

International KULI User Meeting 2019

Thermal and Hydraulic Design of a Fuel Cell Car with KULI 12 and Co-Simulation

Agenda

Thermal and Hydraulic Design of a Fuel Cell Car with KULI 12 and Co-Simulation

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Thermal Management System in KULI 12

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Proof of Concept by Simulation

Introduction

Audi h-tron

Audi's first Fuel Cell Electric Vehicle (FCEV)

Development Objective of FCEVs



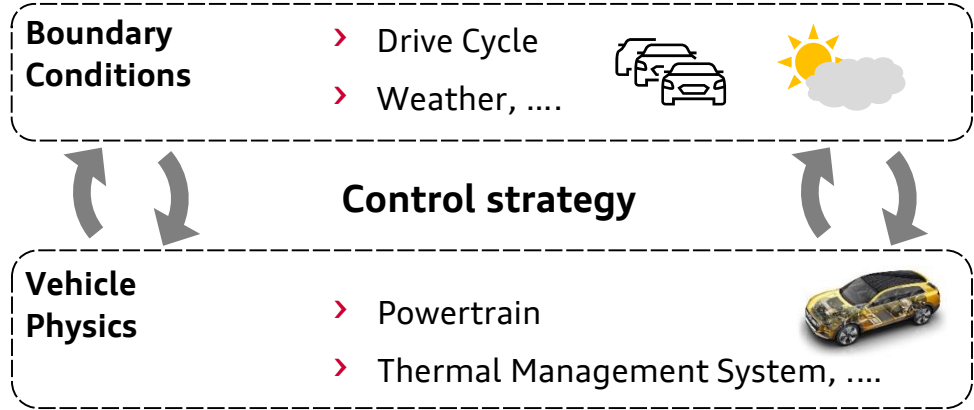
h-tron

Vehicles...

- > ...that have a short refueling time (100% Filling) → 24/7 availability
- > ...for a high daily driving distance
- > ...that are locally free of emissions
(globally free of emissions while employing hydrogen from renewable energy)



Virtual Development Process

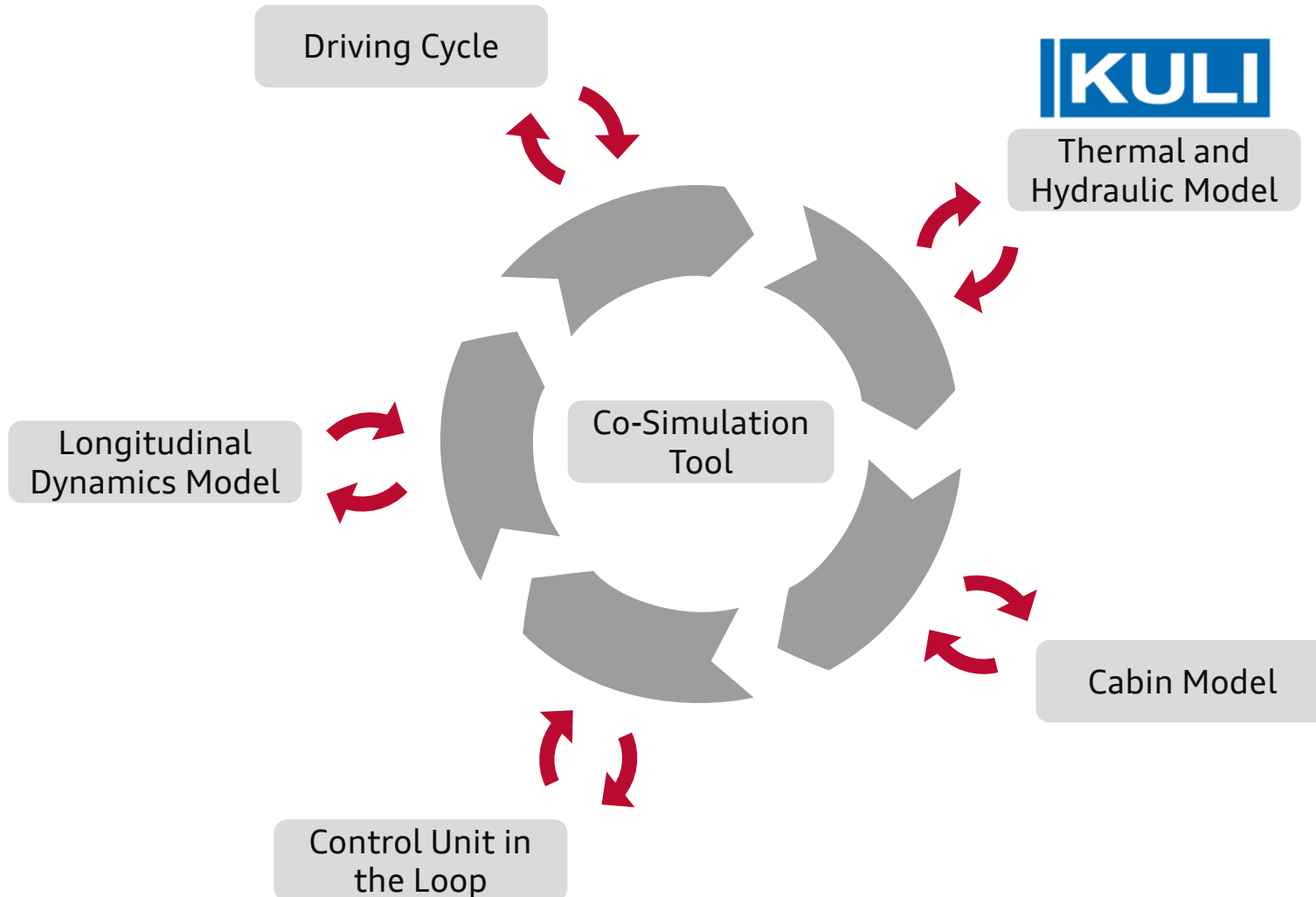


Holistic design approach has to take into consideration all

- > Energetic flows
- > Logical connections
- > Boundary conditions

Virtual Development Process

KULI Model within the Co-Simulation



Co-Simulation enables...

