CFD SCHUCK

Ingenieurgesellschaft mbH

Software-Based Optimization of E-Machine Spray Cooling Systems

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➢ *Outline*

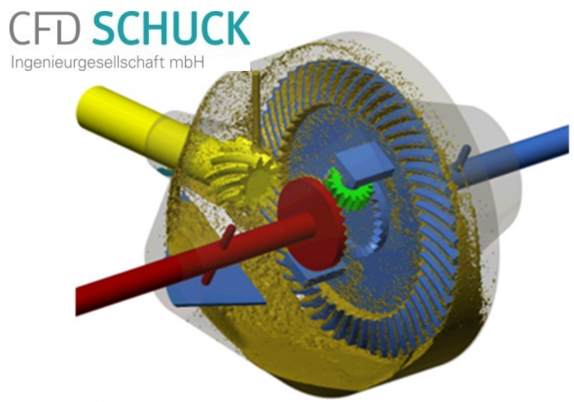
- Motivation
- CFD for E-Machine Design Process
- New Optimization Method for Spray Cooling Systems
- Results
- Conclusion

Optimization of E-Machine Spray Cooling Systems

➢ *Company Profile*

- Engineering services in Computational Fluid Dynamics
  - established in Heidenheim in 1990
  - 20 employees at 3 locations
- More than 25 years of simulation experience
  - 10 years of experience regarding cooling of electric machines
  - Use of all key commercial CFD software packages
- Core competences
  - support of product development via CFD simulation
  - development of tailor-made simulation methodologies
  - CFD-training and consultancy

CAD data: DrivAer © Lehrstuhl für Aerodynamik und Strömungsmechanik, TU München



CAD data from KISSsoft (www.KISSsoft.AG)

➢ *Motivation*

- Development of Electric Machines
  - trends towards reduced development time
  - increasing power to weight requirements

  => importance of effective thermal management

  => requirements of innovative cooling concepts

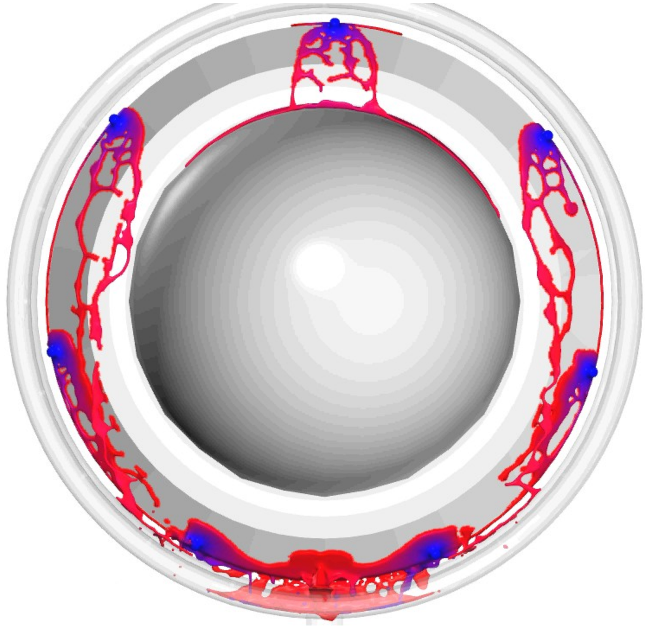
  => use of simulation tools is recommended

- Application of Computational Fluid Dynamics (CFD)
  - well established in automotive industry
  - prediction of component or cooling liquid temperatures
  - development of heat balances

