Integration of Thermal Management Tools into the Vehicle Development Process with Special Consideration of Aggregate Cooling

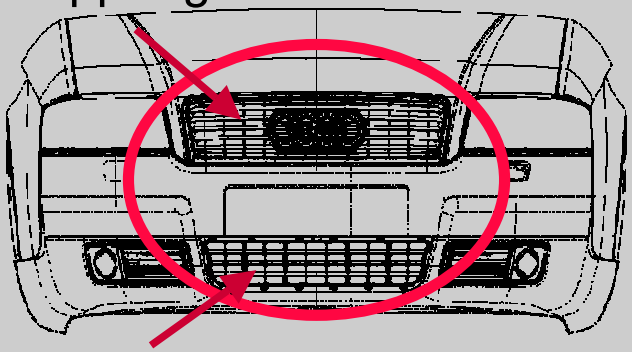
Dr.-Ing. Stefan Micko, AUDI AG, I/EK-41

Overview

- KULI within the Development Process of Cooling Systems at AUDI
- Running Design Verification supported by KULI
- Actual Applications using the KULI-Engine Model

Design Verification – Geometrical Influences

upper grill

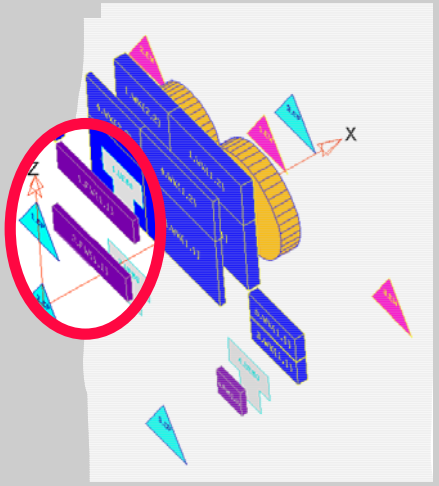


lower grill

Demand

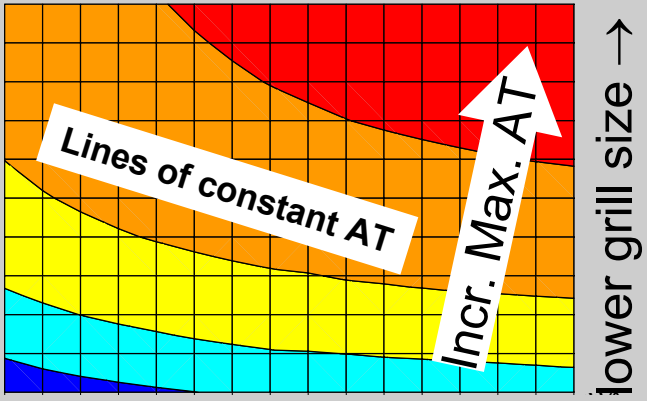
Design Verification Process

Variation of Air Intake Size



Knowledge