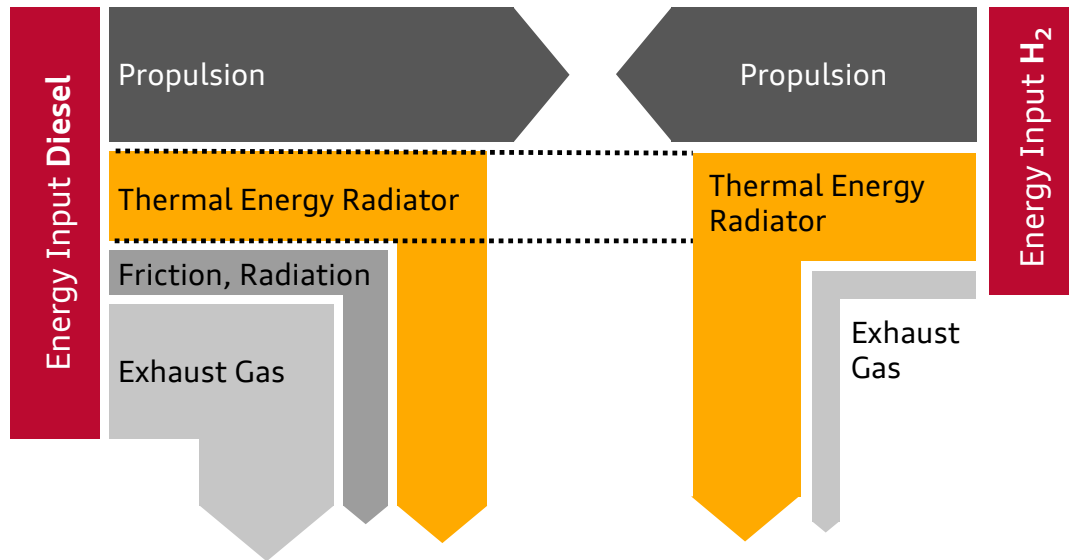
- > ...holistic vehicle simulation
- > ...to use the advantage of every software

Challenges regarding Thermal Management

Thermal Management Challenges of a FCEV

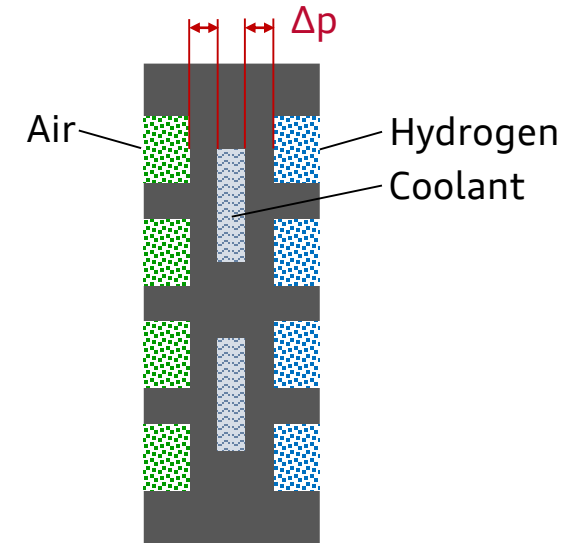
Sufficient Cooling and Pressure Sensitive Components

Energy Flow Comparison: Combustion Engine vs. FC



Source:
Berger, Oliver: Thermodynamische Analyse eines Brennstoffzellensystems zum Antrieb von Kraftfahrzeugen. Dissertation, Universität Duisburg-Essen, 2009

Schematic Layout of a Bipolar Plate in a Fuel Cell



Source:
Nöst, Michael [and others]: Thermal Management of PEM Fuel Cells in Electric Vehicles, in: Daniel Watzenig and Bernhard Brandstätter (eds.): Comprehensive Energy Management: Safe Adaptation, Predictive Control and Thermal Management: Springer International Publishing 2018, pp. 93-112

Cooling challenge due to



- > High heat dissipation
- > Low temperature differences to environment

$$\dot{Q}_{Cooler}(P_{drive}, v_{vehicle}, \dot{V}_{CF}, \dot{m}_{air}, T_{CF}, T_{ambient}, \dots)$$

