KULI User Meeting

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Use of KULI in the development of engine cooling systems

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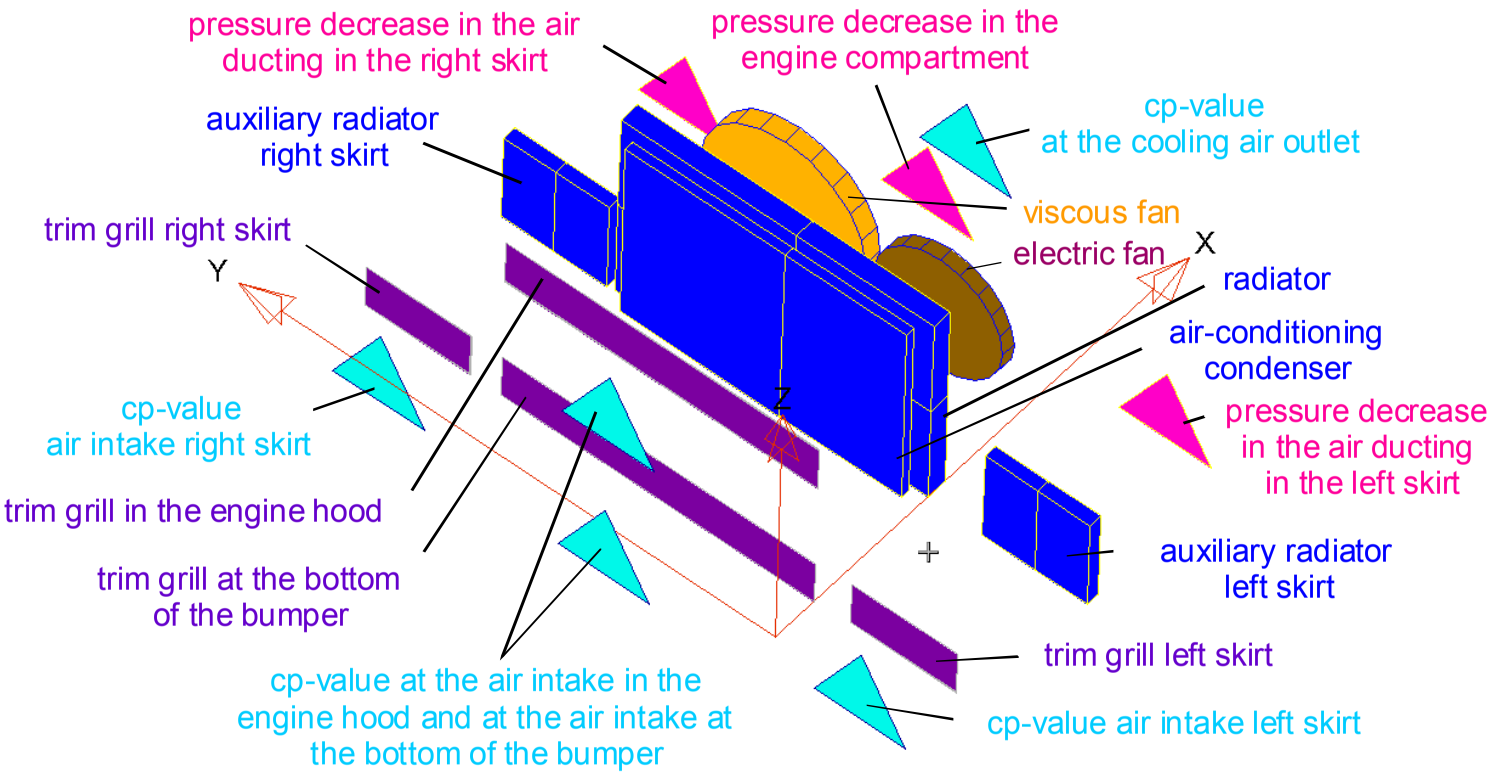
Tasks of concept development / simulation in the development of cooling systems

