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Arbeitsbereich für Energieeffizientes Bauen

COMSOL CONFERENCE 2018 LAUSANNE

Flow Optimization of a MVHR combined with an Exhaust air Heat Pump by means of CFD Simulation

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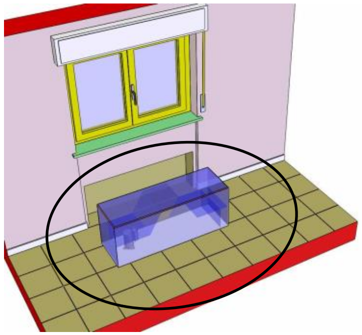
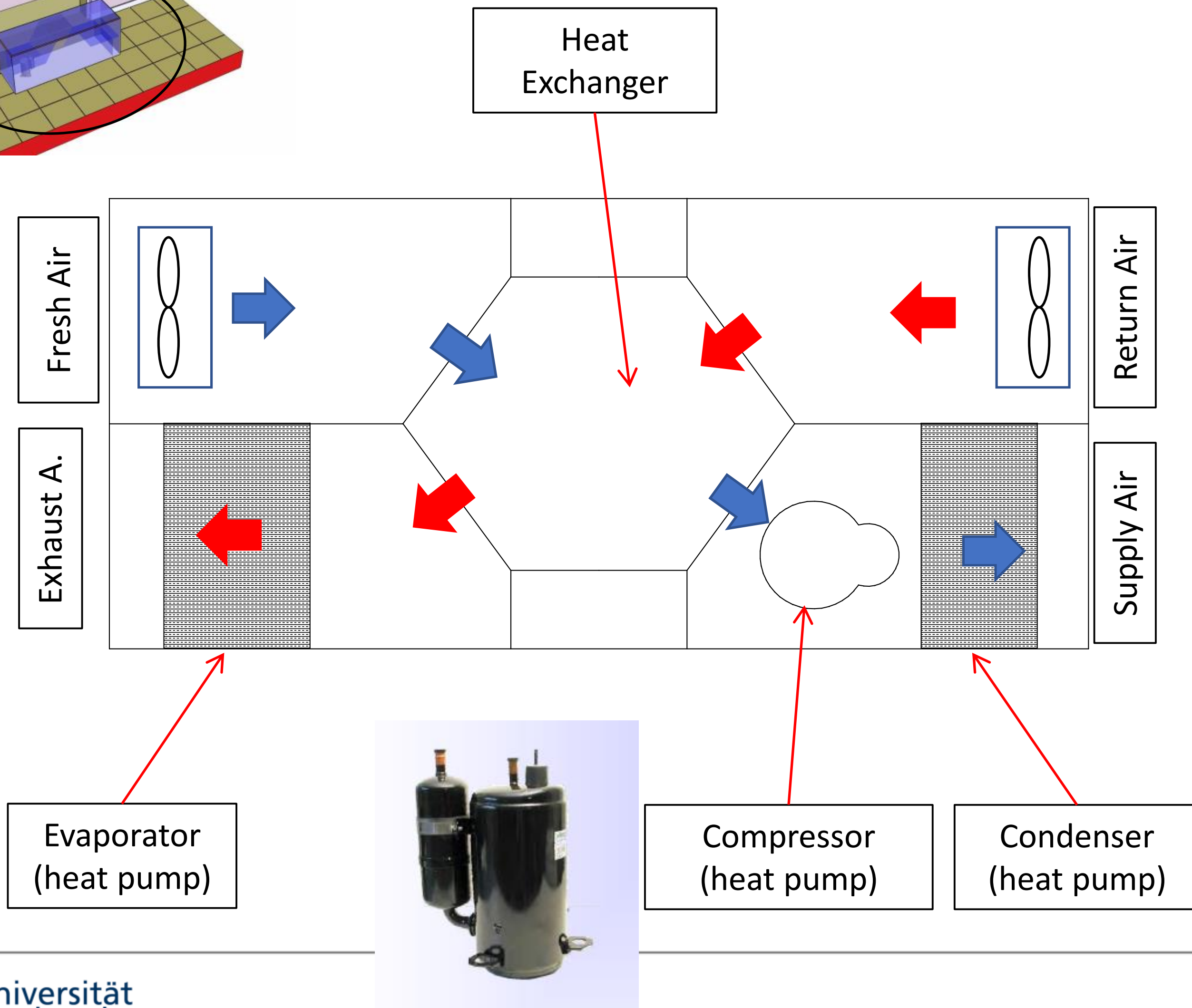
MVHR (Mechanical Ventilation Heat Recovery) + Heat Pump



