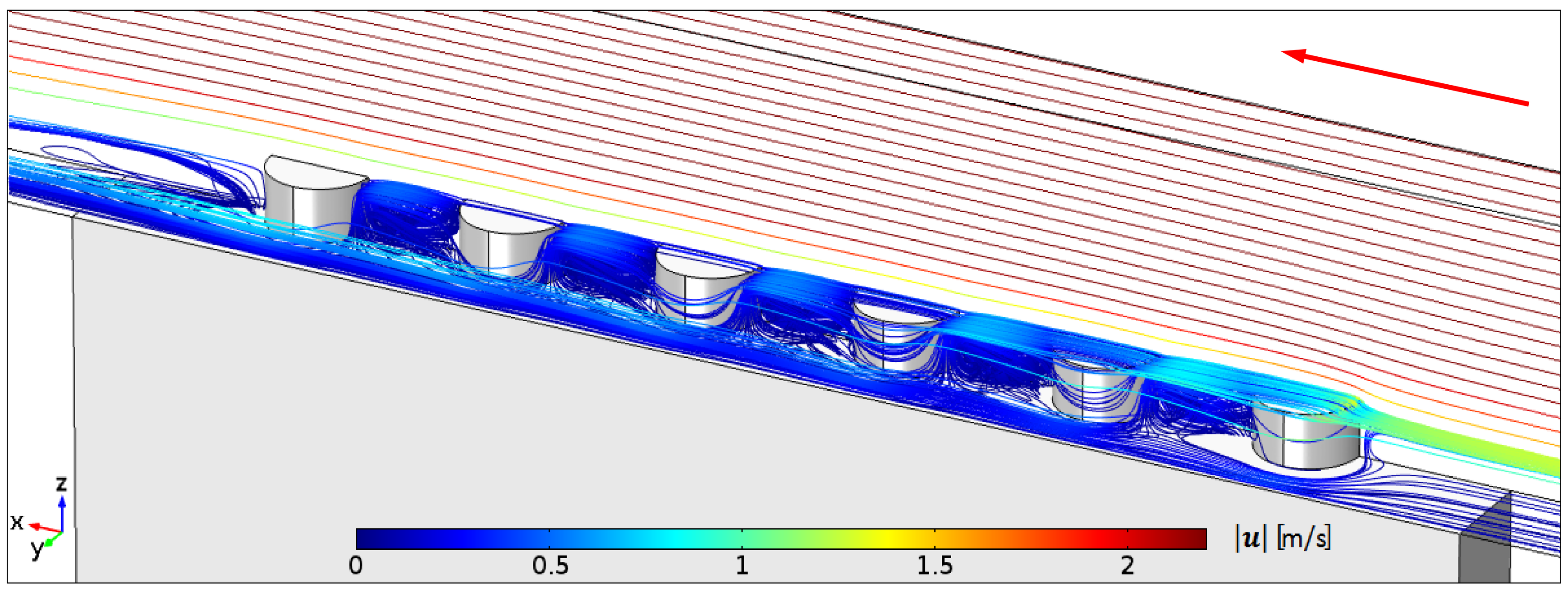

Fig. 2: Streamlines of the velocity field (cubic pin arrangement; U_0 = 2 m/s)

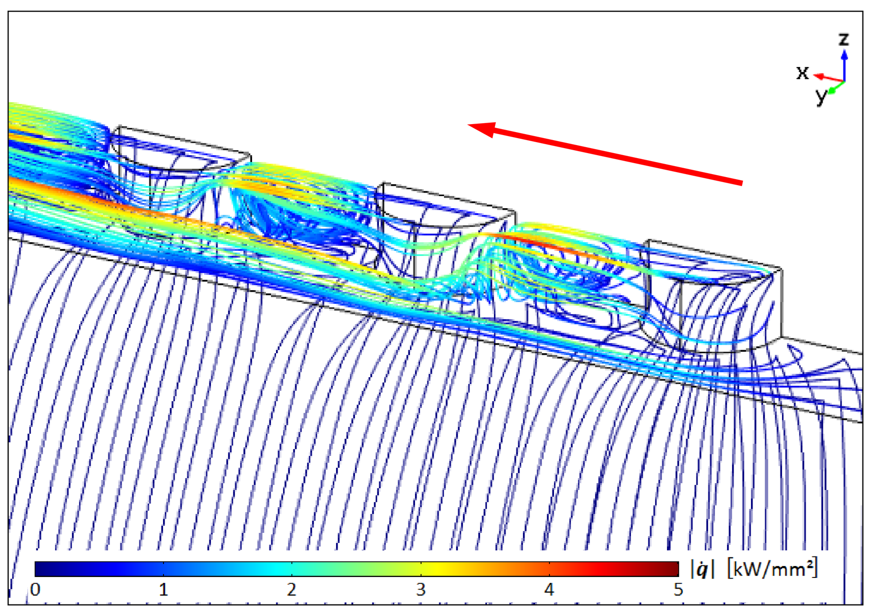

Fig. 3: Streamlines of the total heat flux density field (cubic pin arrangement; U_0 = 7 m/s)