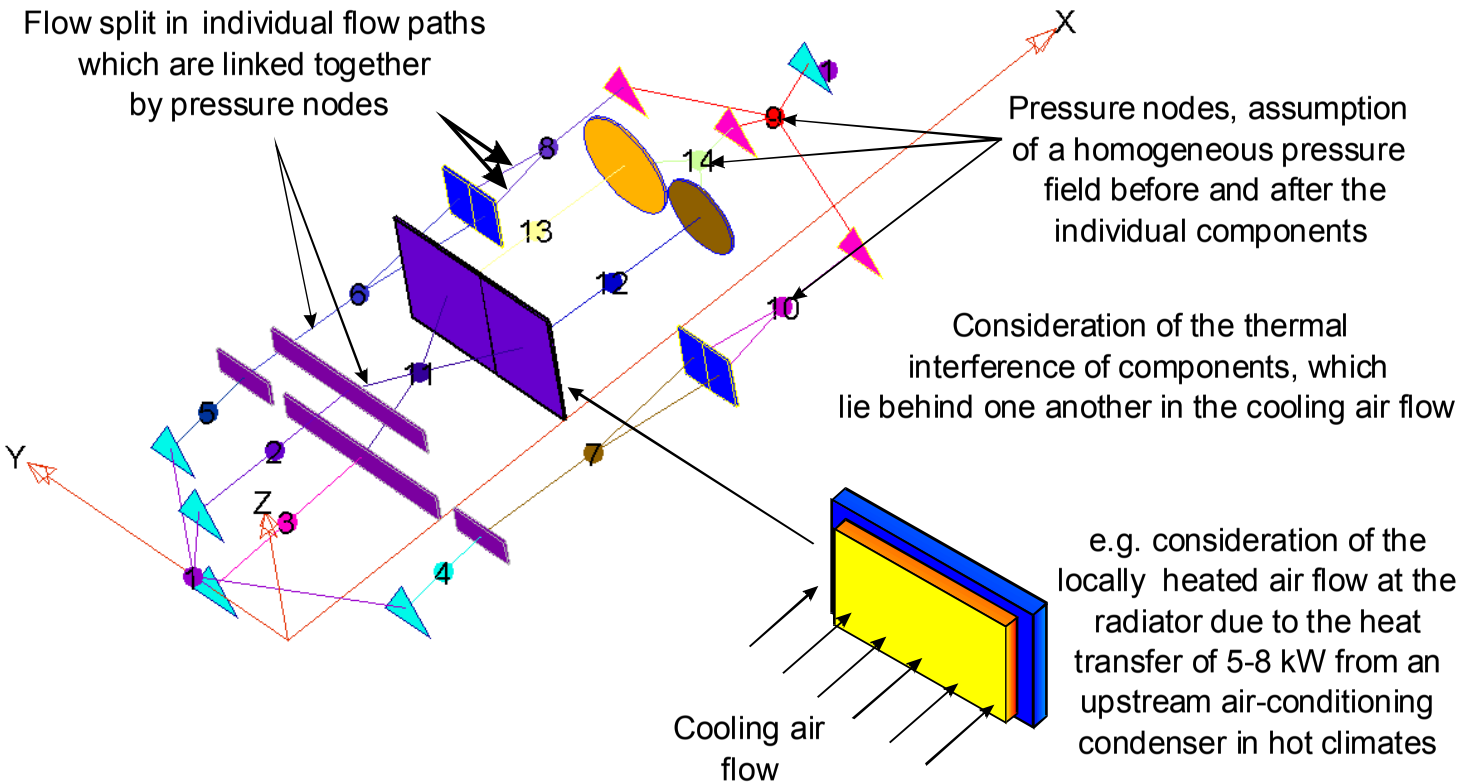
Fundamental objectives

- Design of the cooling system in a way, that the limiting temperatures of components in the engine and also the limiting temperatures of the cooling medium are maintained at all stationary extreme operating levels of the car
- Quantitative evaluation of variants in the very early stage of development referring to
  - Cooling efficiency
  - Occupied space
  - Costs
- Saving of development costs and time and minimizing cost of building and testing prototypes
- Performing calculations parallel to tests in the later stages of development for optimizing components and controlling testing