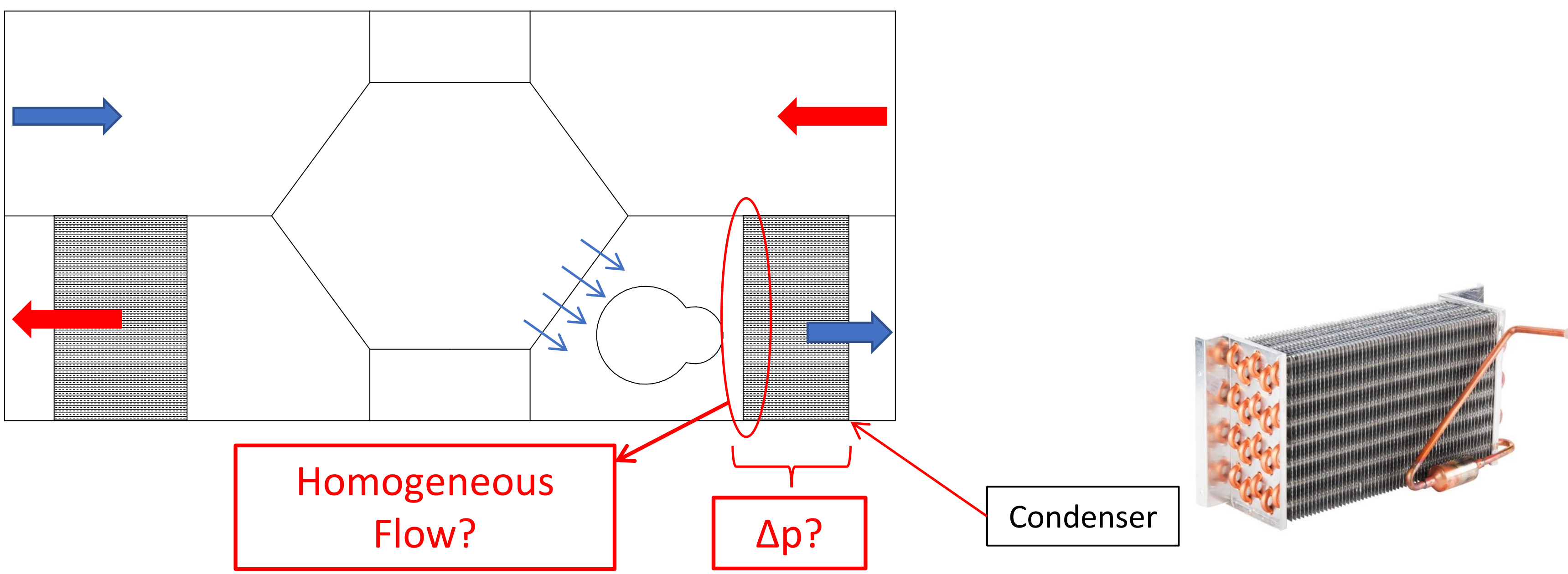
SaLüH!
Sanierungsansätze für Lüftung, Heizung und Warmwasser