Pressure sensitive due to



- > Complex structure
- > Material composition

$$p(\rho_{CF}, \dot{V}_{CF}, T_{CF}, A, R_T, \dots)$$



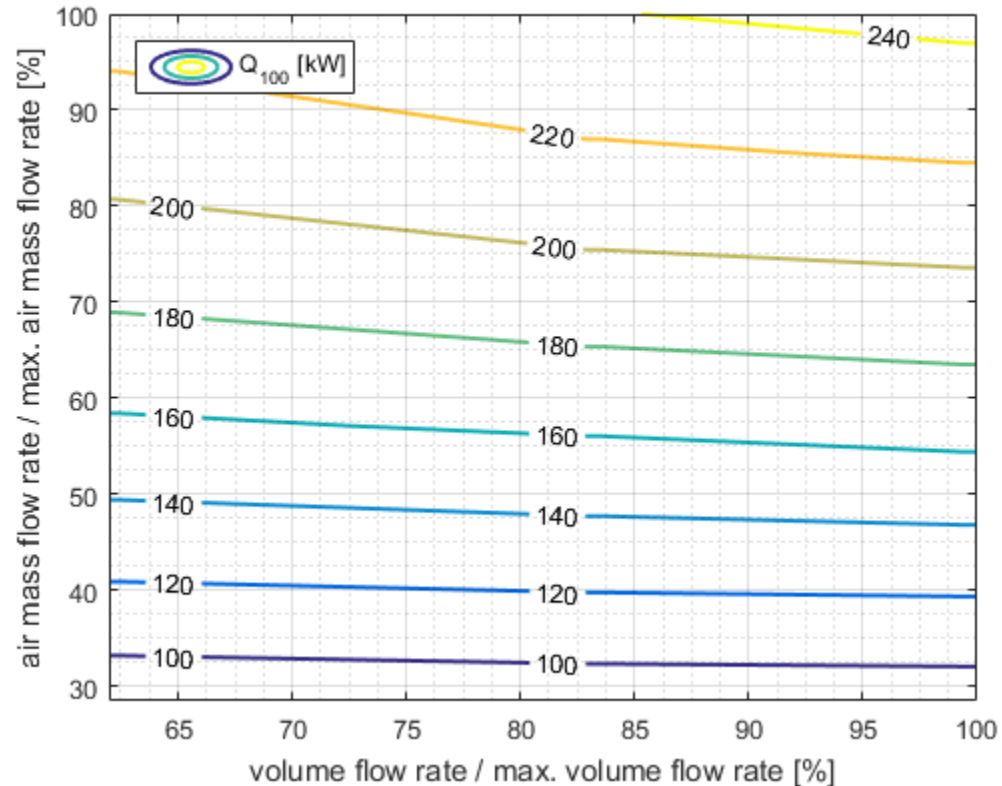
Sufficient Cooling and Pressure Sensitive Components

Dependency between Boundary Conditions

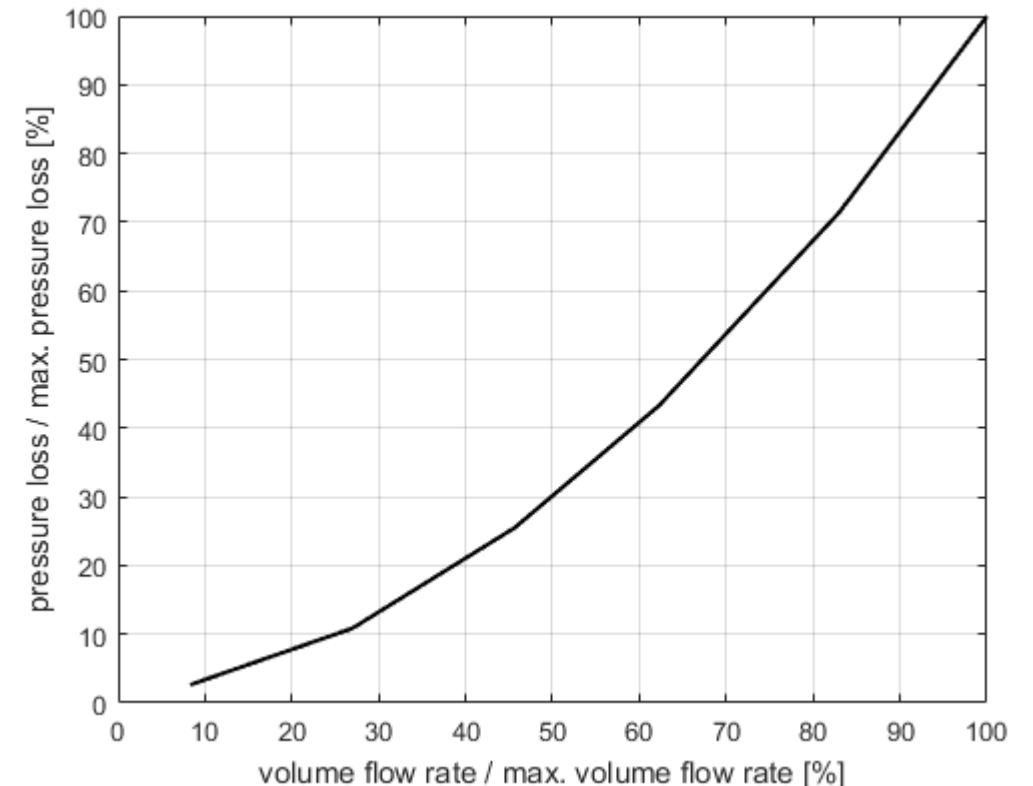
Fuel Cell Boundary Conditions

- › Volume flow rate of FC is considered as a target value
- › Maximum inlet pressure of FC is given