1-dimensional model of a cooling system



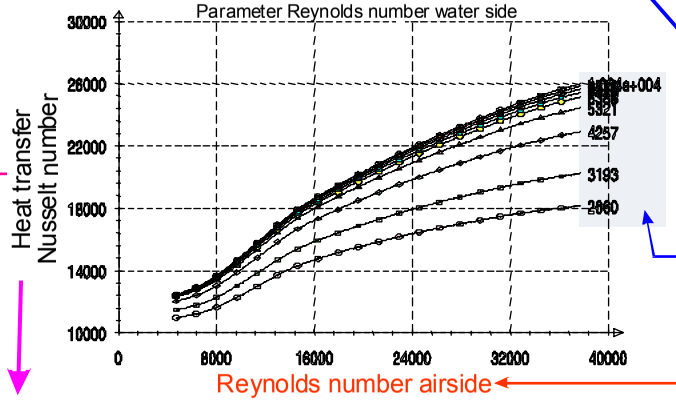
Description of the cooling air flow with a 1-dimensional model



Integrated simulation, the Corba interface between KULI and FLOWMASTER

Parameters

- System components
  - Geometries and positions
  - Operating characteristics
- Ambient temperature
- ▸Rotational speed of the waterpump
- cp-values, aperture cross-sections
- Pressure drop in the engine compartment
- Engine load
- Travel speed, fan speeds



Iteration, $\dot{m}_{Water}=f(T)$

calculation of the mass flow rate of the cooling water

Iteration, $\dot{m}_{Cooling\_air}=f(T)$

calculation of the mass flow rates of the cooling air

convergence

Stationary cooling performance of the system, temperatures of the cooling air and water (charge air, engine oil ..), cooling efficiency in the operating point

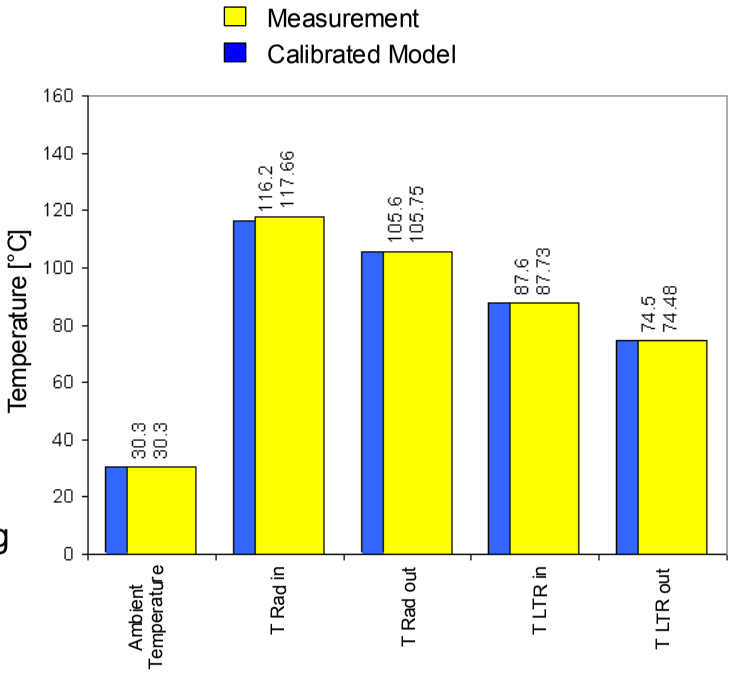
Verification of the simulation model, calibration by the use of a heat balance measurement

Difficulty

- Direct measurements of the pressure decrease in the engine compartment are impossible as well as in the case of a existing prototype

