MOVE. SENSE. STRIKE.

Business Unit Logistic Vehicles

ECS Simulation Conference 2021

Euro 6 standard for a military vehicle - a combined CFD / KULI workflow

Author: P. Frick RMMV; M. Haider-Peterseil ECS / 2021-05-19

RHEINMETALL DEFENCE

FORCE PROTECTION IS OUR MISSION.

RHEINMETALL MAN

Agenda

- Company presentation Rheinmetall MAN Military Vehicles GmbH (RMMV)
- KULI in use at RMMV
- Project conception / scope of work
- ECS Workflow
- RMMV Test bench setup

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RHEINMETALL MAN

Agenda

- Simulation results
- Conclusion / useful benefits for RMMV

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Rheinmetall MAN Military Vehicles GmbH (RMMV)

Rheinmetall MAN Military Vehicles GmbH is a joint venture between Rheinmetall AG (51%) and MAN Truck and Bus AG (49%) and was founded in 2010.

The headquarter is situated in Munich.

Vienna is the competence center for the wheeled logistics vehicles (R&D and production, After Sales, ILS)

Rheinmetall MAN Military Vehicles GmbH is integrated in the Rheinmetall Defence Divison.

Manufacturing location Vienna

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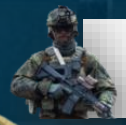
WEAPON AND AMMUNITION

AMMUNITION

WEAPON STATIONS

PROTECTION SYSTEMS

ELECTRONIC SOLUTIONS



INTEGRATED ELECTRONIC SOLUTIONS

AIR DEFENCE & RADAR SYSTEMS

TECHNICAL PUPLICATIONS

VEHICLE SYSTEMS

TACTICAL VEHICLES and TURRET SYSTEMS

WHEELED LOGISTICS VEHICLES

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Rheinmetall MAN Military Vehicles GmbH (RMMV)
Product range wheeled logistics vehicles

RECOVERY SYSTEM

TGS-MIL
MILITARIZED TRUCK SYSTEM

HET

WHITE FLEET TRUCKS

TGM-MIL
MILITARIZED TRUCK SYSTEM

HX – OPERATIONAL TRUCK SYSTEM

PROTECTION

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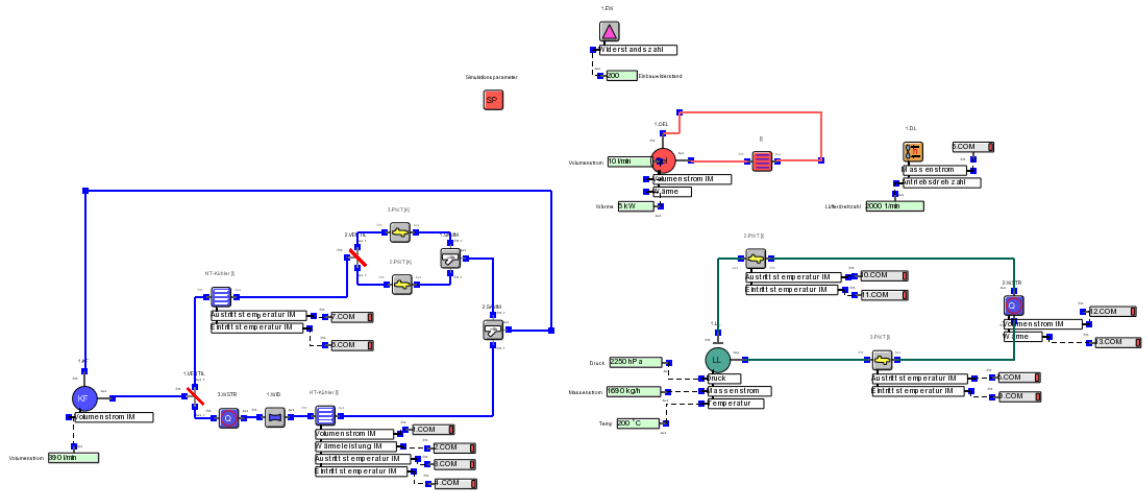
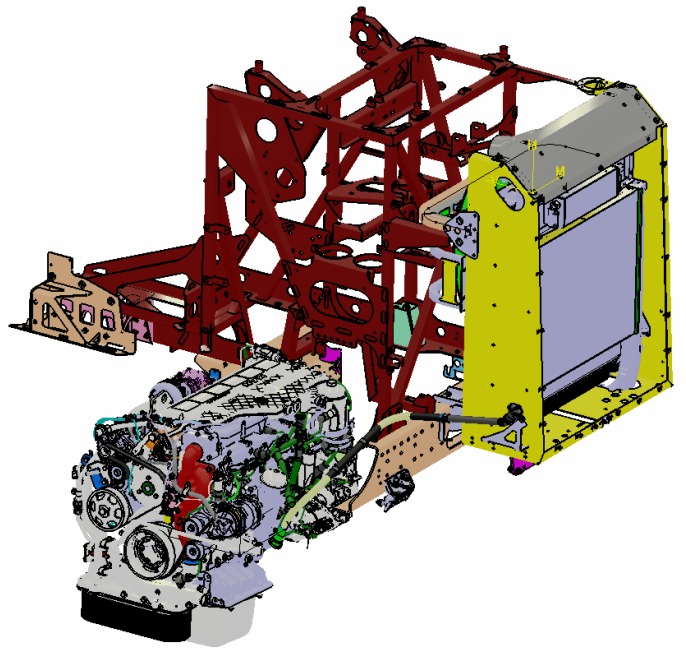
KULI in use at RMMV

Rheinmetall MAN Military Vehicles GmbH is using the ECS Software KULI since 2013.