Cooling Power



Pressure Loss

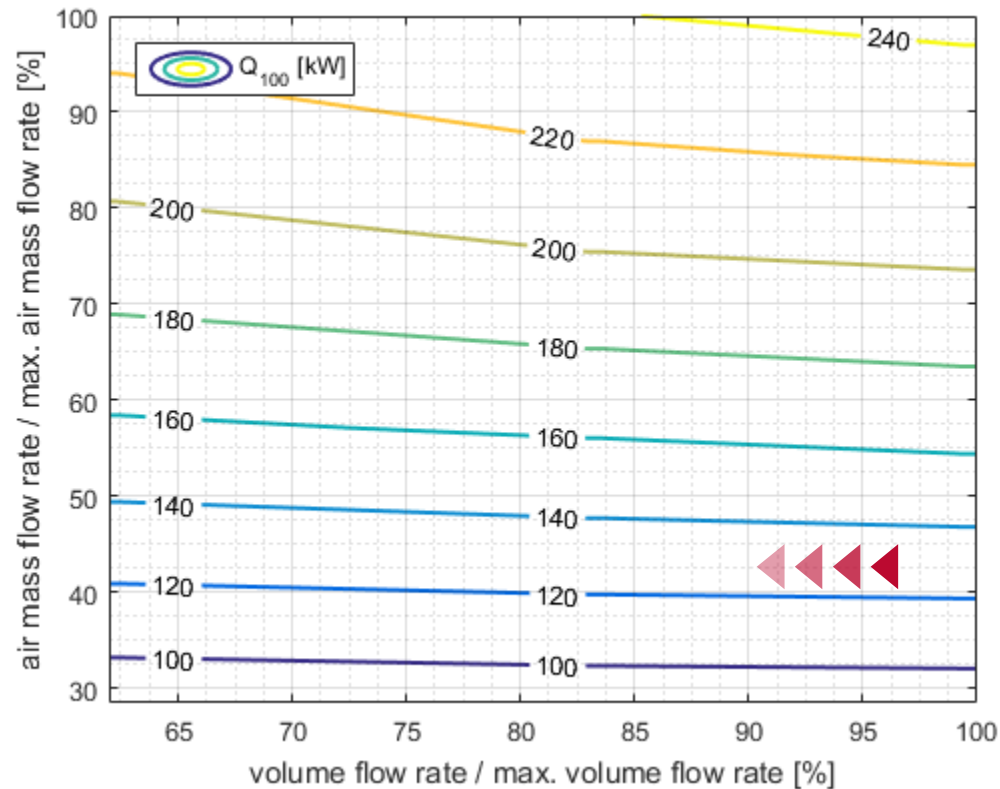


Solution Approach

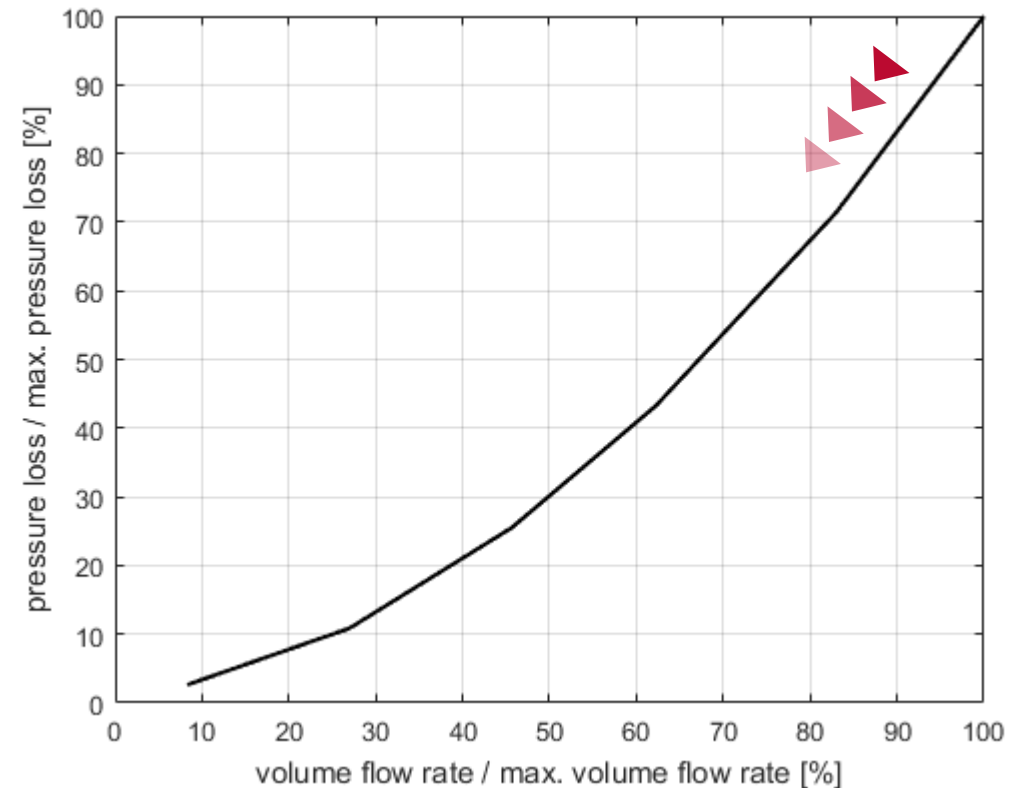
Solution Approach

Reduction of Pressure Loss for Compliance with Pressure Limit

Cooling Power



Coolant Pressure Loss at Radiator



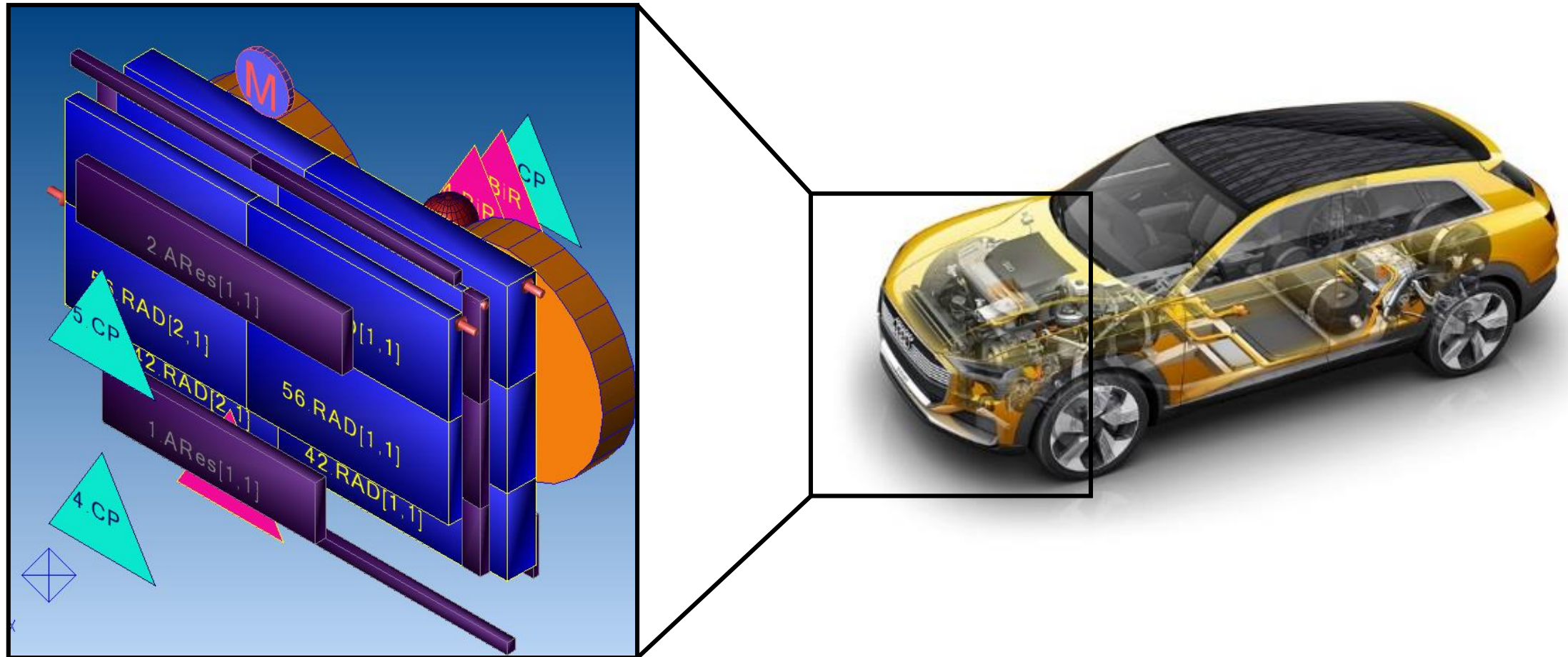
- Adherence of FC boundary conditions regarding volume flow and inlet pressure
- Reduction of the pressure loss by decreasing coolant volume flow rate at the radiator without reducing cooling power