Remedy

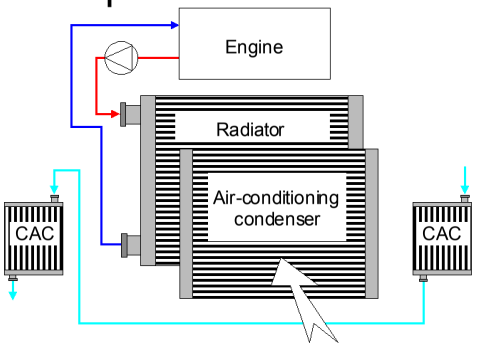
- Measurement of the heat balance at the radiator at several operating points at a series of existing cars in the climatic wind tunnel
  - Ambient temperature
  - Temperature of the cooling water
  - Radiator heat flux to the coolant air
- Modeling of the cooling system and calibrating the heat balance, giving the relationship between coolant temperatures, external temperatures, and escaping heat
- Storage of this expert data of the pressure drop in the engine compartment in a database - usage in the very early stages of development



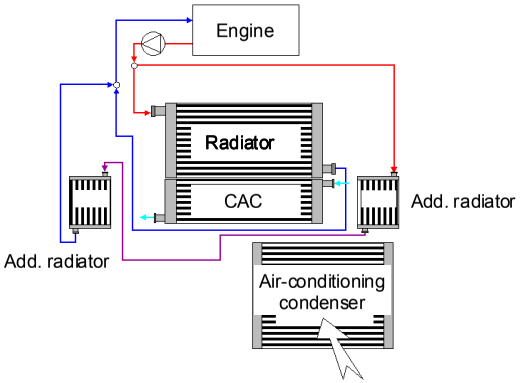
Example of the calibration of a model

Sketch of different cooling concepts for cooling water, engine oil, gearbox oil and charge air

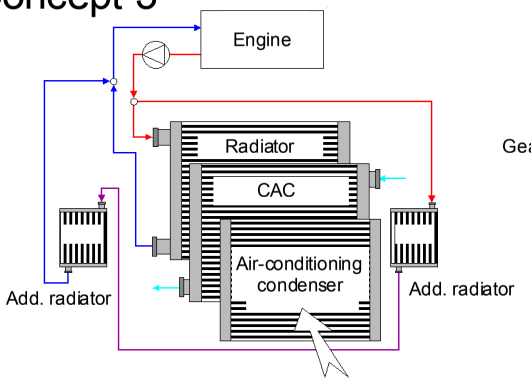
Concept 1



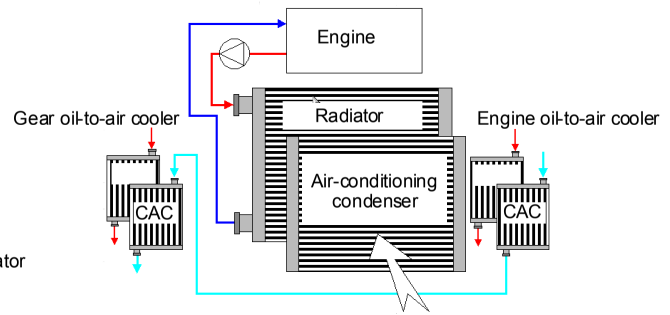
Concept 2



Concept 3



Concept 4



Quantitative comparison of different water cooling systems

Limiting ambient temperature (LAT):

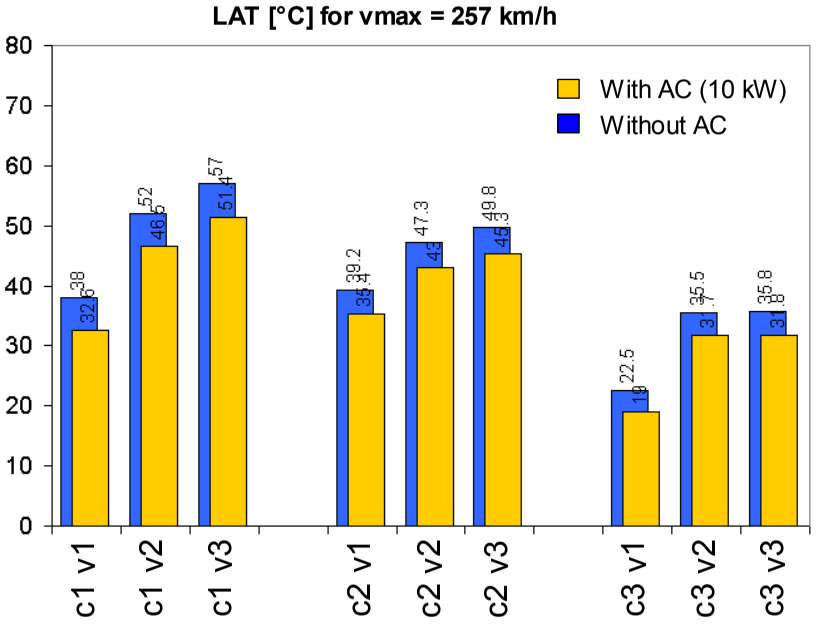
- The ambient air temperature at which the water inlet temperature in the radiator attains the upper limit

