Simulation of Cooling Systems for tractors with „KULI“

4th International KULI User Meeting

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Overview

- Introduction
- Tasks for Cooling Systems Development
- Presentation of Simulation Software „KULI“
- Working with „KULI“
- Examples of Simulation of Cooling Systems for Fendt Tractors
- Results

Introduction

In advanced tractor development an efficient cooling system optimization gets more and more important due to enhanced standards of cooling systems.

Following factors determine these requirements:

- **Continuous increase of power of farm tractor engines.**
- **Legal regulations for emmission control.**
- **Hydraulic systems with enhanced power consumption of equipment**
- **Climate condensers with high heat rejection.**
- **Cab design for optimal sight to working implements.**
- **Reduction of development time and costs.**

Tasks

Optimization of the design process of cooling systems in relation to time, costs and function together with improvement of early quality diagnostics.

Challenge

Optimization of cooling systems - only based on vehicle driving tests and bench tests - are always time- and cost- consuming.

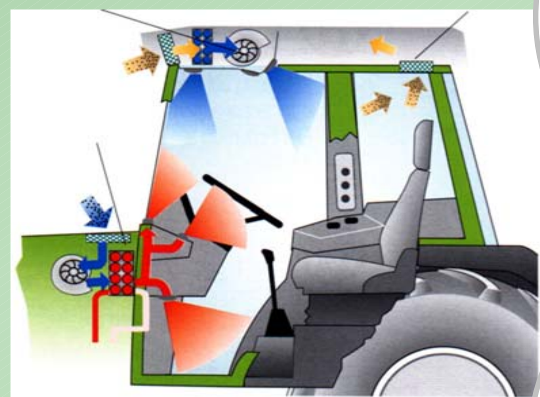
Solution

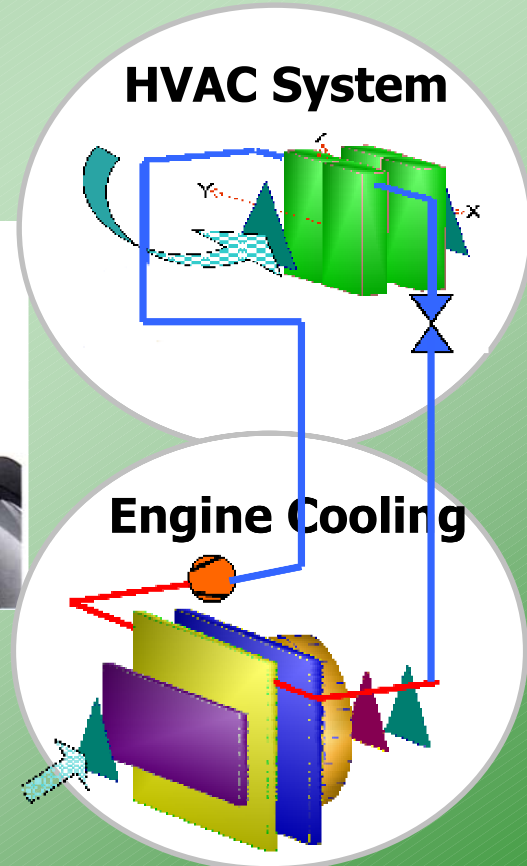
Computational simulation of heat management with the software tool „KULI“ based on experimentally determined data.

Simulation Software KULI

„KULI“ is a software tool for the simulation of:

- Cooling systems
- Air-conditioning
- Cabin heating





„KULI“ was developed by

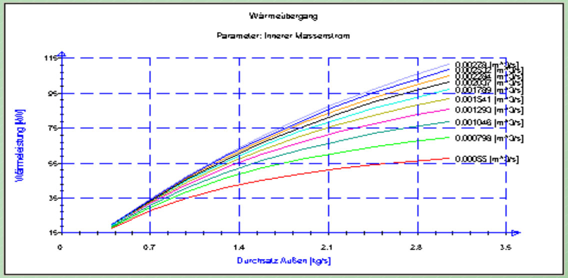
ENGINEERING CENTER STEYR

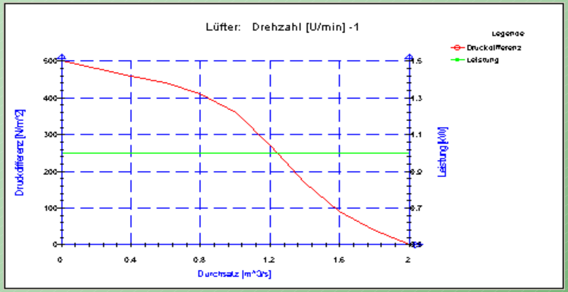
More information at: http://www.kuli.at

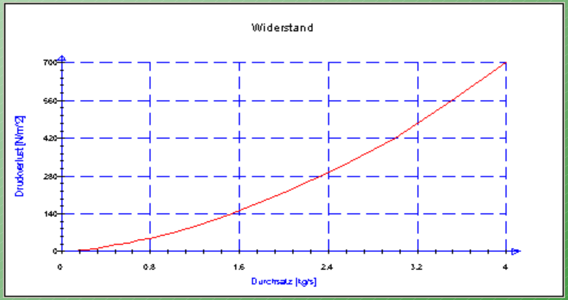
Cooling System Components

The following caracteristic curves define the cooling system components:

- **Heat Exchanger** (WAK, LLK, GÖK, HÖK und KrK)
  - Cooling capacity as a function of the inner flow of the cooling medium and the outer cooling air flow
  - Inner air flow restistance
  - Outer air flow resistance
- **Fan**
  - Volume flow and power consumption as a function of the pressure difference and the fan speed
- **Hood grill**
  - Outer air flow resistance