Thermal Management System in KULI 12

Solution Concept

Vehicle Frontend

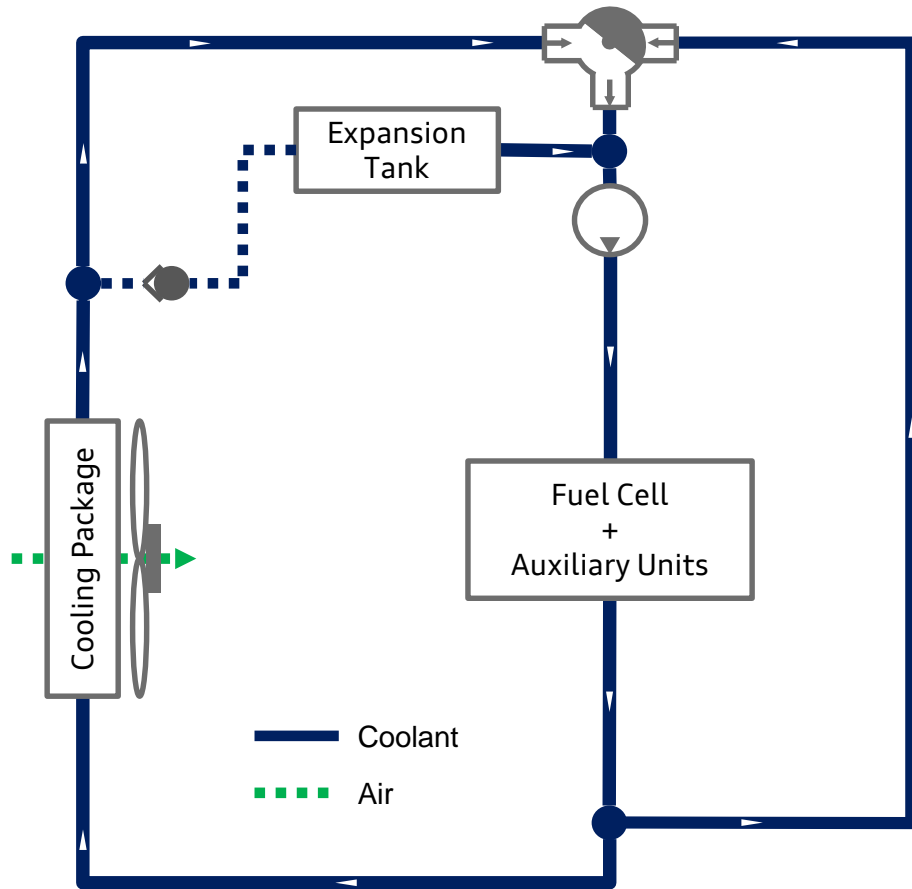
Model of Air Path



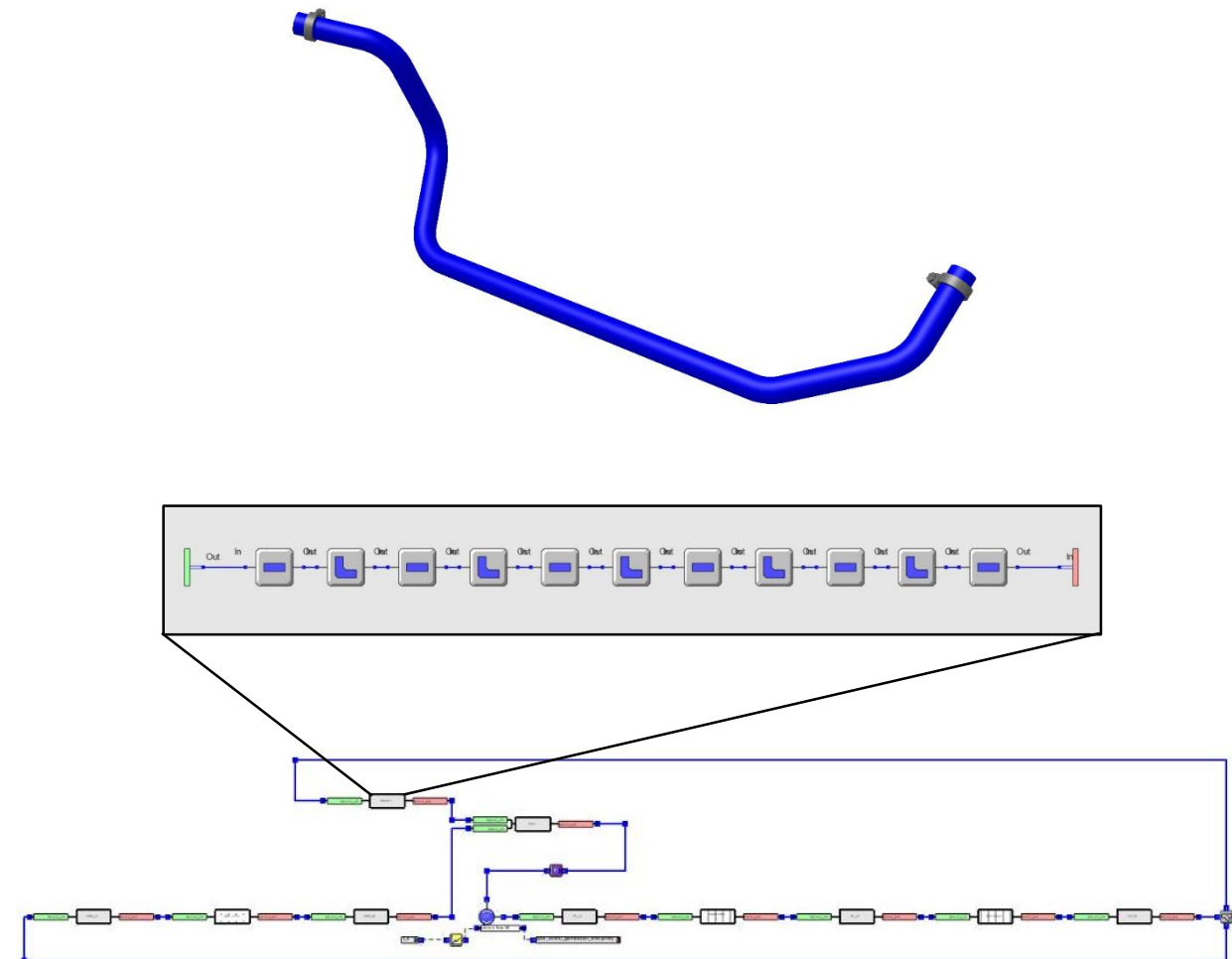