Inlet temperature difference (ITD):

- The temperature difference between the medium which is to be cooled and the cooling medium at the inlet to the heat exchanger

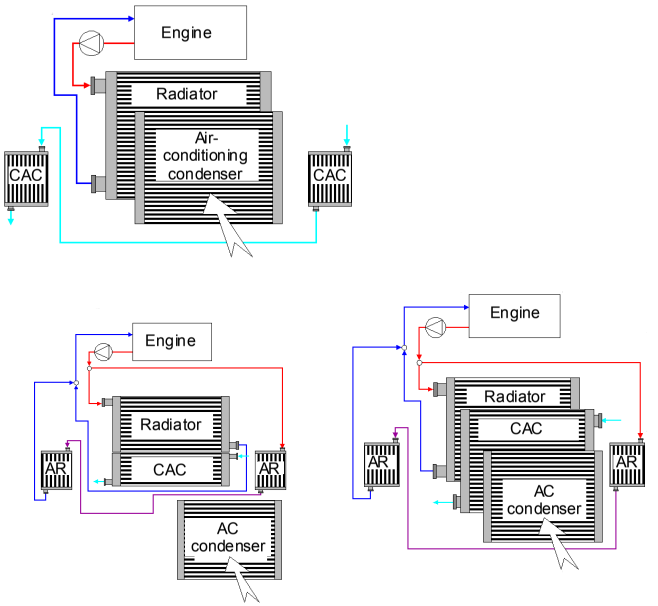
Efficiency of charge air cooling:

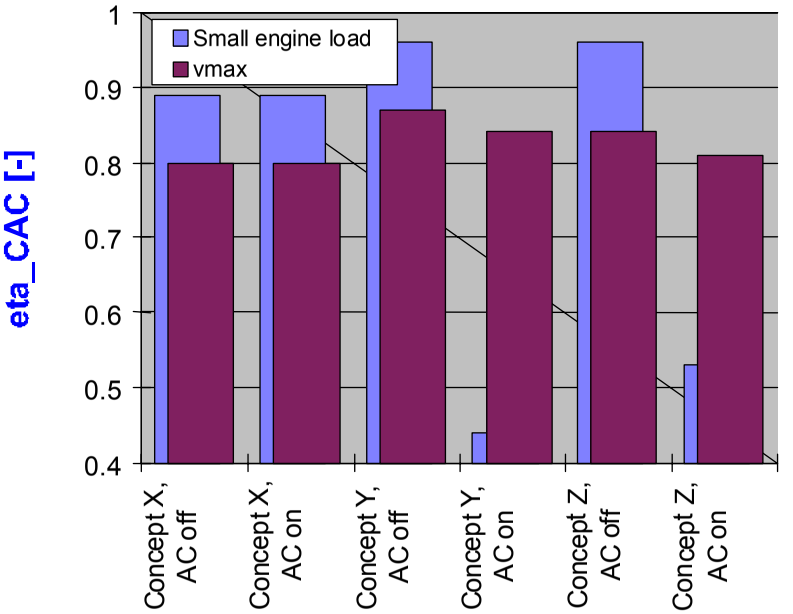
$$\eta_{CAC} = \frac{T_{CA,in} - T_{CA.out}}{T_{CA.in} - T_{Amb}}$$