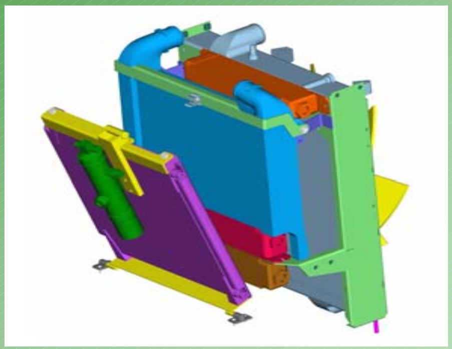




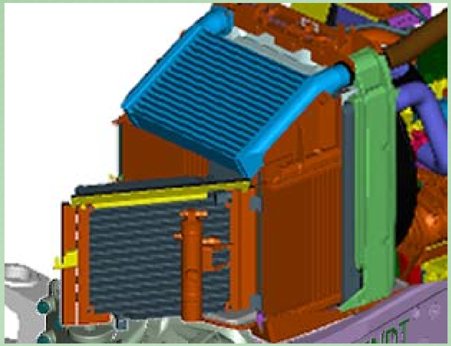


Positioning of Components

Heat exchangers in line



Compact cooling



WAK = water cooler
LLK =air charge cooler
GÖK = gearing oil cooler
HÖK = hydraulic oil cooler
KrK = fuel cooler
HG = bonnet grill
EW = mounting resistance

Definition of Cooling Circuits

Assignment of components and coolants

- Engine
  WAK
- AC
  Condenser
- Gear
  GÖK
- Hydraulics
  HÖK
- Fuel
  KrK
- Charge Air
  LLK

Simulation Parameters of Cooling Circuits

Specification of Heat

- The maps of the rejected heat and the flow of the refrigerant will be defined as a function of the engine torque and the mean effective pressure for each cooling circuit.

↓

For example you can calculate
ATB = air to boil

$$ATB = T_{.max} - T_{.In} + T_{Ambient}$$

Thermic load of the cooling circuits is caused by:

• the operation profile
• the concept
• the tractor performance class

These simulation parameters are determined either theoretically or by drive tests or bench tests.

Simulation paramenters are essential to the quality of results.

Simulation Paramenters of Cooling Circuits

Temperature Specification

- Input of inlet temperature and the und volume flow rates of the coolant as a function of the engine speed and the engine‘s mean effective pressure.

↓

For example you can calculate die cooling air flow rate of the coolers

- By specification of the max. allowable operating temperature the max. cooling capacity of the cooler at any operating conditions of the tractor can be calculated.

Determination of Simulation Parameters

The output heat quantity is determined by the simulated operating conditions of the tractor