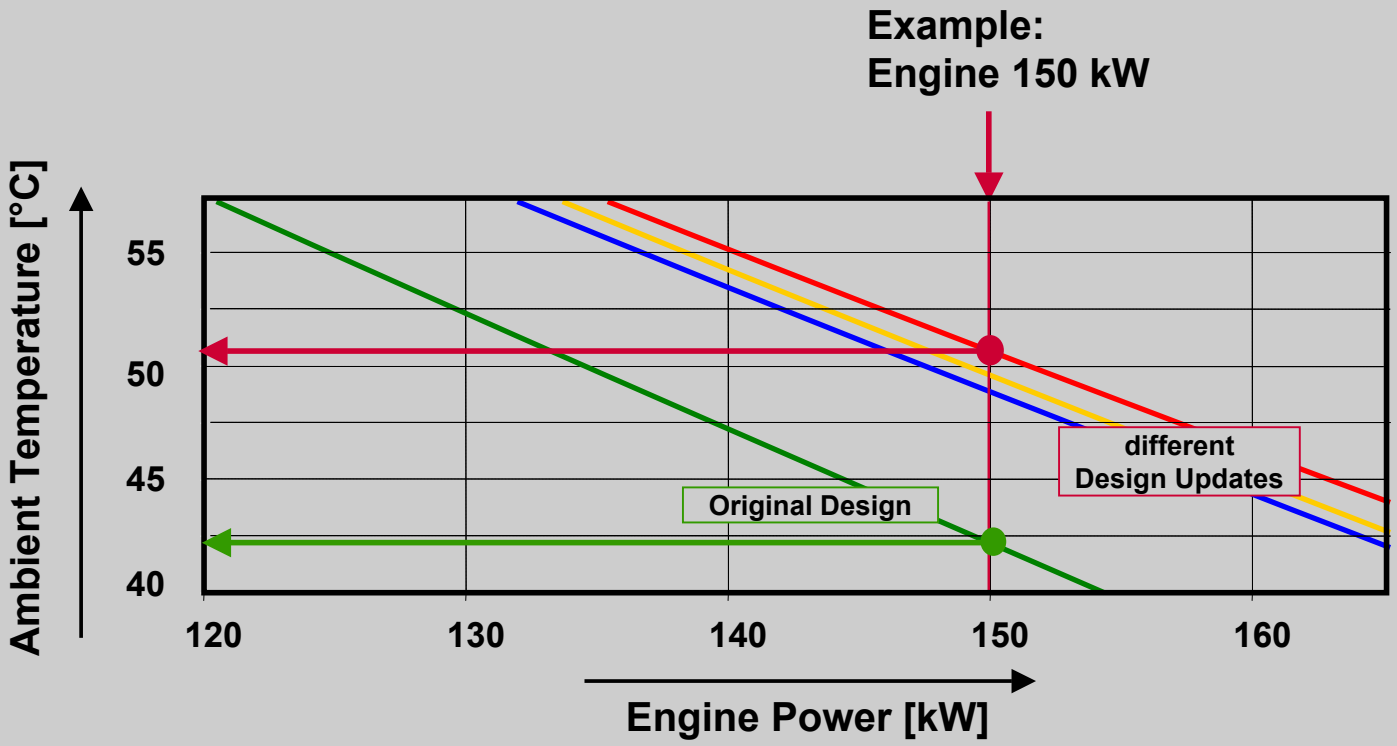
Usable **A**mbient **T**emperature



Fixed boundary condition: Cooling system operating point

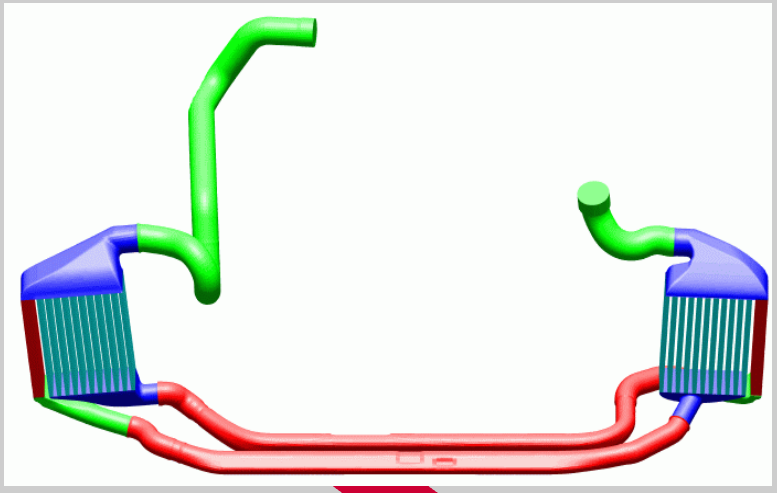
KULI-Results

Design Verification – Engine Power



- **Demand**: AT-Value for increased engine Power
- Heat Rejection Forecast using KULI Engine Model or Upsizing Method
- Oil and Water Temperatures should be considered

Charge Air Cooling – System Modeling



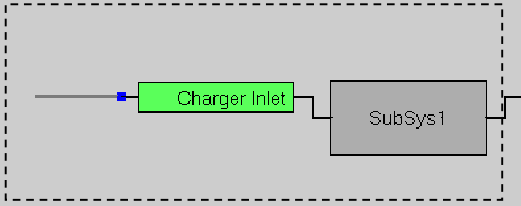
KULI Model

Charge Air System:

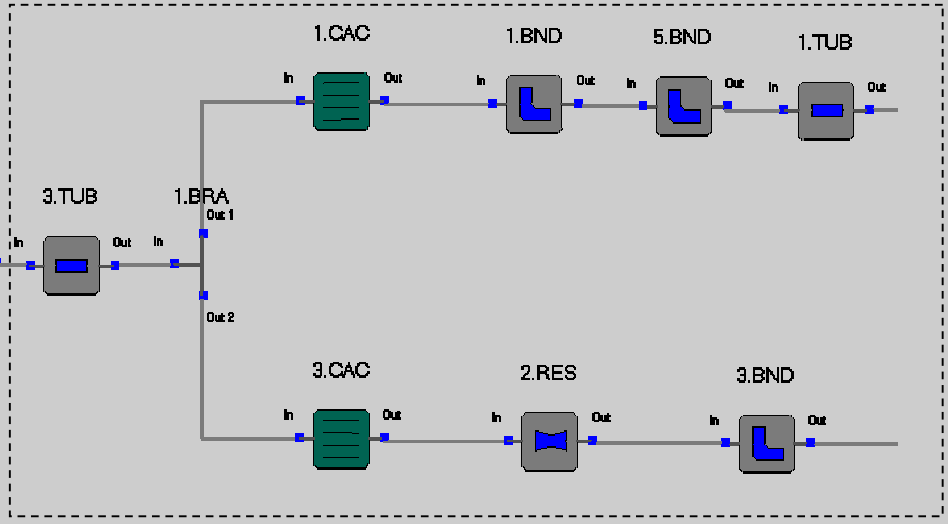
Considerable Influence of the Tubing's and Turbo Charger