Optimization of E-Machine Spray Cooling Systems

➢ *CFD for E-Machine Design Process*

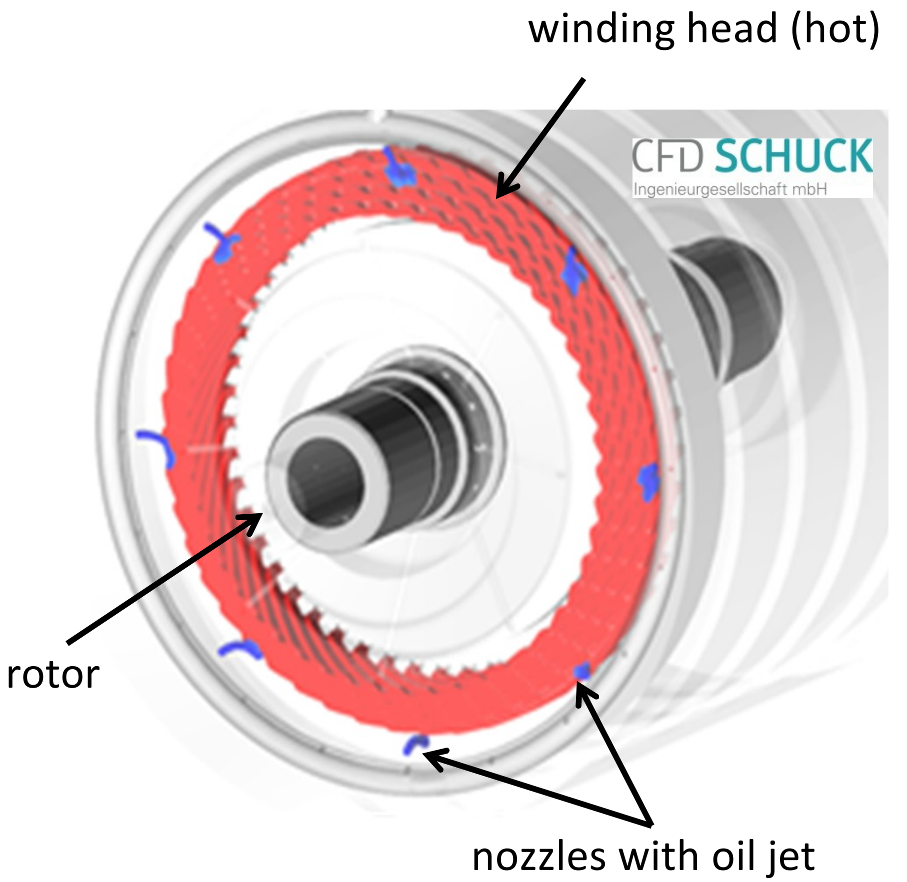
- Application of CFD for E-Machine cooling
  - air cooling with fans
  - water jacket and shaft cooling
  - thermal management of entire E-machine
    - combination of different cooling methods
    - oil spray cooling



Optimization of E-Machine Spray Cooling Systems

➢ *Spray Cooling Systems*

- Objectives of investigation
  - oil flow, surface wetting, contact time
  - heat transfer from winding head surface to oil
  - Process time (5-15sec)
- Parameters
  - nozzles:
    - diameter, angle of inclination
    - number, position, spatial distribution
  - operating conditions:
    - oil flow rate, initial oil temperature
    - winding head geometry and temperature
    - fluid rotation due to rotor



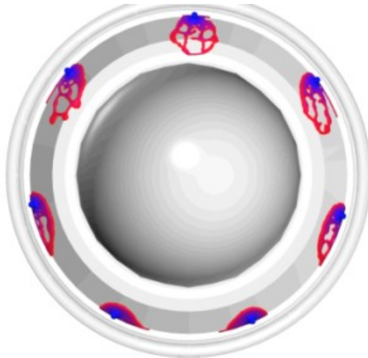
Optimization of E-Machine Spray Cooling Systems

➢ *CFD based design of Spray Cooling Systems*

- Grid based CFD :
  - detailed physical models available => high accuracy
    - oil: flow, impingement, fluid film, oil-air interaction
    - local heat transfer coefficients, heat flux, heat conduction
  - time for a simulation: 1-2 weeks (HPC-Cluster)

- **S**mooth **P**article **H**ydrodynamics (SPH-CFD)
  - a few physical models available => lower accuracy
    - oil: flow rate, impingement, wetting,
    - one-way air-oil coupling
    - total heat transfer from surface to particles
  - time for a simulation: few hours (workstations)