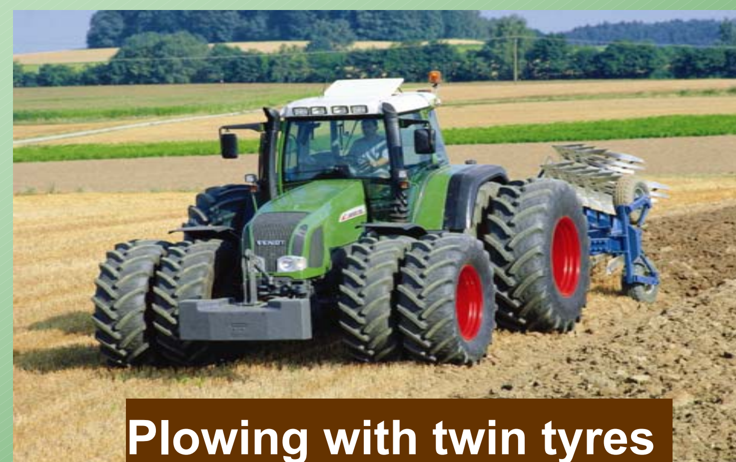
↓	↓	↓
Pull	**PTO**	**Transport**

Examples for „Vario - driving stragegies“

Mowing with Rüfa

50km/h with 40 t trailer

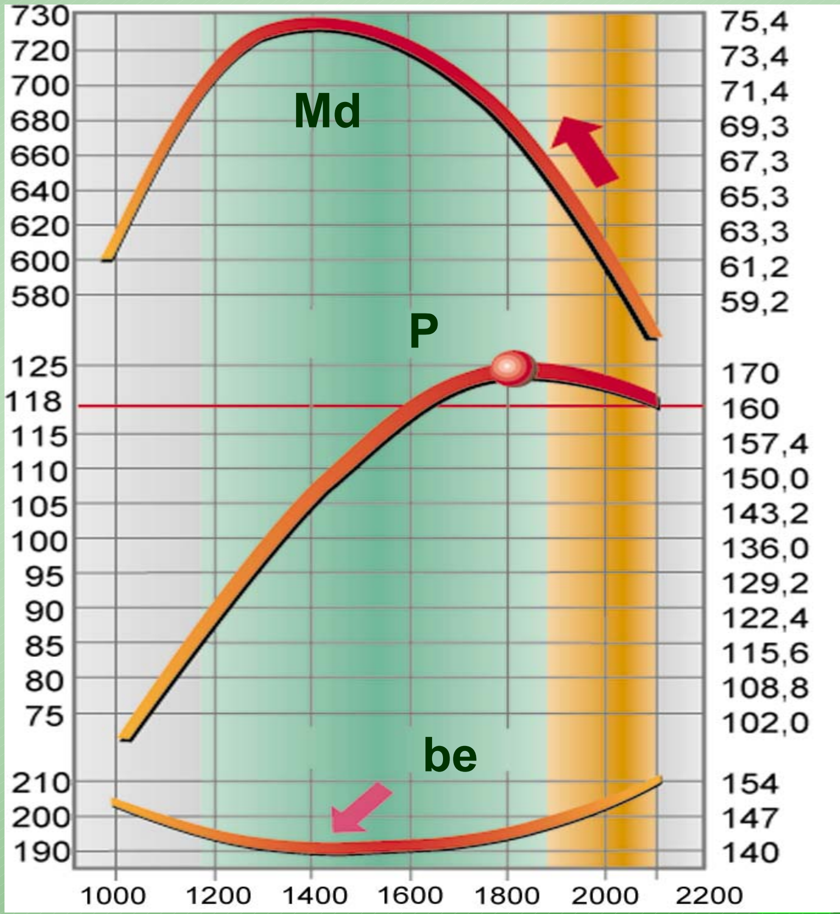
Seed bed combination



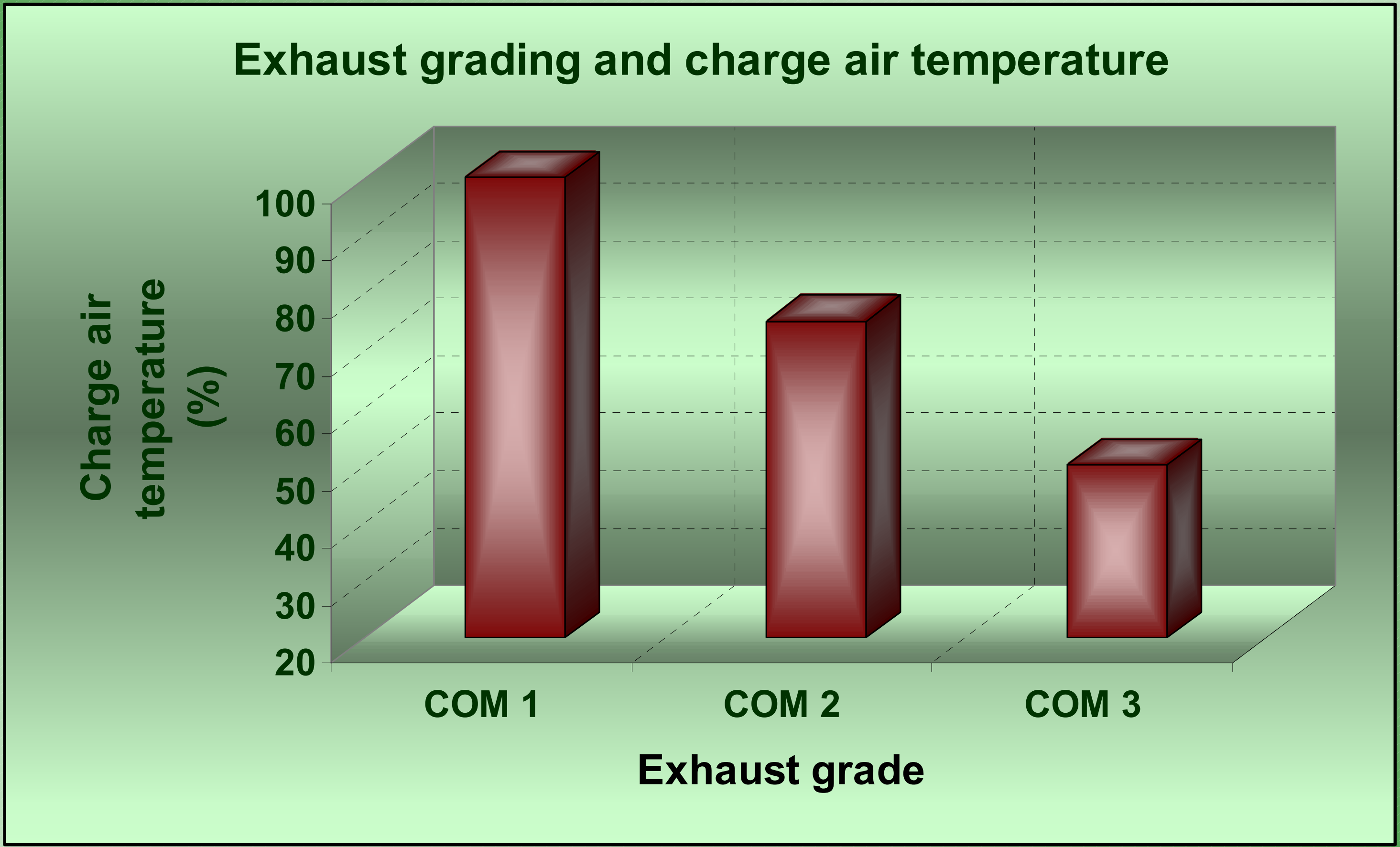
Plowing with twin tyres

Engines Performance Data for Fendt - Tractors

- Performance range 36 to 220kW
- Constant power range >20%
- Power increase >4%
- Torque increase > 35%
- Starting torque > 110%



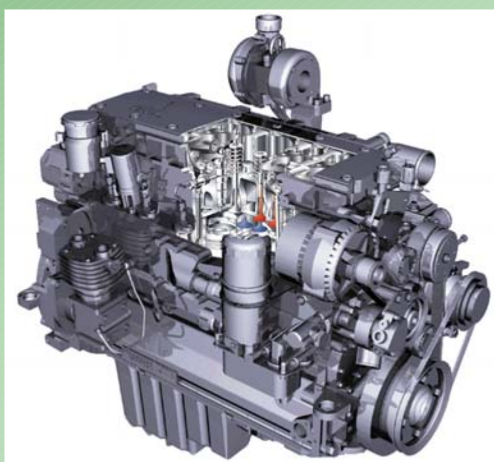
Legislative standards für exhaust emission