1D-Pressure Loss Calculation based on Geometric Dimensions of Tubes and Hoses

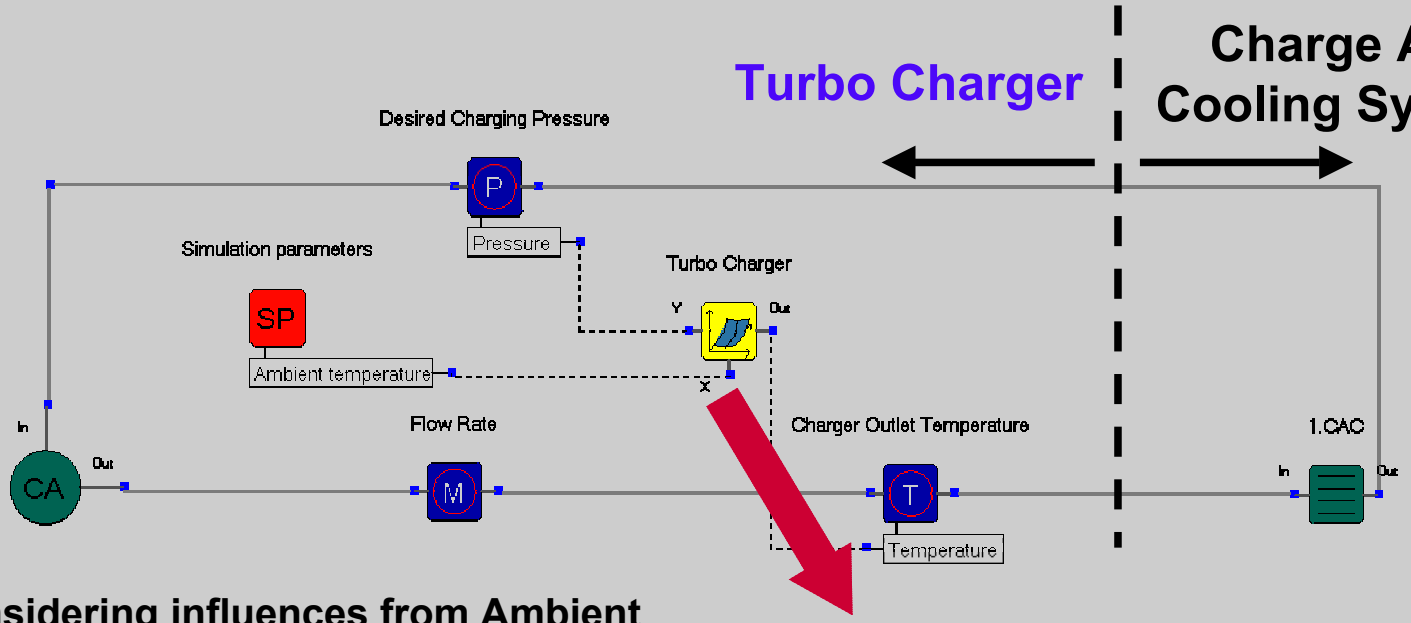
Simultaneously Consideration of Heat Transfer



Subsystem Turbo Charger



Charge Air Cooling – Turbo Charger Model

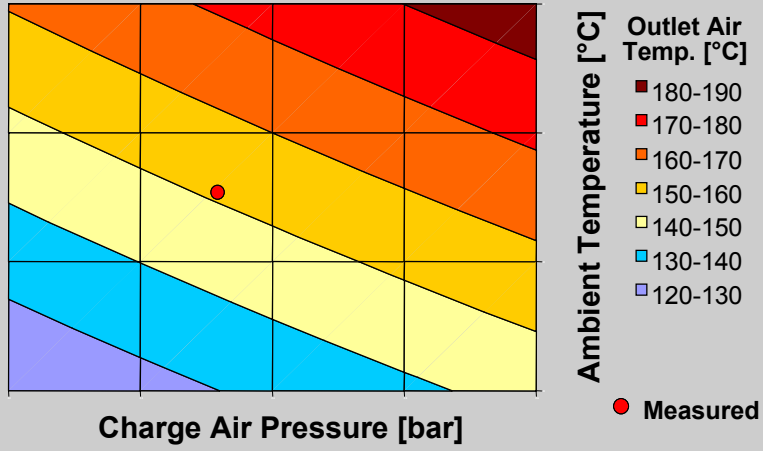


- Considering influences from Ambient Temperature and Charge Air Pressure
- Using a Turbo Charger Characteristic Map based on Isentropic Efficiency