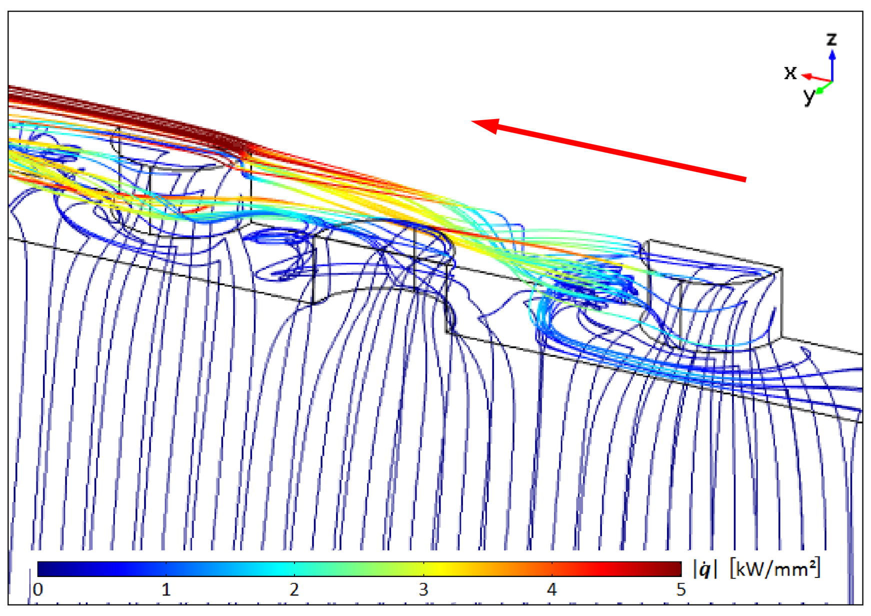

Fig. 4: Streamlines of the total heat flux density field (hexagonal pin arrangement; U_0 = 7 m/s)

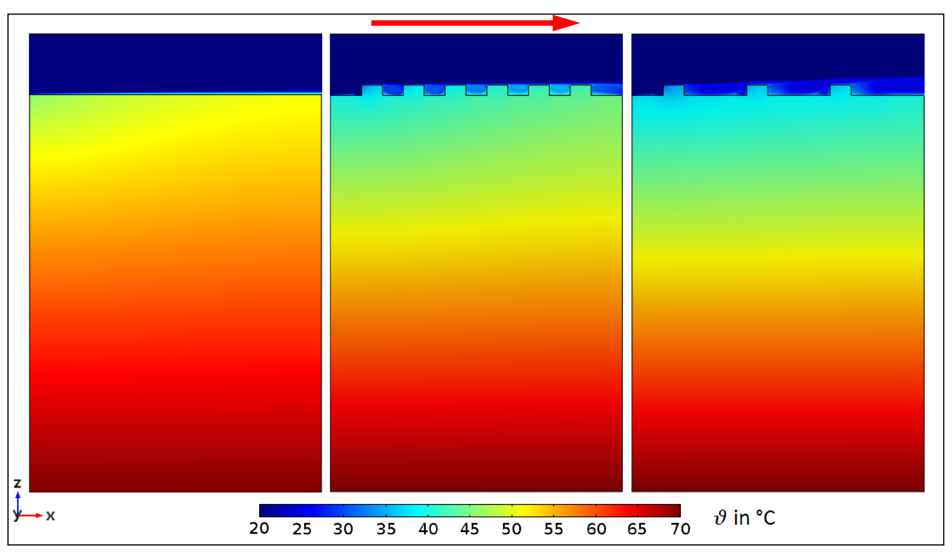

Fig. 5: Temperature distribution (left: plane surface; middle: cubic pin arrangement; right: hexagonal pin arrangement; U_0 = 7 m/s)