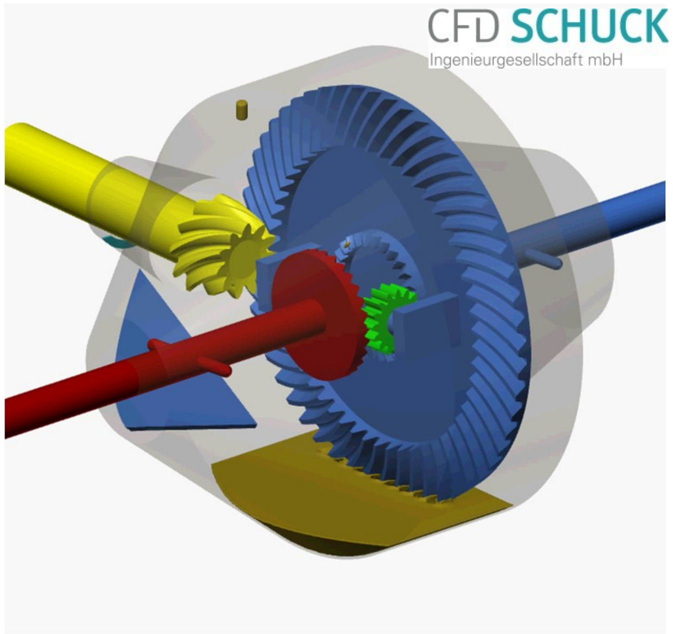
    => Requirement for early design phases