Isentropic Efficiency

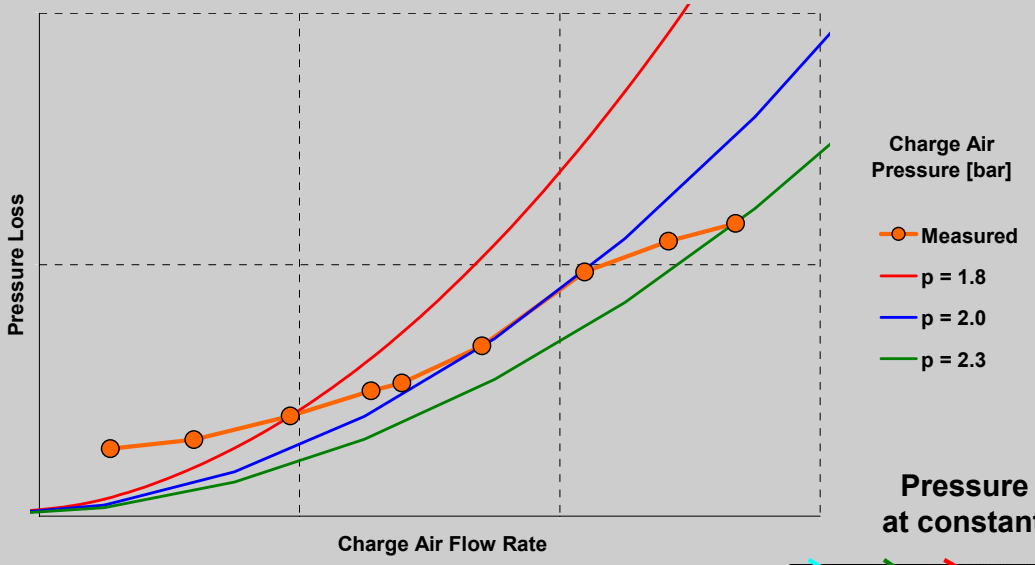
$$\eta_{is} = \frac{T_{in}}{T_{out} - T_{in}} \left[\left(\frac{p_{out}}{p_{in}} \right)^{\frac{\kappa-1}{\kappa}} - 1 \right]$$

Predicted Turbo Charger Characteristic
(Based on one measured condition)



Charge Air Cooling – Simulation Experiences

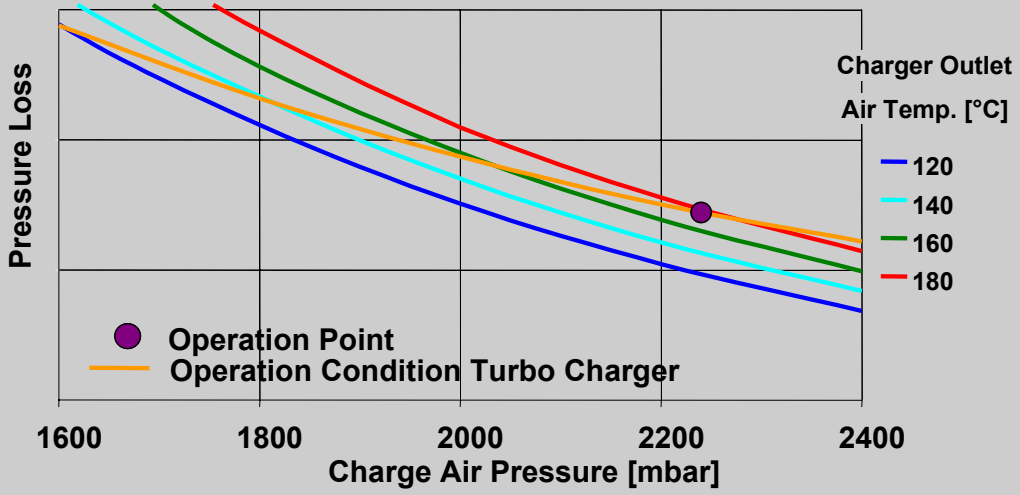
Influence of Charge Air Pressure to the Pressure Loss