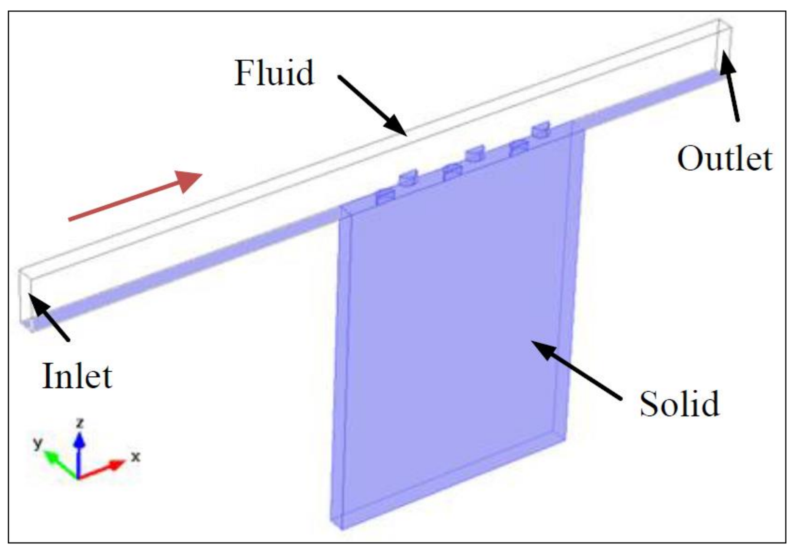

Fig. 6: Model geometry showcase for pin arrangement

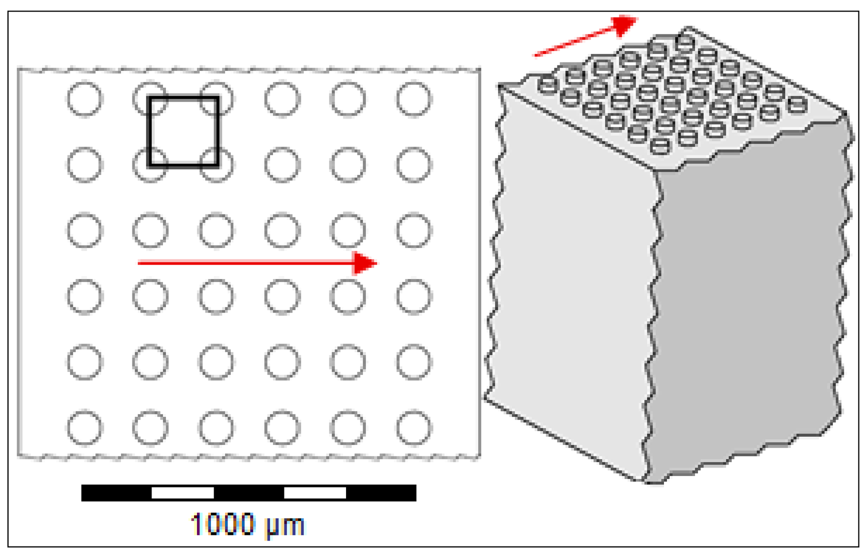

Fig. 7: Microstructure with cubic pin arrangement

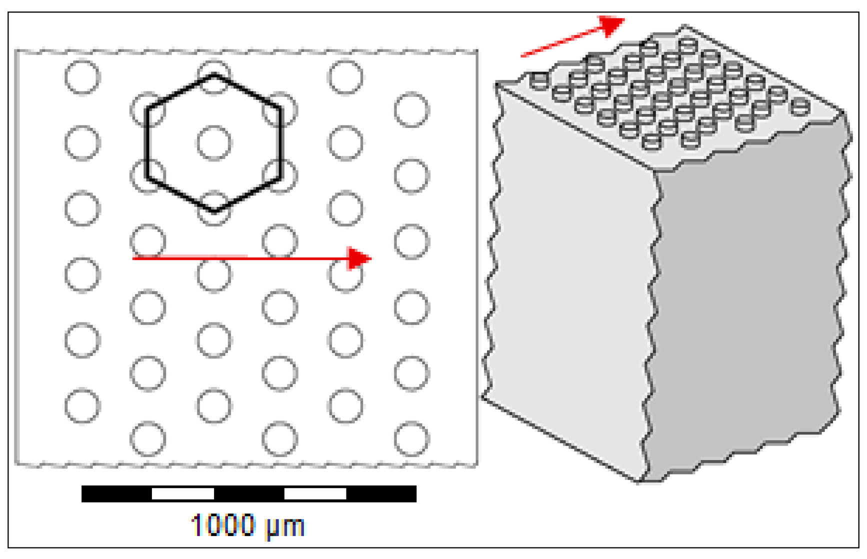

Fig. 8: Microstructure with hexagonal pin arrangement

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