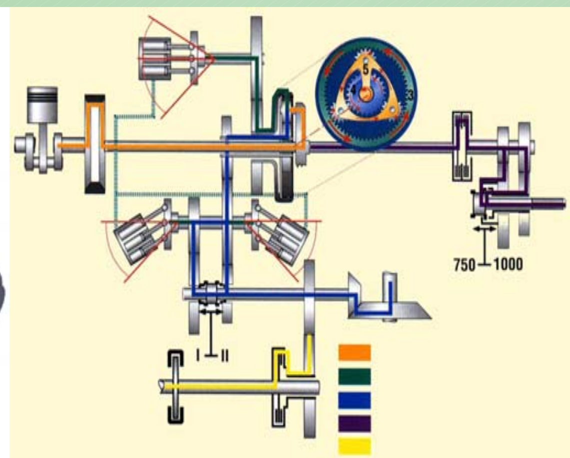


Modern Drive Aggregates for Tractors

Constant power range
1700 to 2100 rpm

Continuous variable speed
0 to 50 km/h





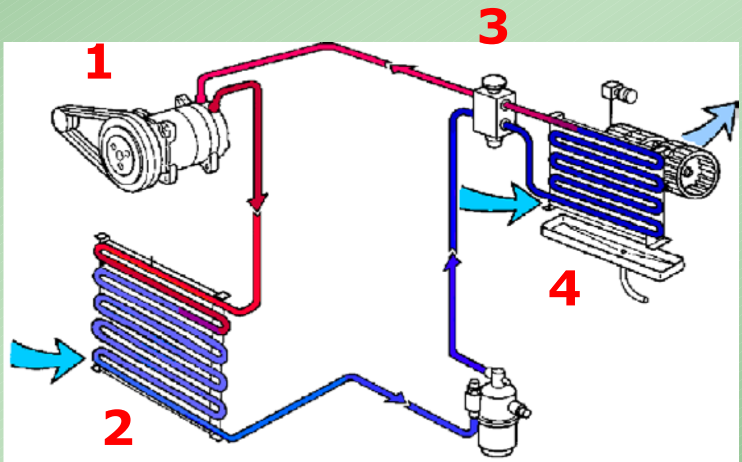
Complex Hydraulic Equipment

- **Powerful axial piston pump; Pressure and volume controlled.**

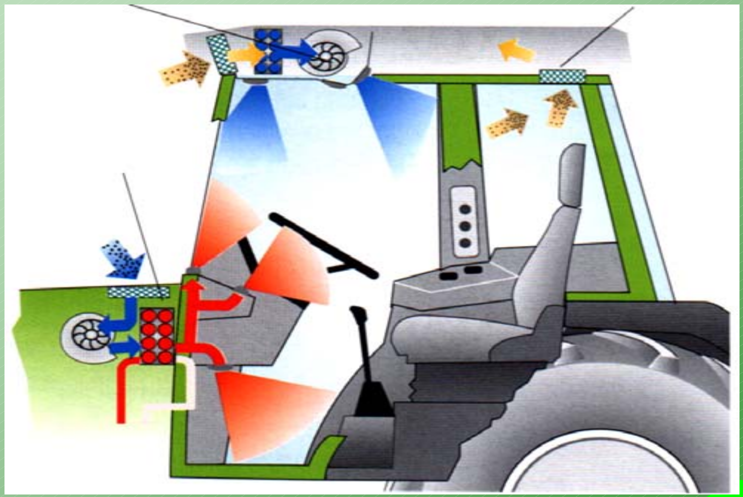
- **Highest comfortable handling by electric valves**

- **The load-sensing-system is a standard for hydraulic systems related to capacity, efficiency and flexibility**