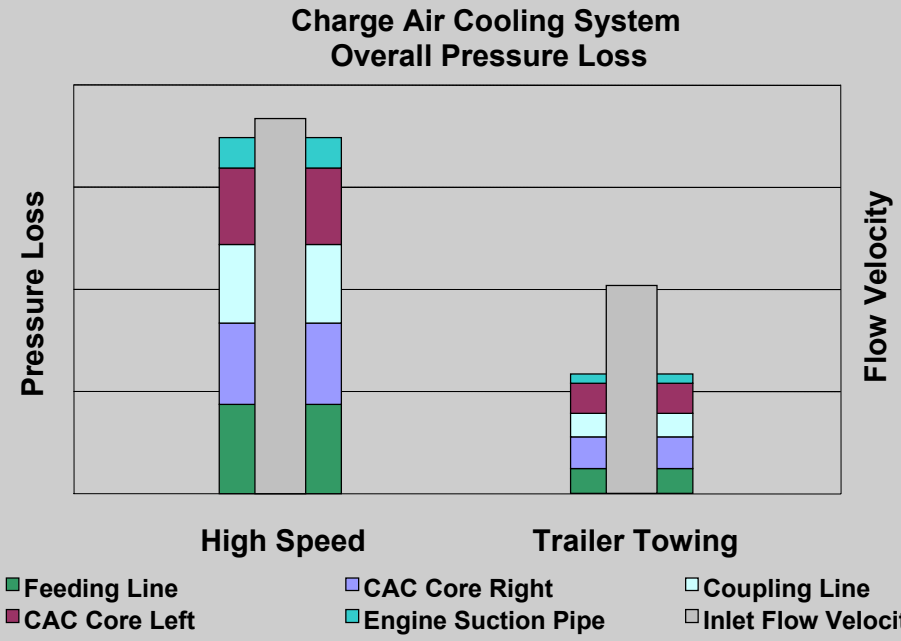
Influence of Charge Air Pressure Level to the System Pressure Loss

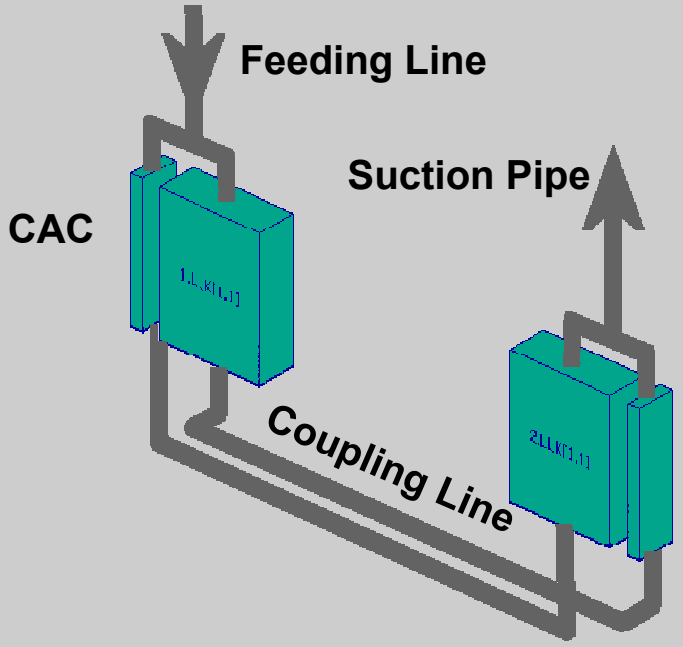
- Engine Power requires a certain Mass Flow Rate
- Pressure and Temperature are not independent

Pressure Loss and Charge Air Pressure in Context at constant Charge Air Flow Rate and Ambient Temp.