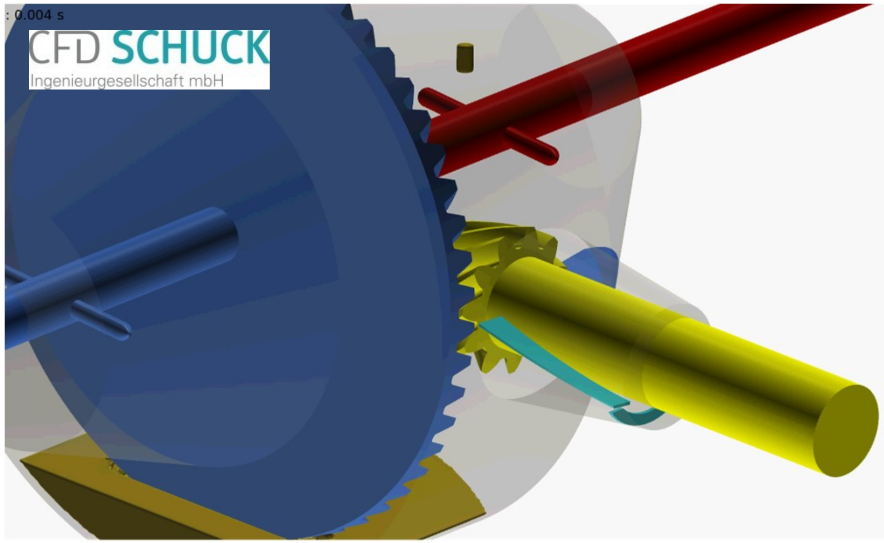


Optimization of E-Machine Spray Cooling Systems

➢ *Examples of SPH simulations*

- GearBox-Optimization





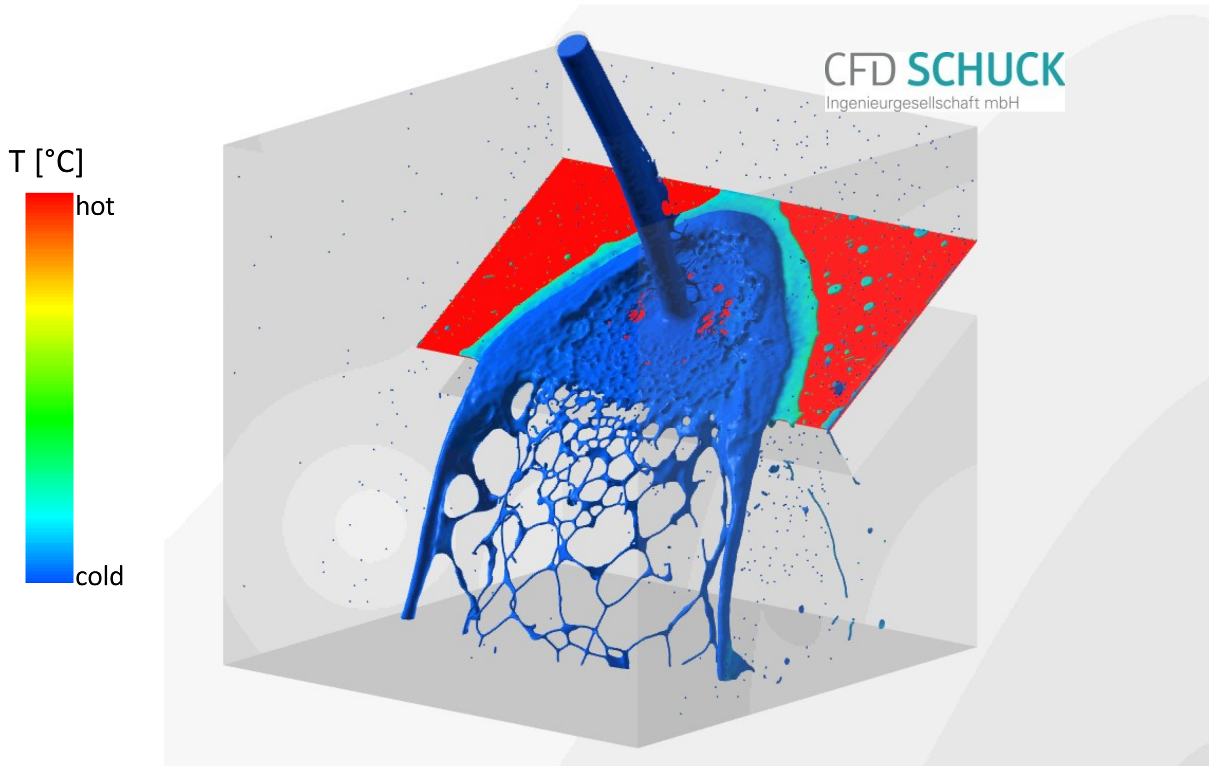
CAD data from KISSsoft (www.KISSsoft.AG)