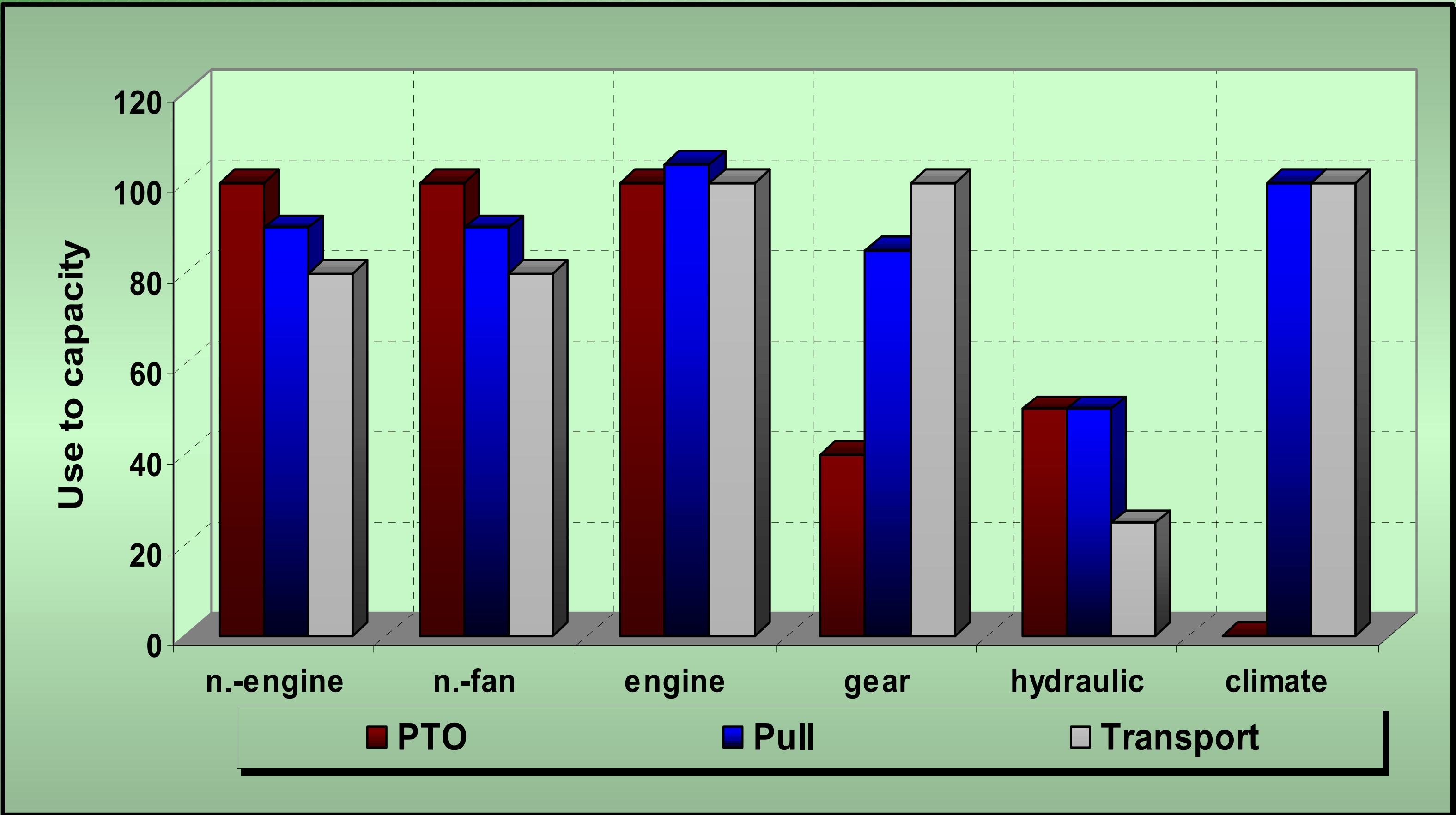
Powerful Air Conditioners



- **Condensers with high cooling power grant optimal cab comfort**



Simulation Parameters from Driving Tests

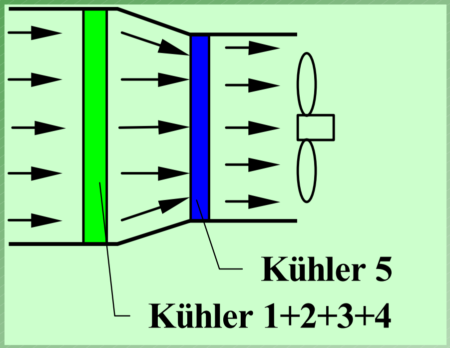


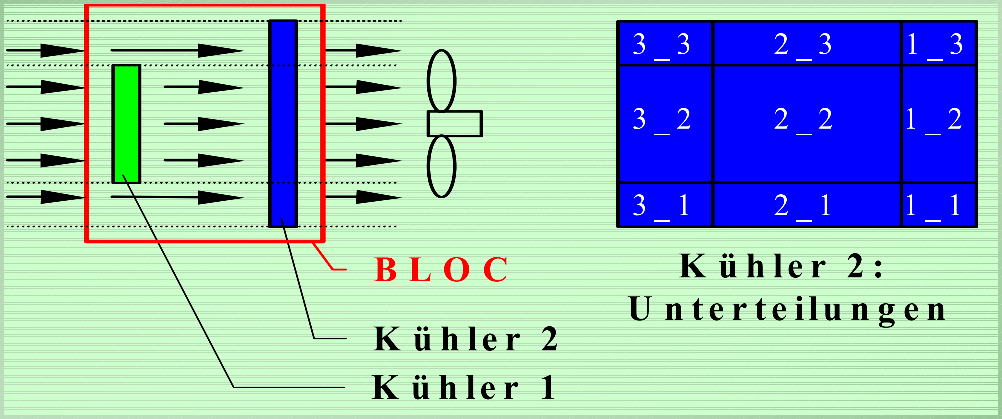
Tractor Simulation Parameters

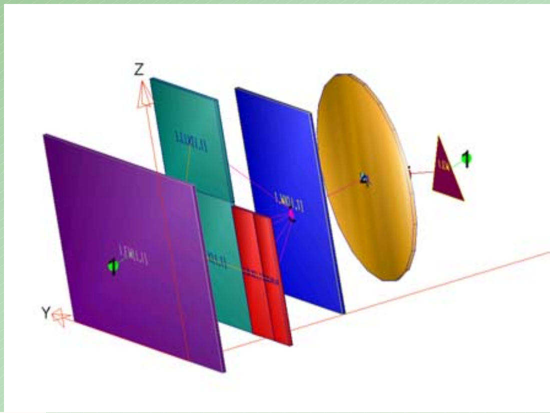
By variation of following parameters exactly defined working conditions of the tractor can be simulated

- **Engine speed: =>** (1700, 1900 und 2100 rpm)
- **Engine mean effective pressure: =>** (as info for engine load condition)
- **Speed: =>** (0 to 50km/h)
- **Ambient temperature =>**(25°C for COM 2; or 45°C for ATB)
- **Air pressure: =>** (according to position)
- **Air moisture =>** (for example 60%)
- **Operating condition of air condition: =>** (AC on/off)