Solution Concept

Pressure Reduction by Bypass Control

Schematic Layout of Cooling Circuit



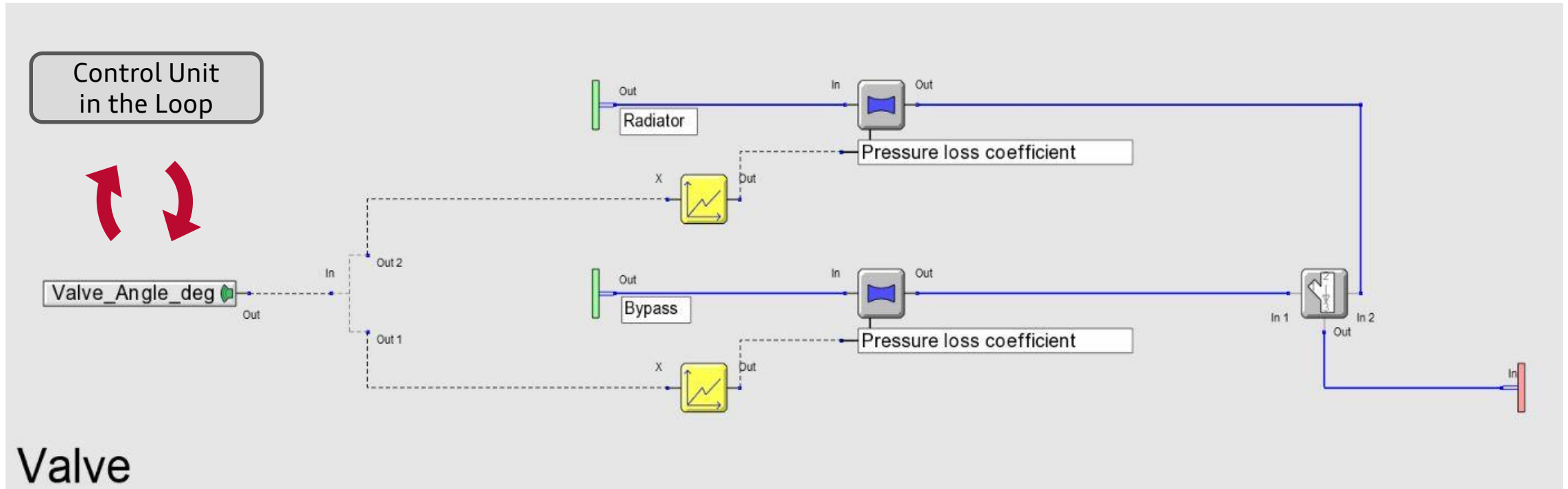
Detailed Model of the Hydraulic Resistances