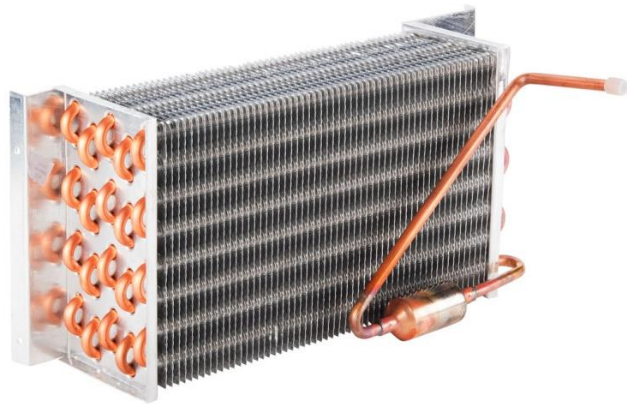
Aims

1 – CFD Model Implementation

2 – Flow optimization



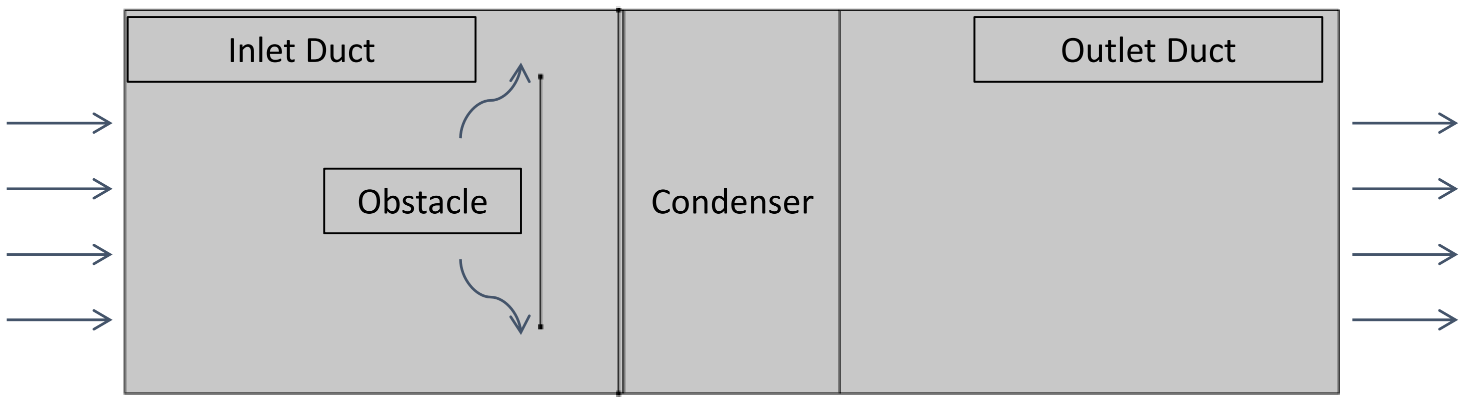
Modeling of the Condenser



~~Complex geometry~~
~~=~~
~~>10^6 Mesh elements~~

1. Pressure drop
2. Fins effect

Model Calibration (COMSOL®)



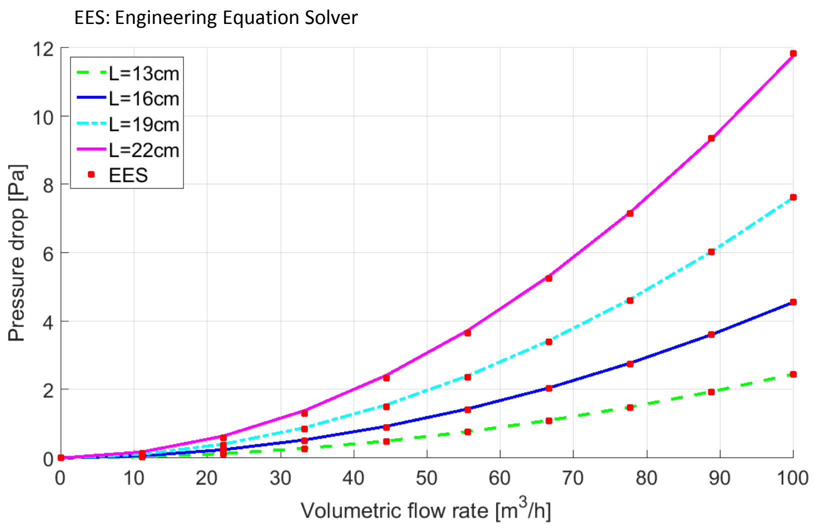
Condenser – "Porous Model"

Brinkman equations

$$\frac{1}{\varphi}\left(\frac{\partial \bar{u}_i}{\partial t} + u_j \frac{\partial \bar{u}_i/\varphi}{\partial x_j}\right) = -\frac{1}{\rho_0}\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\frac{\nu}{\varphi}\left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right)\right] + \frac{1}{\rho_0}F_i$$

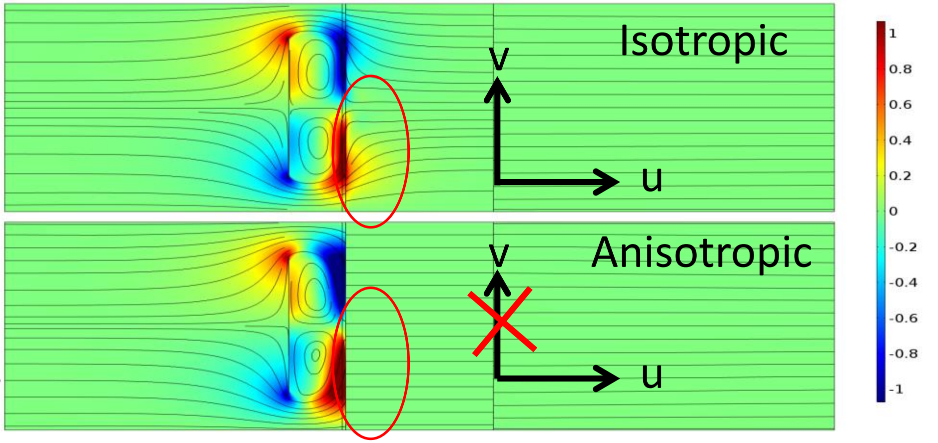
Pressure drop

$$\begin{cases} F_i = -\left(\sum_{j=1}^{3}\frac{\mu}{K_{ij}}u_j + \sum_{j=1}^{3}\frac{C_F\rho}{\sqrt{K_{ij}}}|u|u_j\right) \\ \frac{\Delta P}{L} = a\cdot|u| + b\cdot|u|^2 \end{cases}$$



Modelling of the fins

$$\begin{cases} K = \begin{pmatrix} K_{xx} & K_{xy} & K_{xz} \\ K_{yx} & K_{yy} & K_{yz} \\ K_{zx} & K_{zy} & K_{zz} \end{pmatrix} \\ K_{xx} \gg K_{yy} \Rightarrow u \gg v \end{cases}$$