Optimization of E-Machine Spray Cooling Systems

➢ *Examples of SPH simulations*

- Oil impact and flow on hot surfaces

Oil-Heating



Optimization of E-Machine Spray Cooling Systems

➢ *New Design methodology for spray cooling*

- Quick and reliable comparison of design concepts
- Optimization of designs

  => minimum of total time for investigation

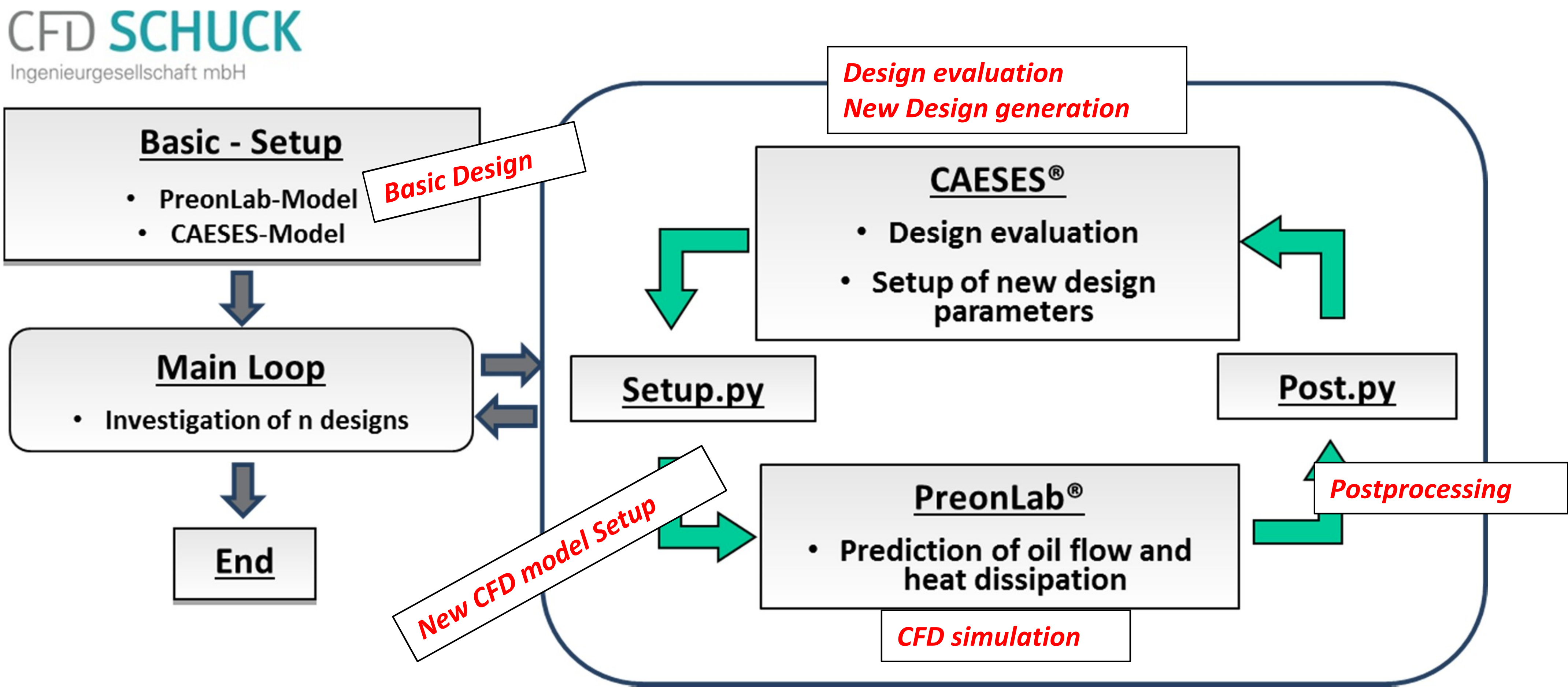
  => fully automated workflow

  - parametric CAD and CFD models
  - software based optimization

- Software
  - SPH Solver: PreonLab (FIFTY2 Technology)
  - Optimization: CAESES (FRIENDSHIP SYSTEMS)
  - proprietary Python-based scripts

Optimization of E-Machine Spray Cooling Systems

➢ *Optimization Workflow*



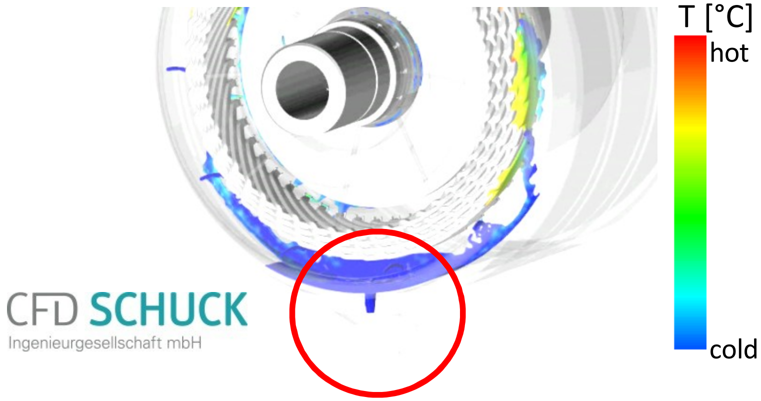
Optimization of E-Machine Spray Cooling Systems