Modeling of cooling air flow







Calculation

„KULI“ calculates

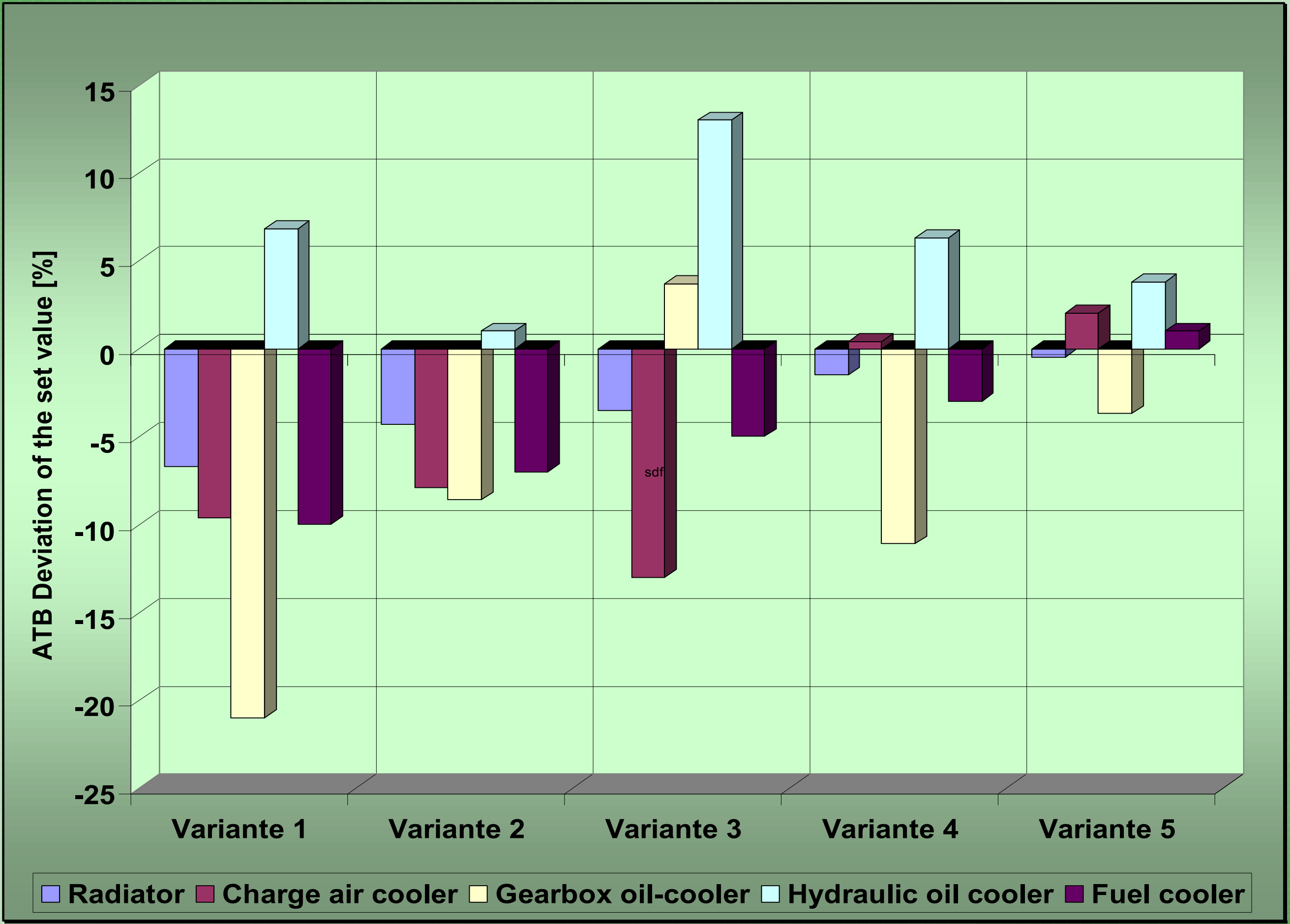
the heat balance of the total cooling system for each simulation parameter defined in an operation point of the tractor.

Results

The calculation results include:

- Level of temperature of all cooling circuits of the cooling system.
- Cooling performance balance of every component.
- Power consumption of the fan
- Pressure loss of the total cooling system as well as it‘s components.