Solution Concept

Valve Position Control

Valve Angle provided by Co-Simulation



Valve



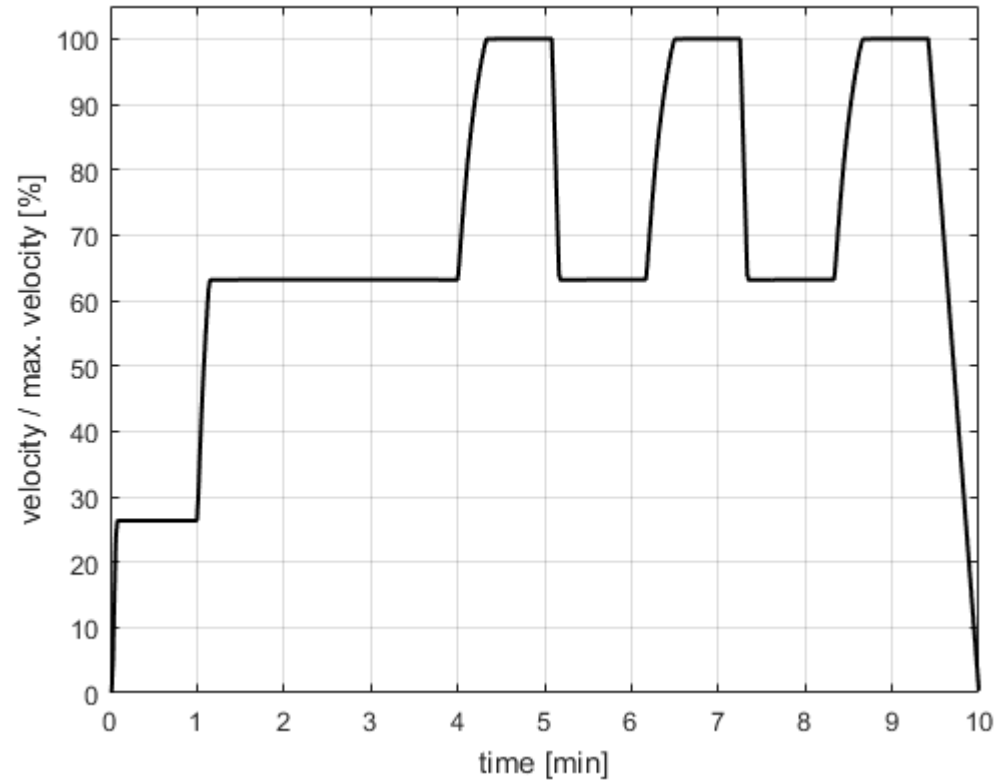
Consideration of maximum inlet pressure and cooling performance