- **Elimination of options with low efficiency**
- **Reduction of construction costs of prototypes as well as testing time**

Comparison of different concepts concerning the efficiency of charge air cooling





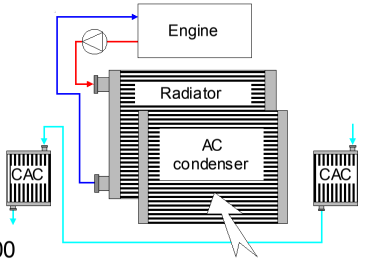
$$\eta_{CAC} = \frac{T_{CA,in} - T_{CA.out}}{T_{CA.in} - T_{Amb}}$$

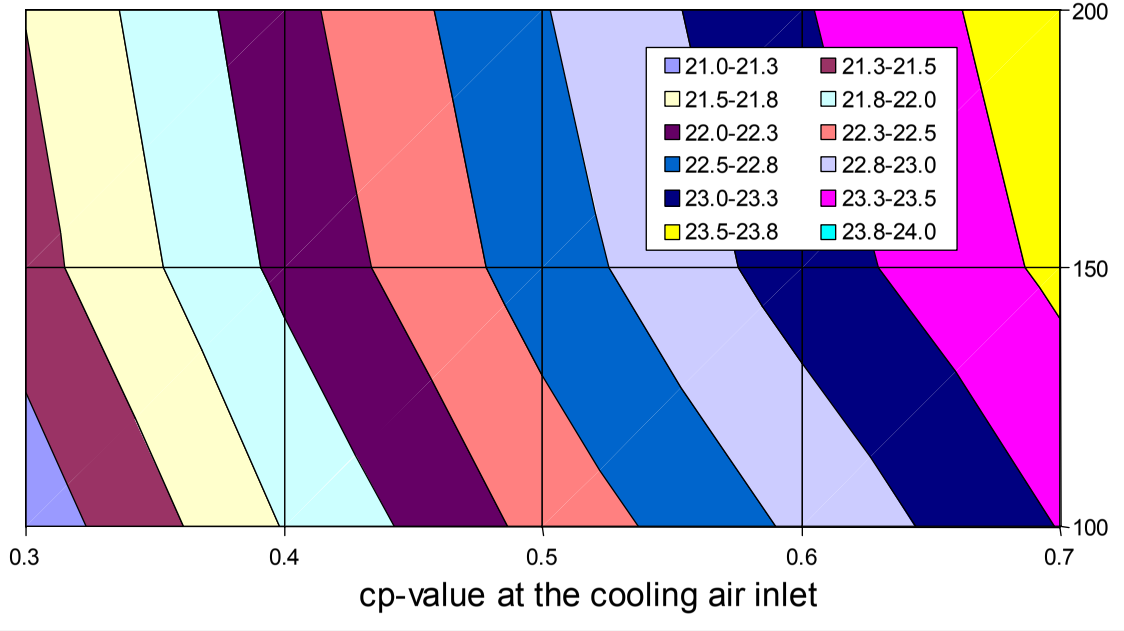
Additional Results:

- Outlet temperature of the charge air
- Charge air cooling performance
- Pressure drop in the intercoolers

Example: Sensitivity study of the charge air cooling performance in the skirts

Performance of a specific charge air cooling system [kW] as a function of the cp-value at the cooling air inlet and the inlet area at the operating point vmax





Further development of the simulation tools

Methodic objectives

- Extended interface to 3D-CFD
- Simulation of unsteady processes
  - transient heat up and cool down, e.g.
    - Stop and go
    - Periodic acceleration and deceleration of the car
- Construction of an interface for the description of the unsteady thermal heat balance of the engine

Technical objectives

- Direct calculation of the pressure drop in the individual cooling air branches on the basis of CAD data without recourse to experimental results (virtual product)
- Demand-oriented and strategic control of the heat fluxes by a systematic regulation of the transport medium cooling water