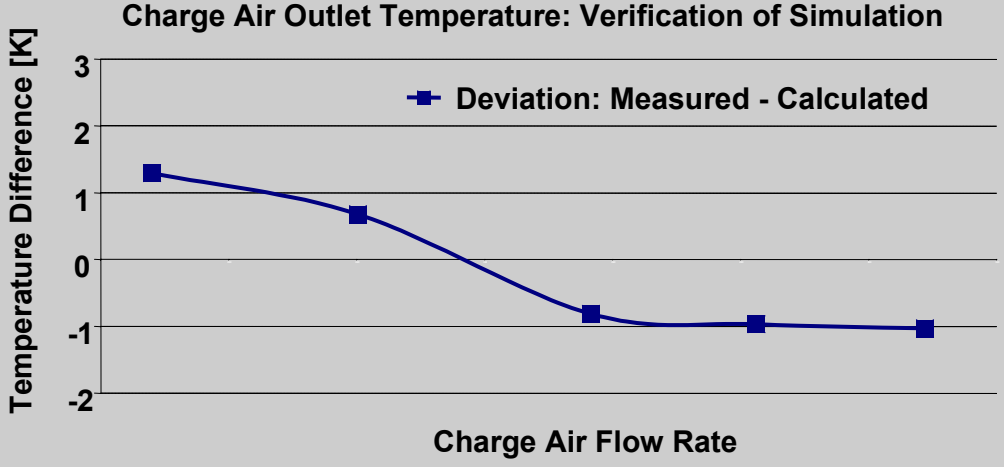


Charge Air Cooling – Simulation Results

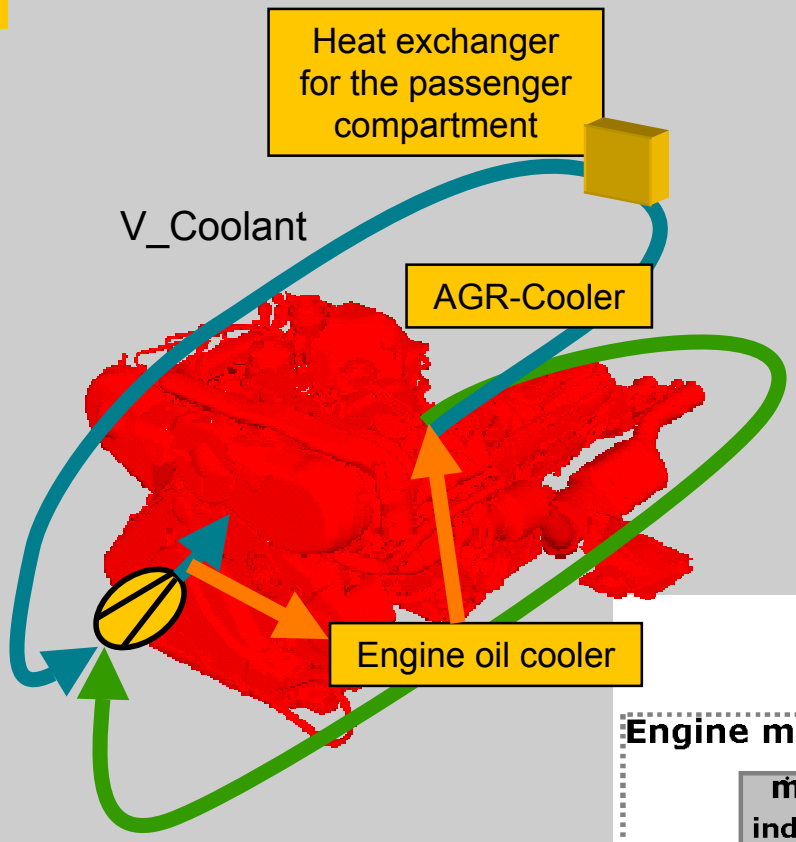




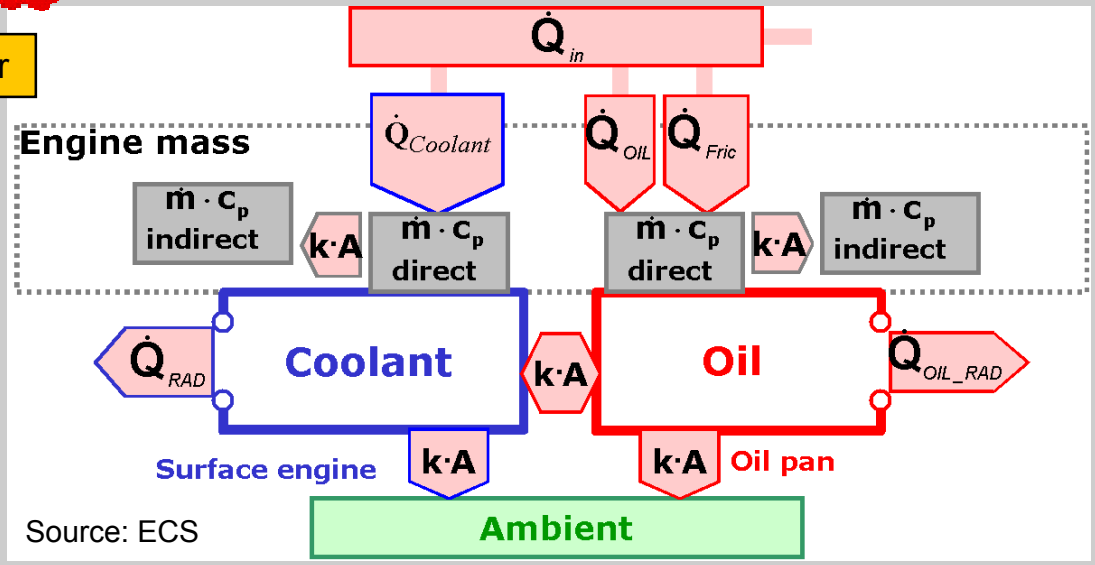
- Easy Parameter Studies
- Analysis of different Configurations (with or without Bypass)