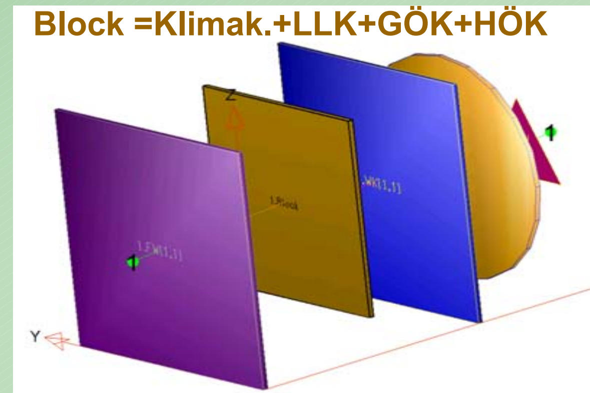
Results of variant Series



Farmer 300 C

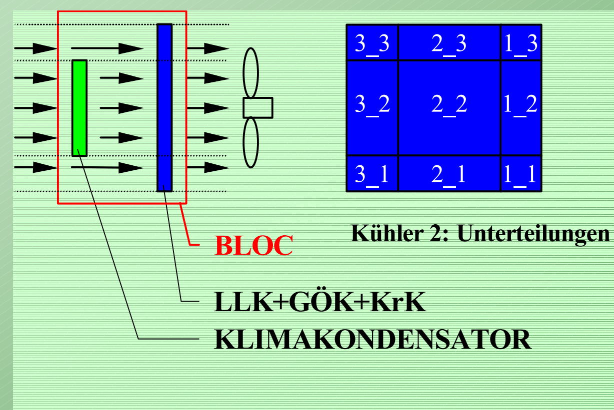
Positioning of coolers in line

Cooling air flow



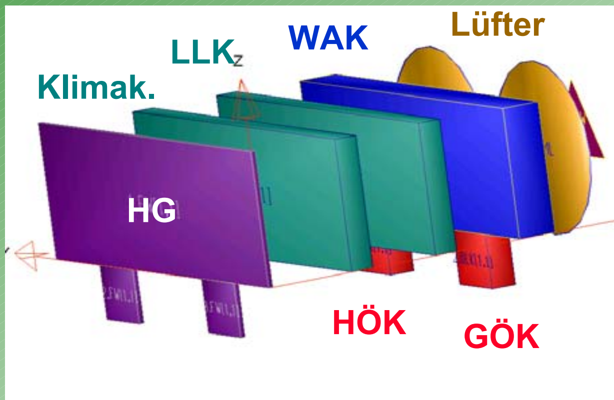
Cooling system in line

Air flow with block formation

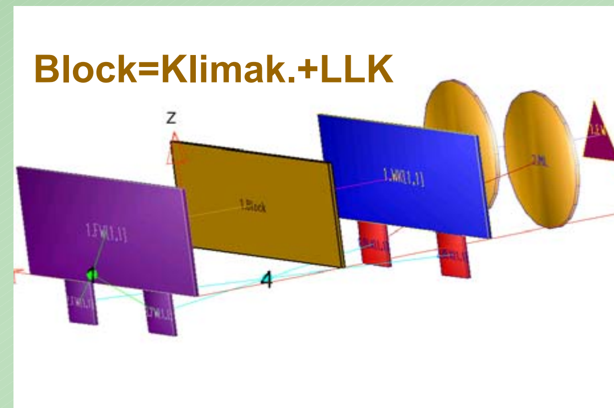


XYLON 524

Component arrangement

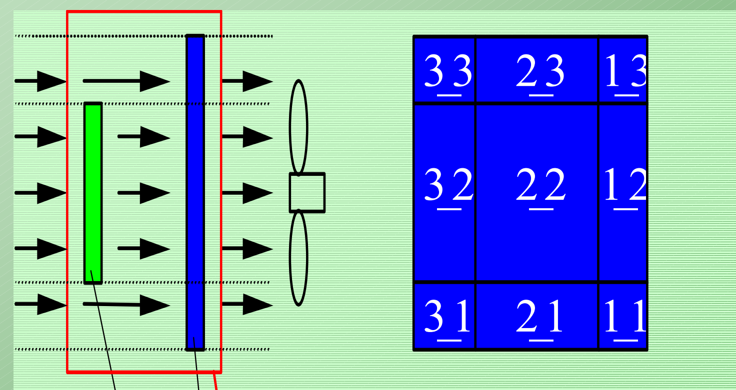


Cooling air flow



Under body cooling

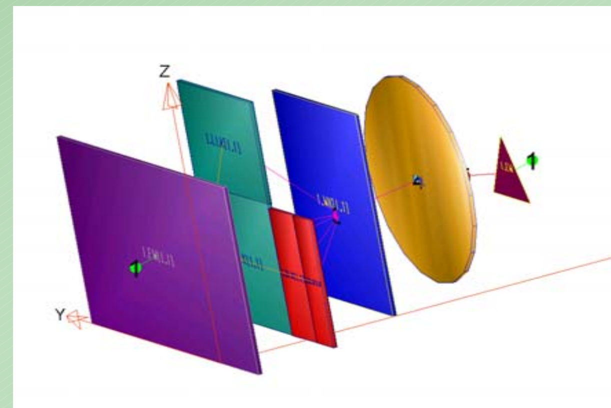
Cooling air flow block formation



FAVORIT 700

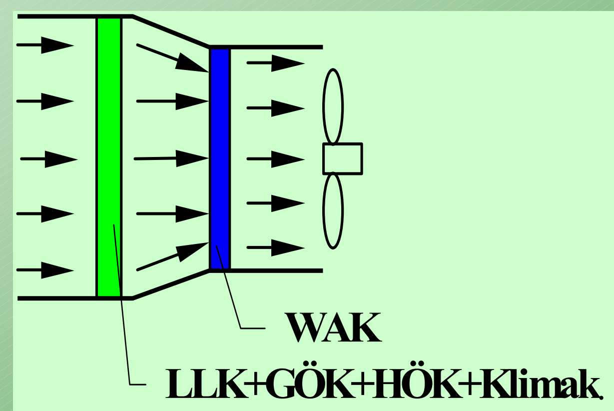
Component arrangement

Cooling air flow



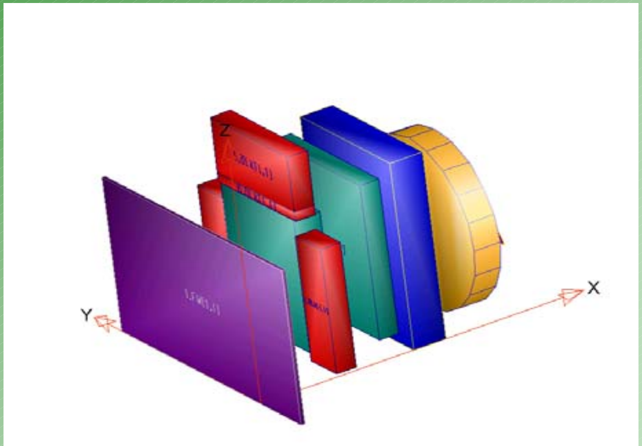
Compact cooling

Air flow compact cooling

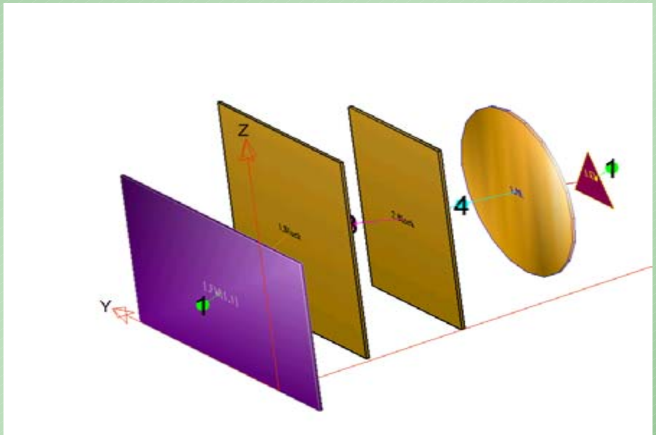


FAVORIT 800

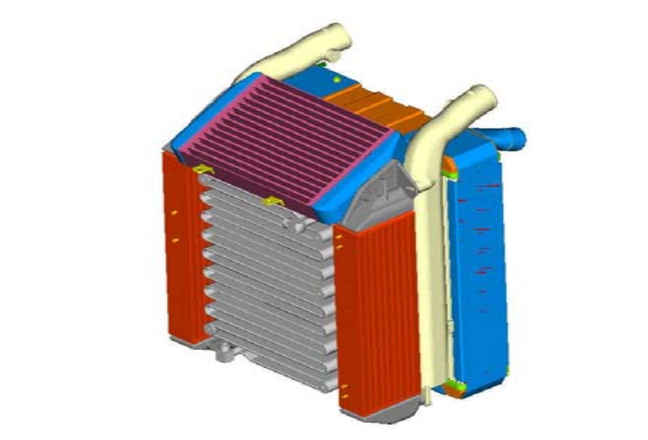
Component arrangement



Cooling air flow



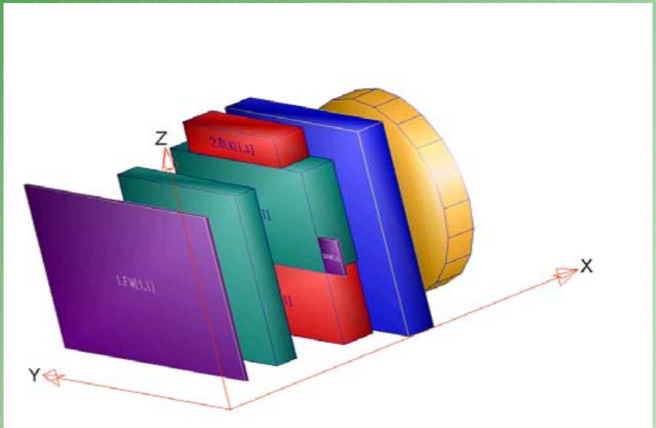