Proof of Concept by Simulation

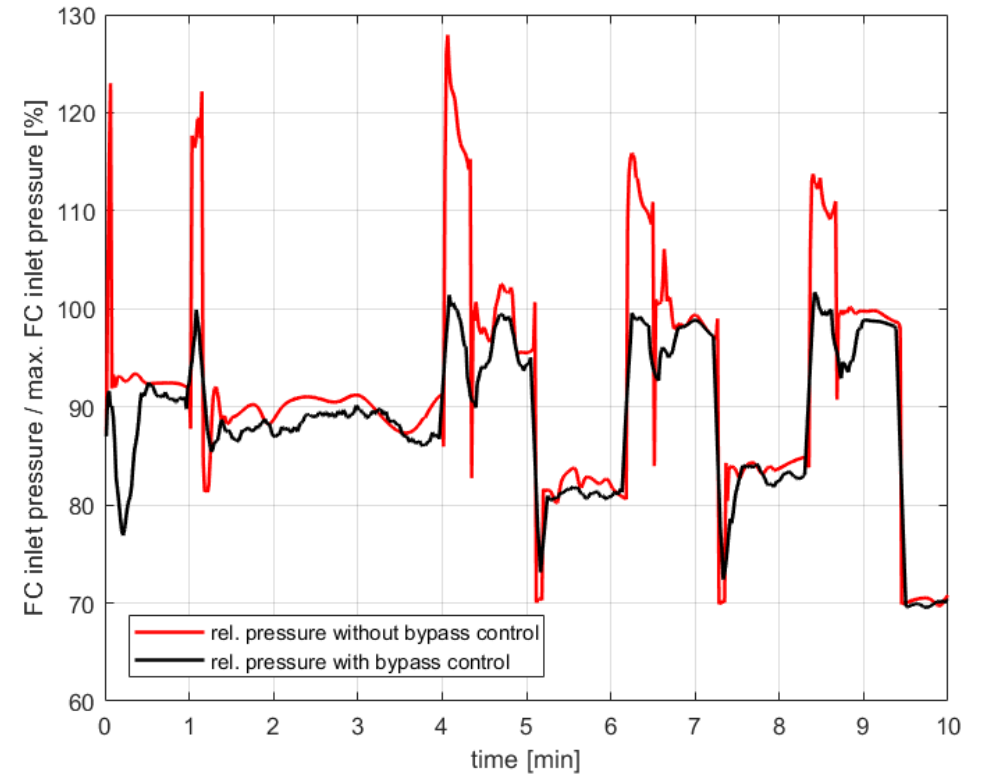
Proof of Concept

Fuel Cell Inlet Pressure

Drive Cycle



Fuel Cell Inlet Pressure

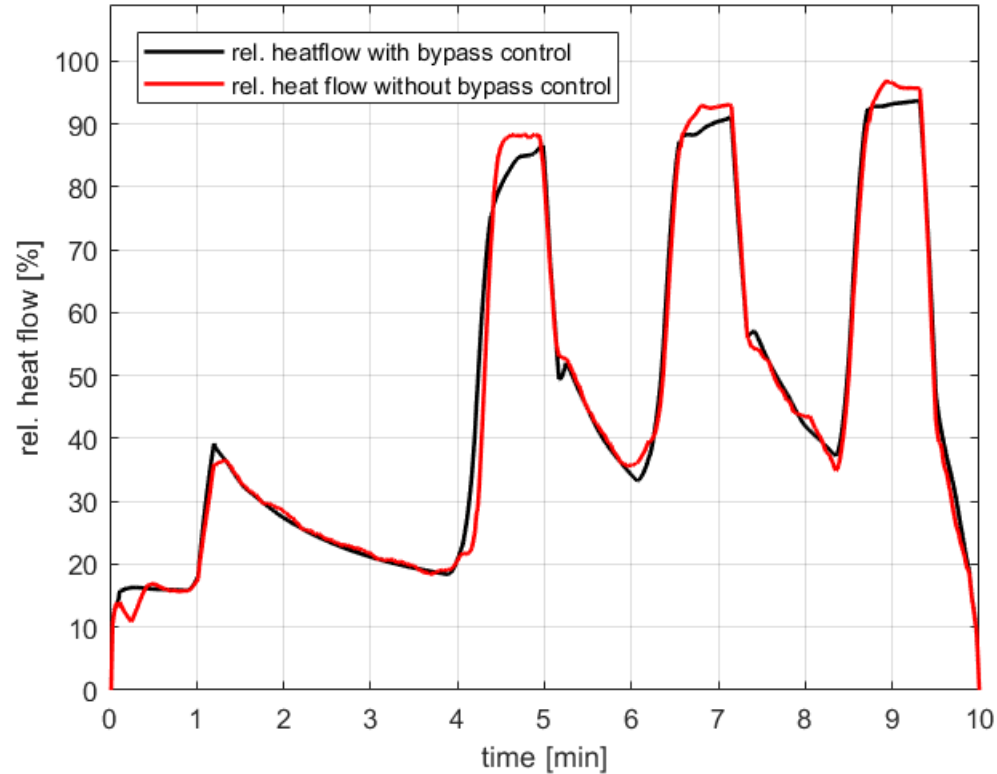


Negligible small exceedance of pressure limit

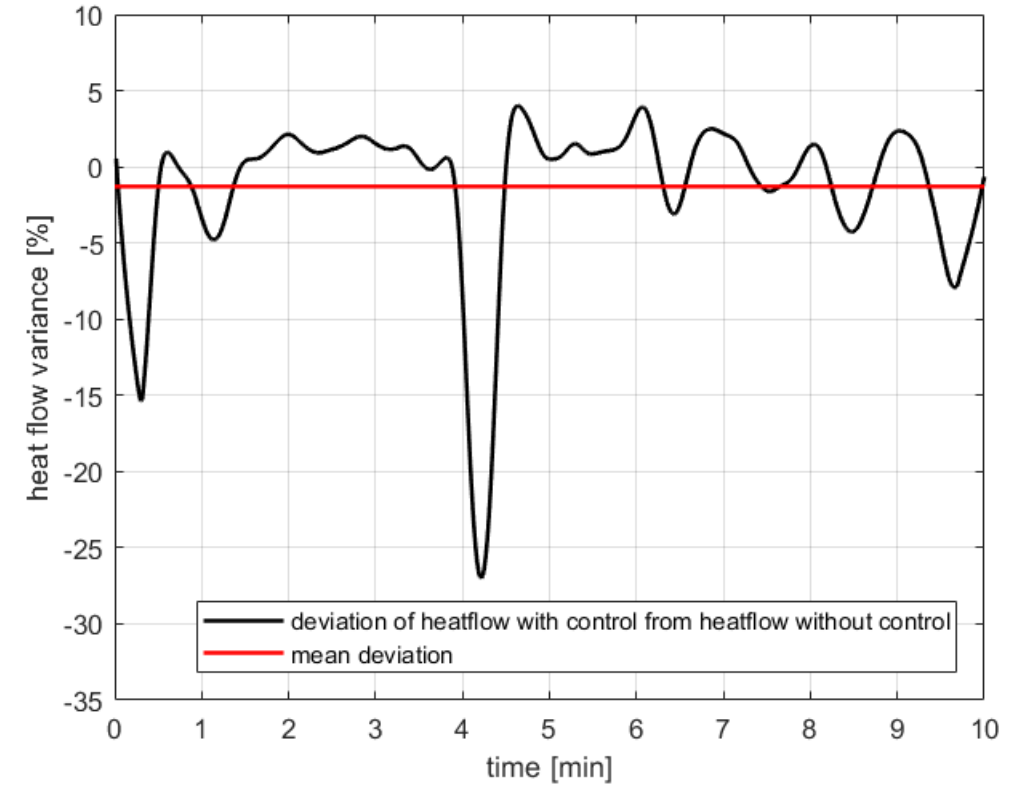
Proof of Concept

Cooling Power at Radiator

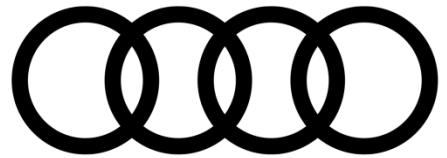
Cooling Power



Variance of Heat Flow



No significant decrease in cooling power



Thanks for your attention!