Engine heat fluxes, HEATSIM engine model



- **Measurements required**
- **Q° oil; Q° coolant**
- **Temperatures at heat up or cool down**

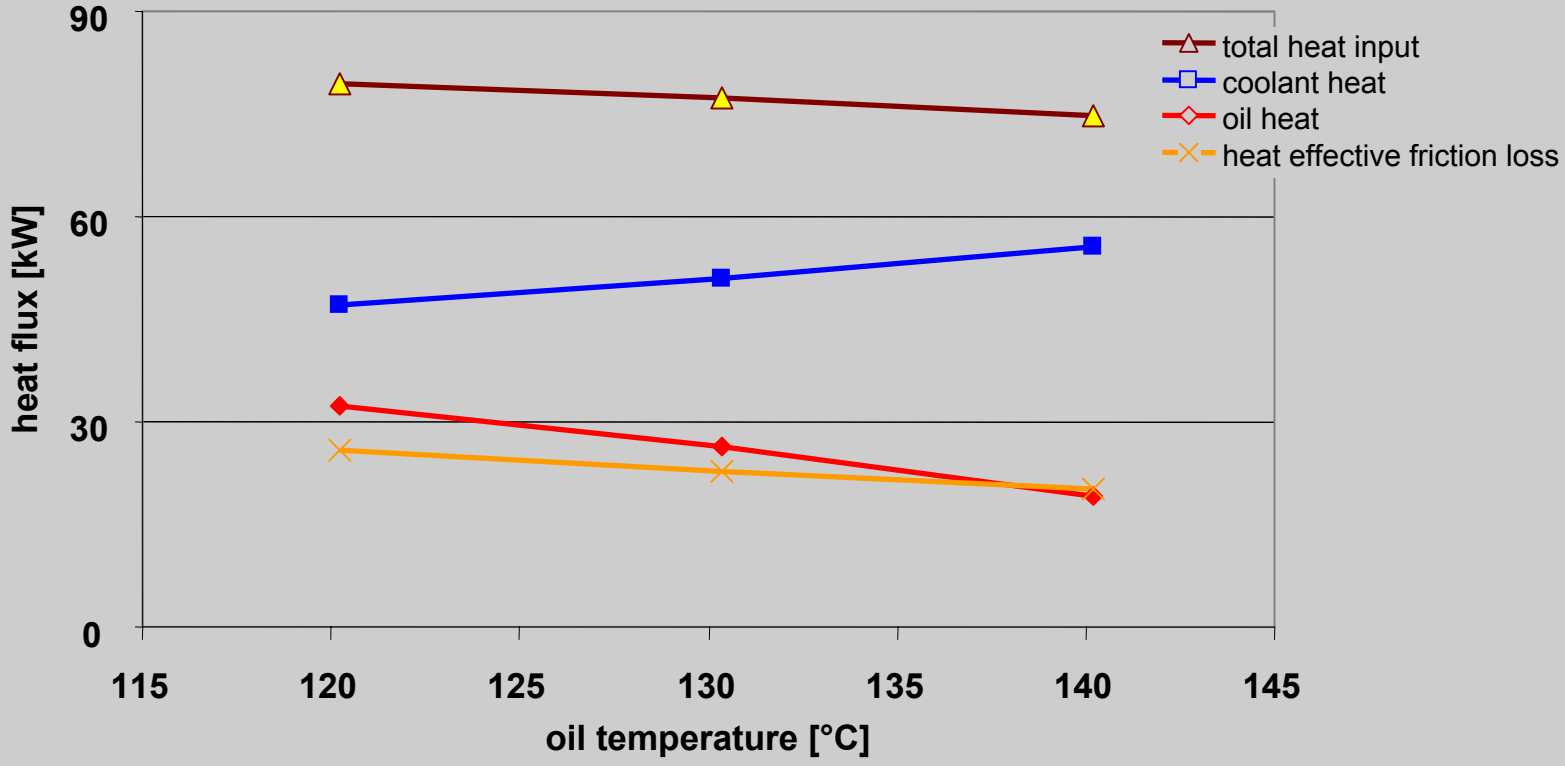


Source: ECS

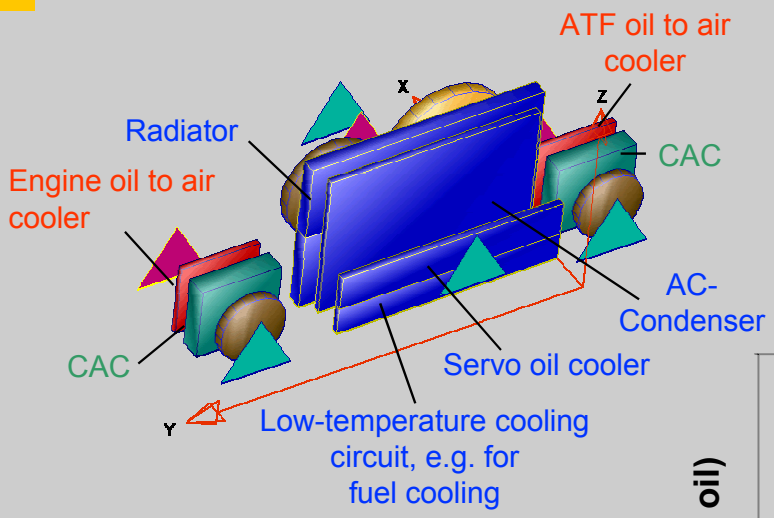
Engine Model

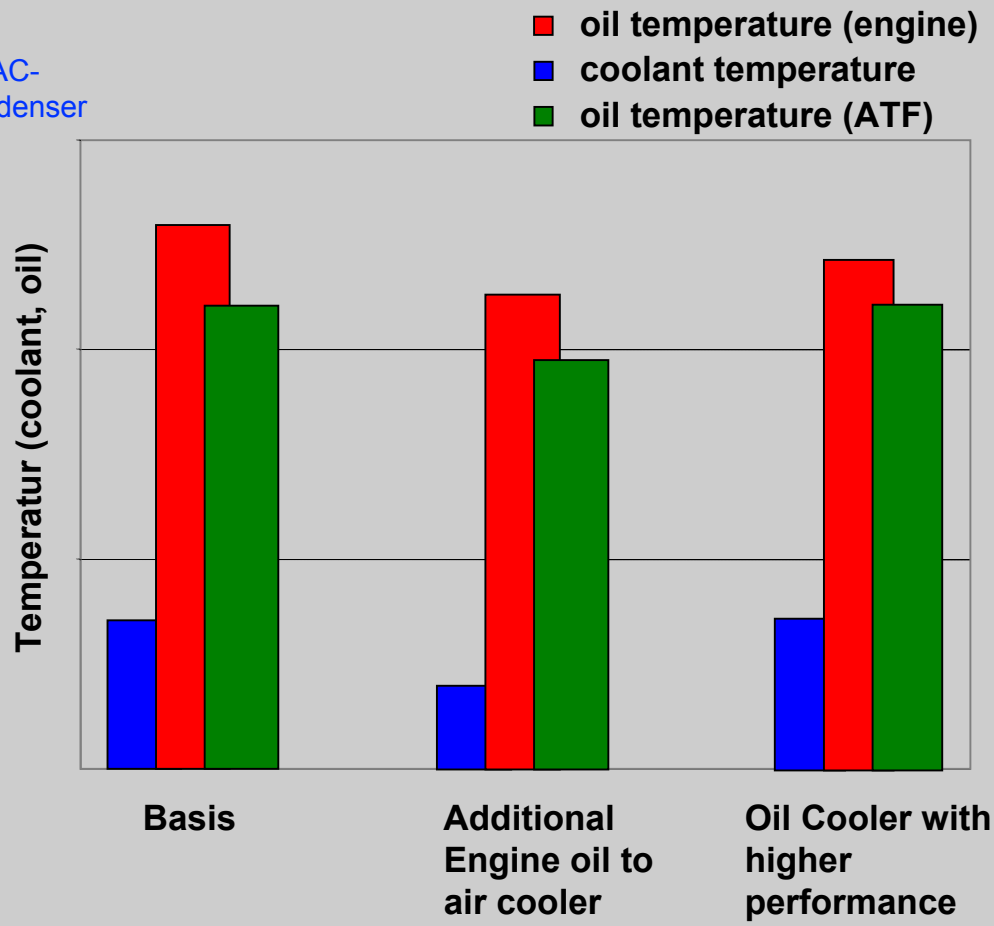
The total heat input as well as the heat flux to oil and coolant depends on the oil and coolant temperatures

- **const. engine speed**
- **const. Coolant temperature (95°C)**



Oil temperature





- **Easy Parameter Studies**
- **Analysis of different Configurations**