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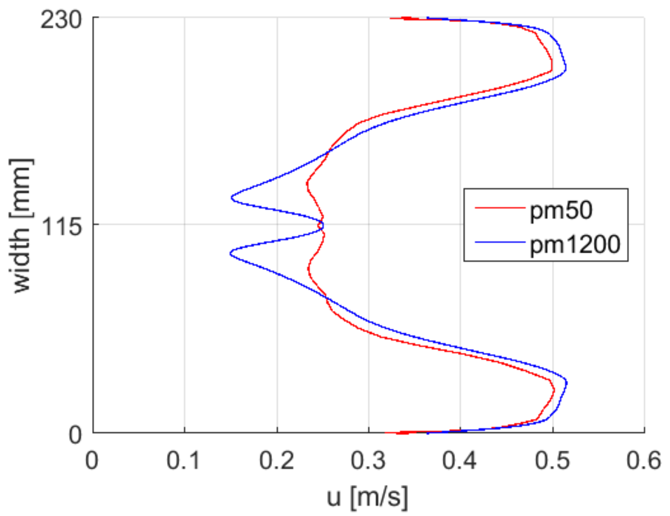
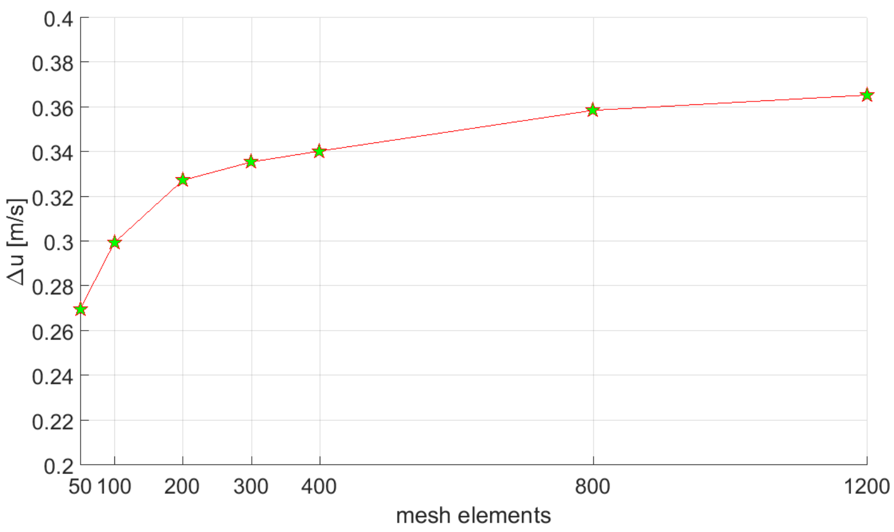
Mesh Optimization