CFD based design of Spray Cooling Systems

- Thermal SPH-simulation of winding head wetting
  - Fast investigation of geometry and loadcases

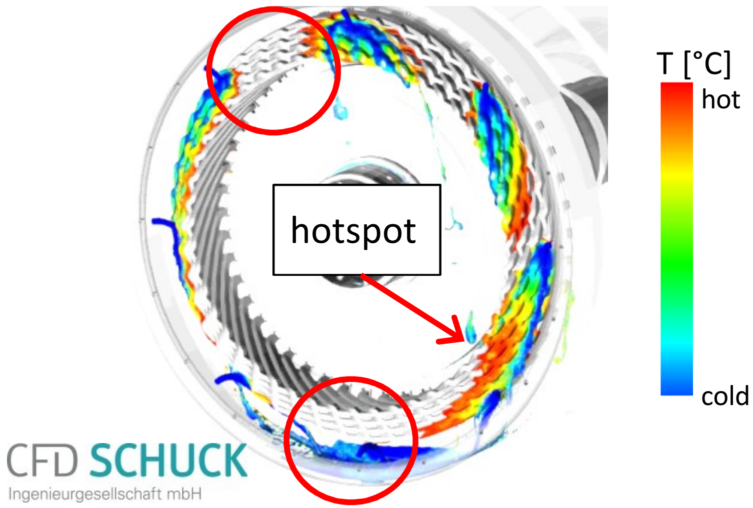
  => Evaluation of system dimension
  - Oil damming

    => increase of outlet dimensions



  - Evaluation of winding head wetting
    - No oil impact from every nozzle
    - Insufficient wetting and oil flow

    => variation of nozzle number and diameter



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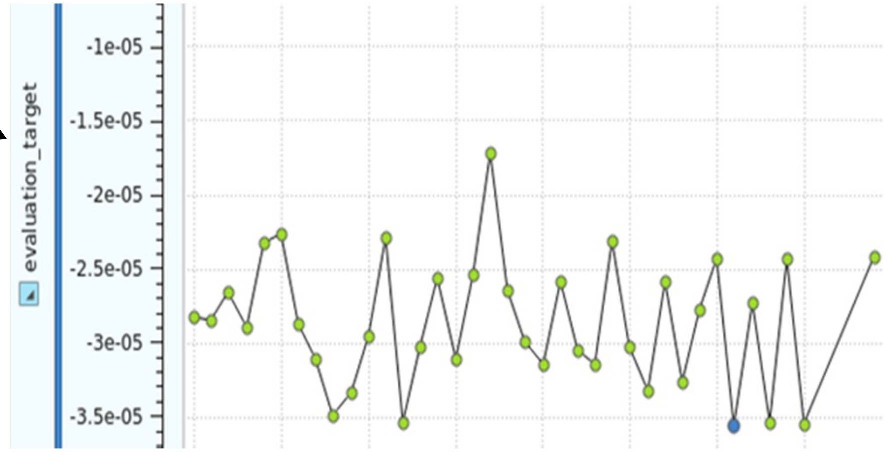
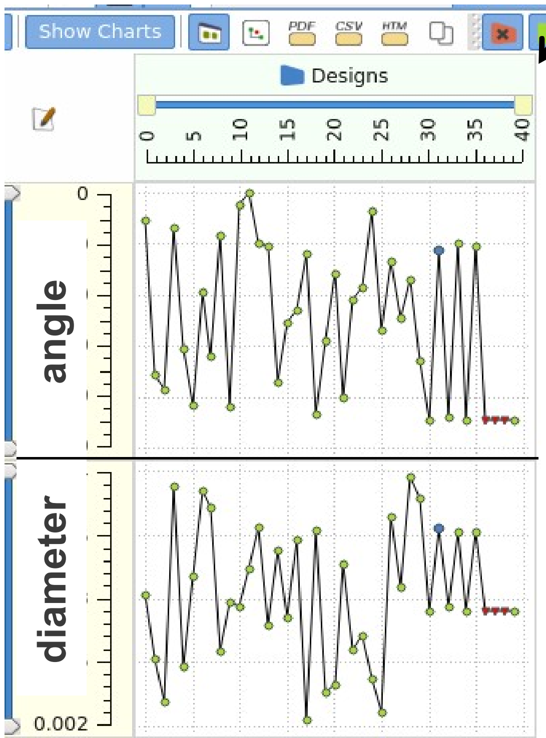
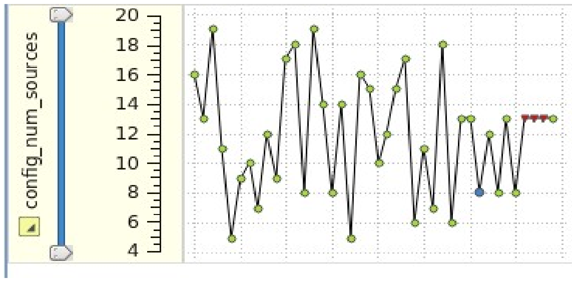
➢ *Results: Evaluation of different designs*