Cooling system FAV 800



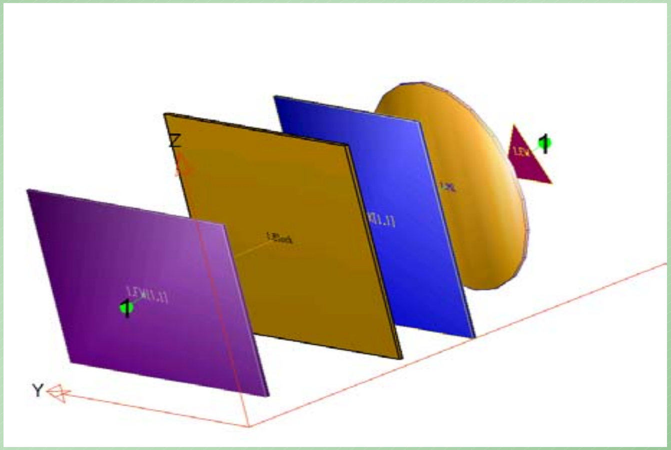
Service position

FAVORIT 900

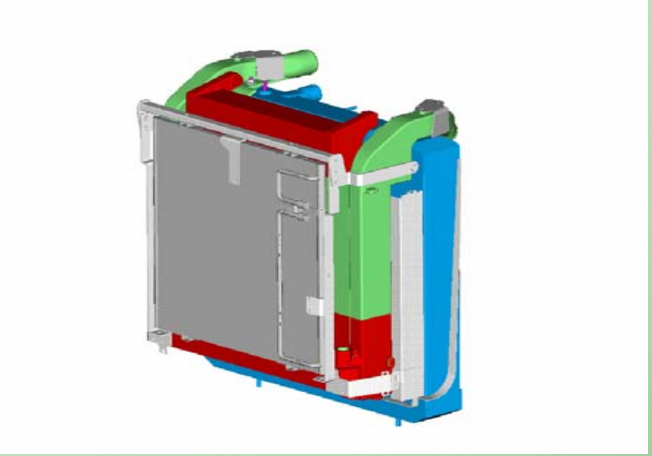
Component arrangement



Cooling air flow



Cooling system FAV 900



FAV 930

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Results

Numerical simulation with „KULI“ contributes considerably to the development process of cooling systems by:

- **Improvement of early identification of characteristics.**
- **Reduction of development time and costs by saving several „hardware loops“.**
- **Integration of complex simulation parameters in the development process.**
- **The growing complexity and shorten innovation cylces of cooling systems can better be taken into account.**

An efficient development of cooling systems for modern tractors is not managable without simulation nowadays.


Thank you for your Attention
FENDT