Pressure drop

ΔP: max. error = 0.08%

Velocity profile at the condenser's inlet



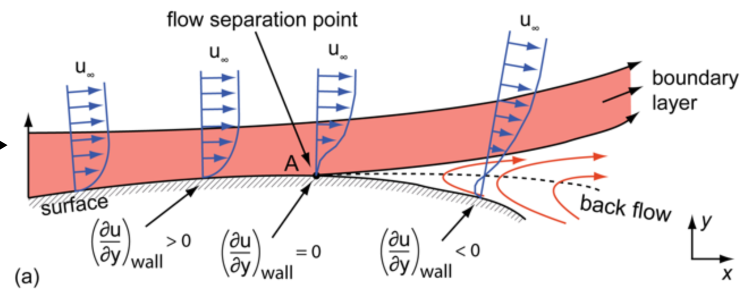


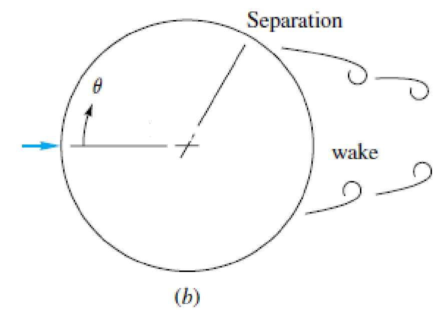
Δu: max. error = 40%

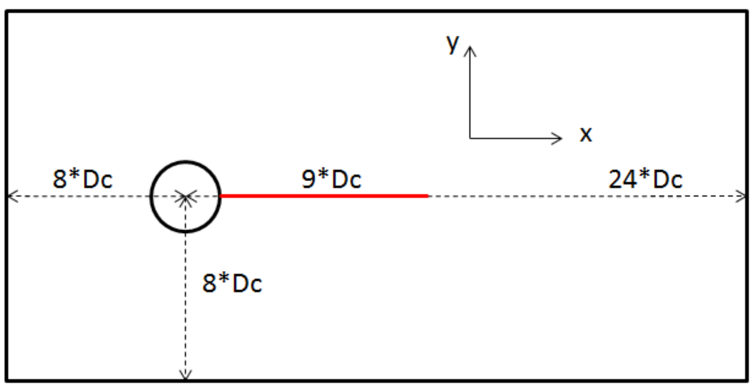
Turbulence Models

COMSOL®: turbulent flow

Compressor: $Re_D = 2500$



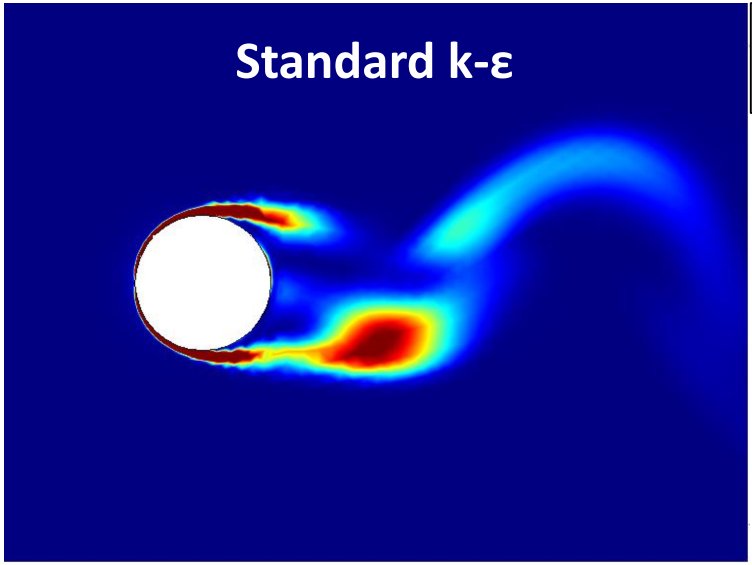




Benchmark:

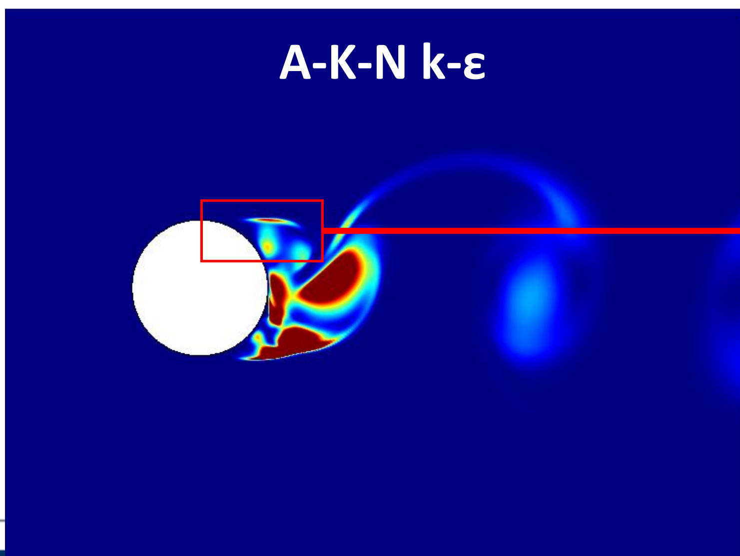
Schiller-Linke → transitional boundary layer

Turbulence Models – Transition

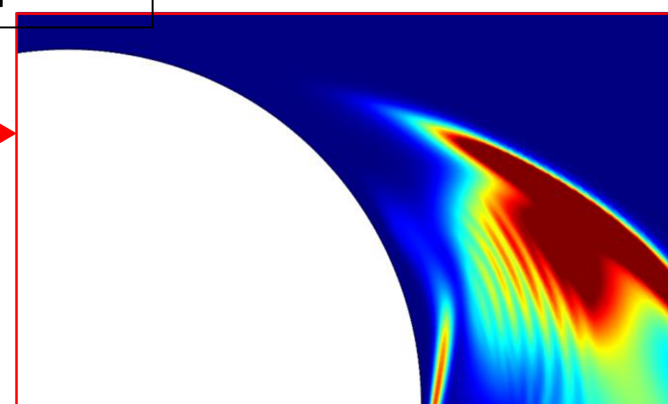


High-Reynolds-Number Model

Turbulent kinetic energy production [W/m³]