- Objective function = f(designs)
  - surface wetting, heat transfer
- Impact of design parameters





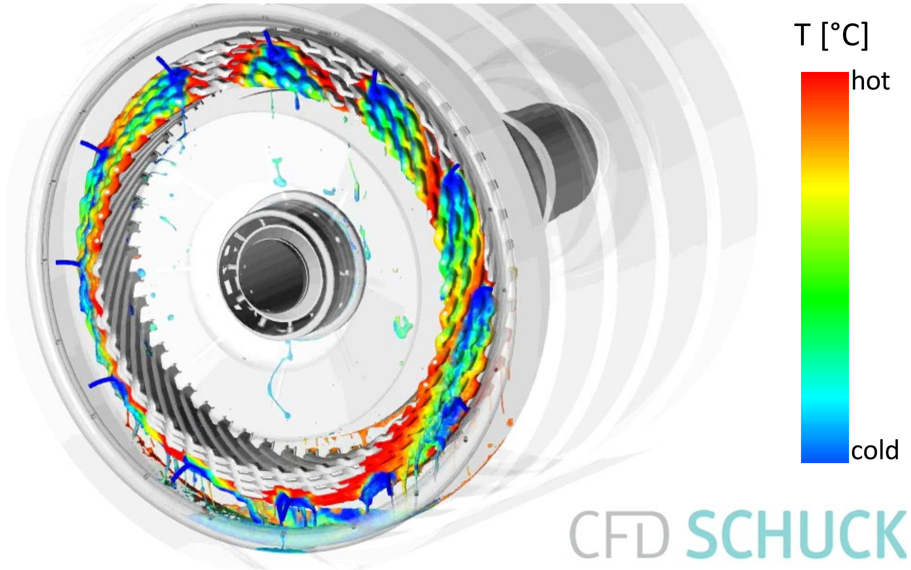
Number of nozzles



Optimization of E-Machine Spray Cooling Systems

➢ *Results: System Optimization*

- Loadcase:
  - Fixed values for oil flow rate and temperatures
- Objective function:
  - heat transfer
- Design parameter:
  - diameter and number of nozzles,
  - angle of inclination
- 30 designs within appr. 60h
- Hardware:
  - Linux workstation, 24cores
  - Intel® Xeon® CPU
    - X5650: 2.67MHz



➢ *Conclusion*

- A novel and fast design methodology for spray cooling systems was developed and successfully applied.

- The oil injection system and the oil cooling of a winding head could be quickly studied by a SPH-CFD approach. Parametric CAD and CFD models
  - allow the evaluation of geometry parameters and operating conditions
  - minimize the total time of simulation up to some hours per design

- A fully automated optimization workflow was established by combining the SPH-CFD solver with optimization software and proprietary Python subroutines.
  - Cooling of the winding head was optimized by adjusting geometry parameters of the spray cooling system with respect to the operating conditions
  - Optimized designs can be achieved within a few days

Thank you for your attention