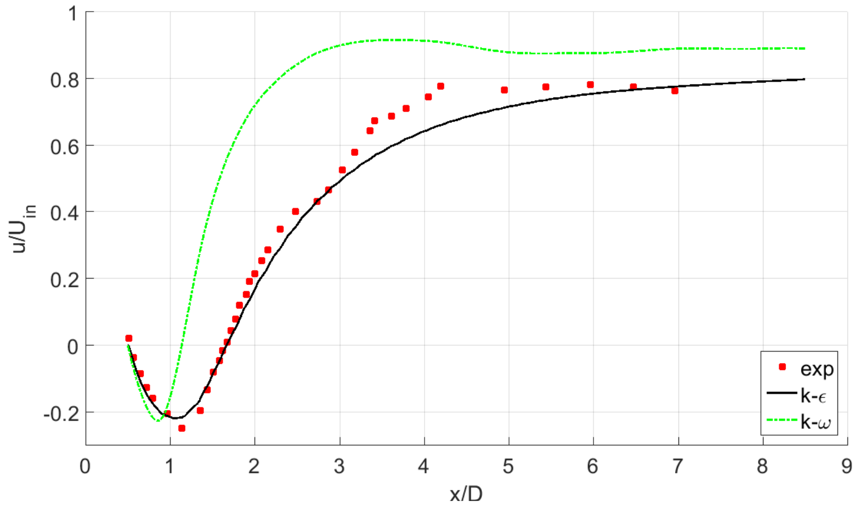
Low-Reynolds-Number Model



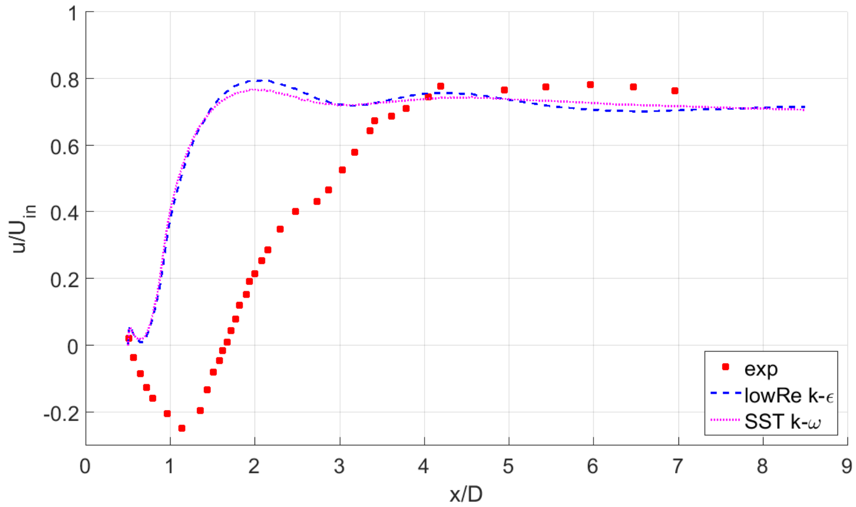
Abe-Kondoh-Nagano

Turbulence Model – Recirculation Length

High-Reynolds-Number Models



Low-Reynolds-Number Models



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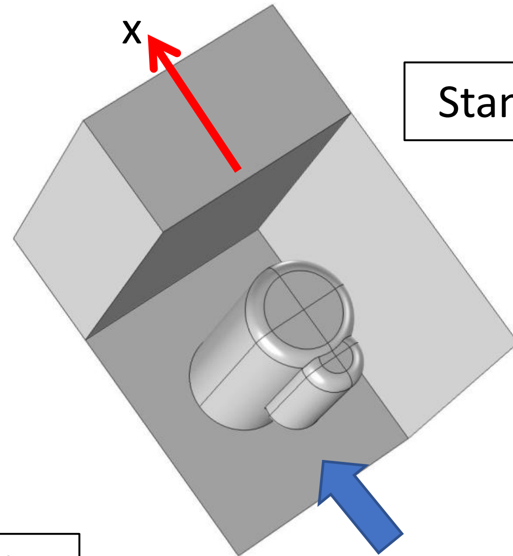
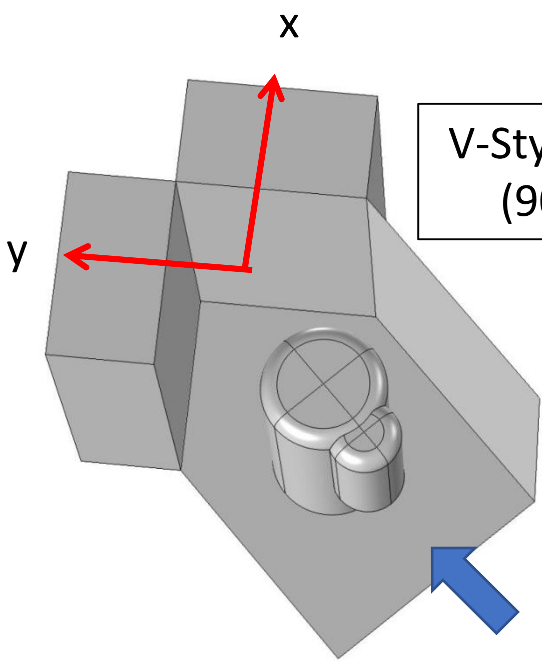
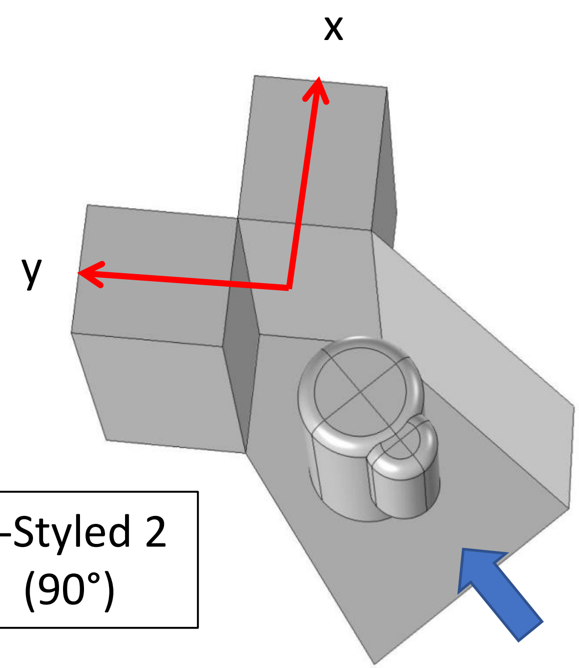
Optimization – Investigated variants



Standard



V-Styled 1
(90°)

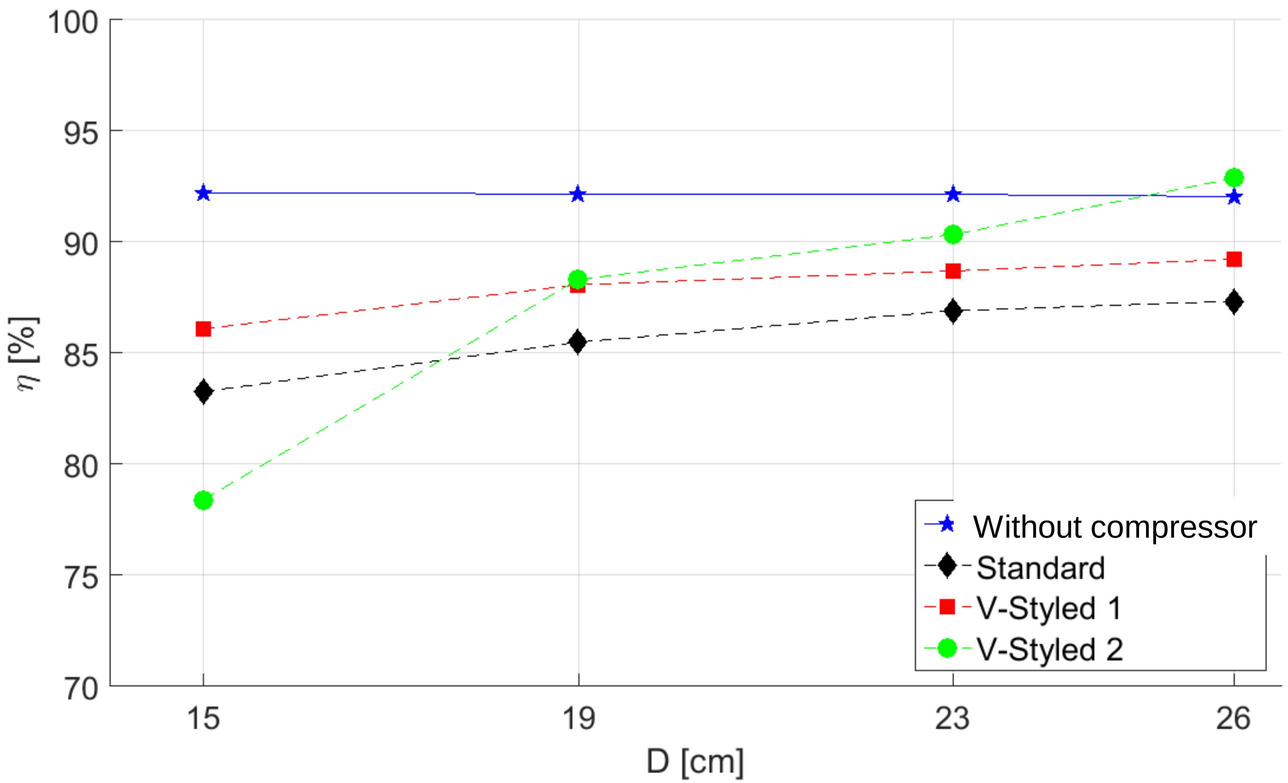


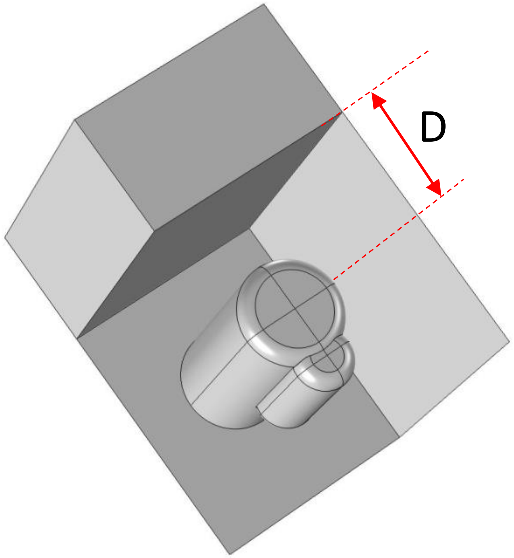
V-Styled 2
(90°)

Optimization – Flow Homogeneity

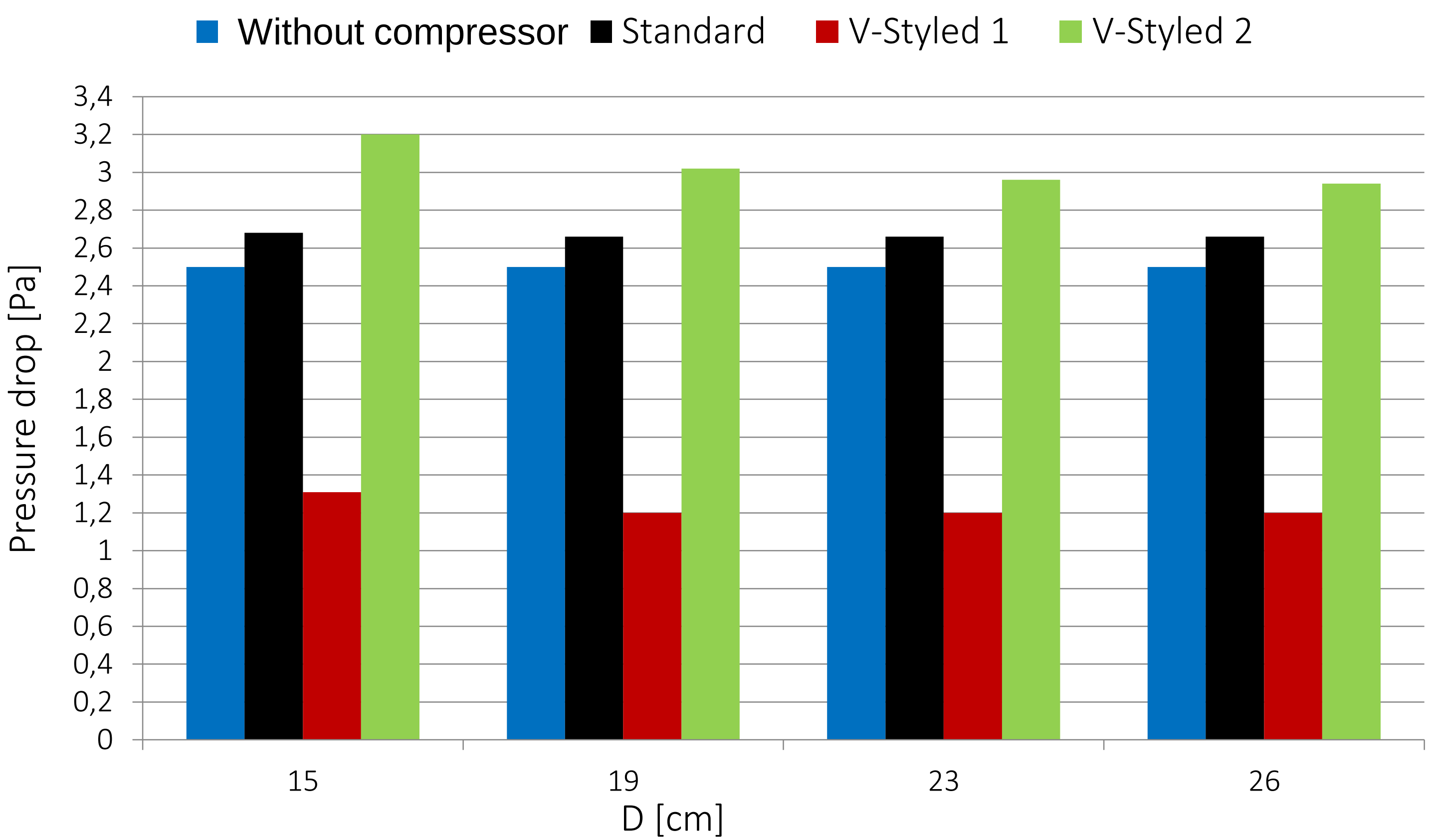
$$\eta(u) = 100 - \left(\frac{s_N}{u_{mean}}\right) \cdot 100$$

$$s_N = \sqrt{\frac{\sum_i^N (u_i - u_{mean})^2}{N}}$$





Optimization – Pressure Drop



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Conclusions

1. ''Porous'' Model:
- Low computational cost
- correct pressure drop prediction
- velocity profile very sensitive to the mesh quality

1. Turbulence models: Turbulent viscosity vs. transitional flow

2. Optimization: V-styled condensers > Lower pressure drop with the ''large'' inlet duct (V-Styled 1)

Future Work

1. Validation of the ''Porous'' Model via CFD simulation of the flow through the heat exchanger

2. Validation of the models through comparison with 3D- benchmarks

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Thank you for your attention