The first project was the development of a cooling package for the MAN D08 EGR Euro V engine (340HP, double stage charged).





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Project conception / scope of work

Starting in 2015 with a concept of the integration of the MAN D26 Euro VI**c** engine in a HX2 chassis, the internal decision in 2016 was to skip to the MAN D26 Euro VI**d** engine.

The main challenges were:

- Integration of the D26 Euro VId engine with higher permissible coolant temperature and pressure, as well as increased exhaust temperatures (in comparison to the previously integrated Euro V engines in HX2 trucks)
- Integration of the new Euro VId exhaust gas muffler in the cooling rig
- Reducing the intake air temperature for the engine
- Integration of additional oil cooling of the automatic transmission and the transfer case in the coolant circle
- Definition of the radiator size (water and charge air) and the ideal fan speed
- Finding out the proper places for the pneumatic and hydraulic components in the cooling rig behind the cabin (referring to the max. permissible operation temperature)
- Definition of potential deflectors (to reduce air circulation)

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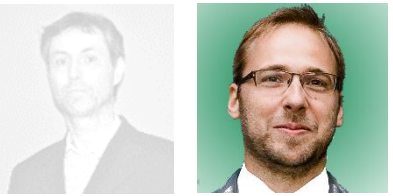

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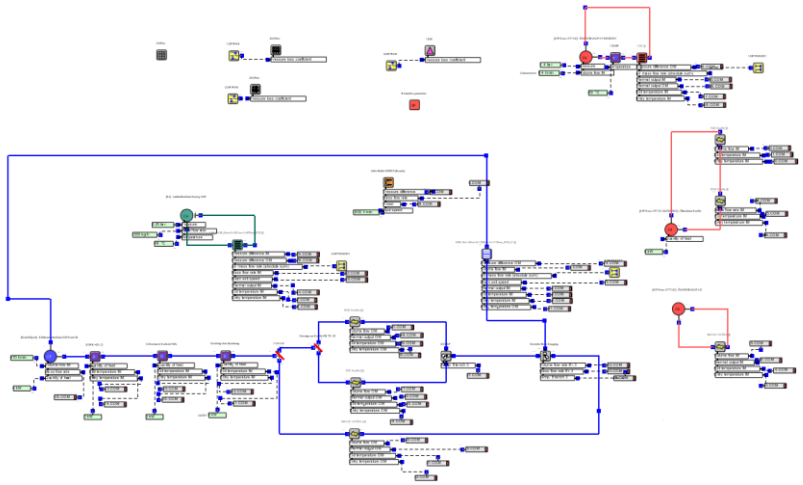
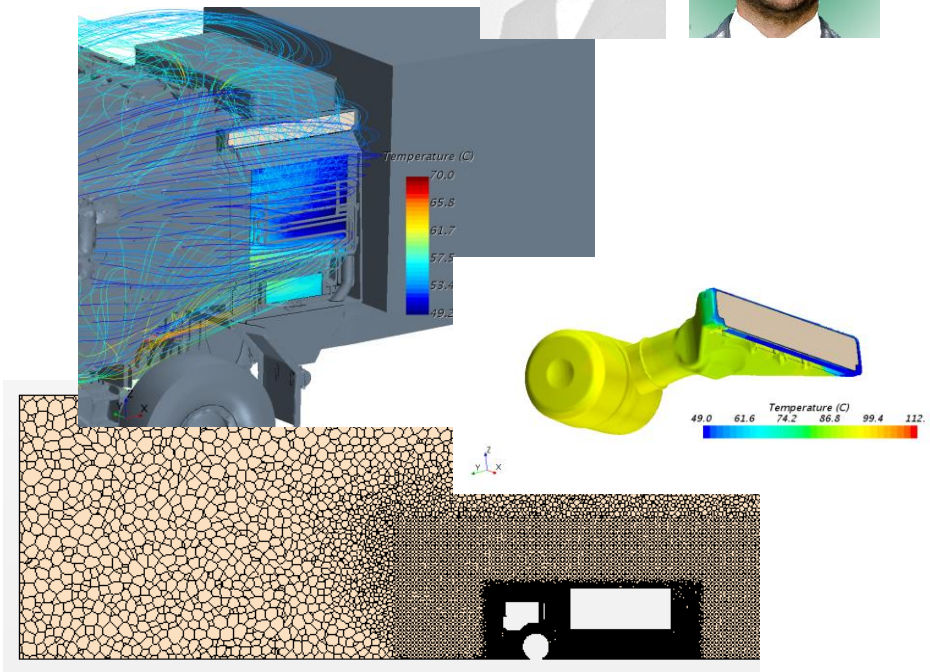
KULI / CFD Workflow



Combination of KULI and CFD

„Best of both Worlds“
4 Steps

1. Cold CFD Simulation
2. Cold KULI Simulation
3. Warm CFD Simulation
4. Warm KULI Simulation



Kuli Model

Advantage	Low Simulation duration (seconds/minutes) Combined Simulation of inner and outer fluid flows
Disadvantage	Only 1D Simulation without detailed flow behaviour

CFD Model

Advantage	3D Simulation Including all Backflows/Shortcuts
Disadvantage	No Simulation of inner fluids (in thr specific case) High Simultian duration (hours/days)

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Source: MAGNA Powertrain, ECS Steyr MAGNA

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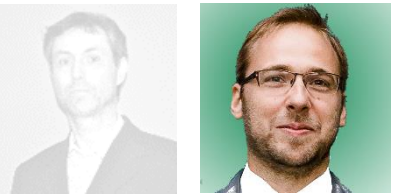
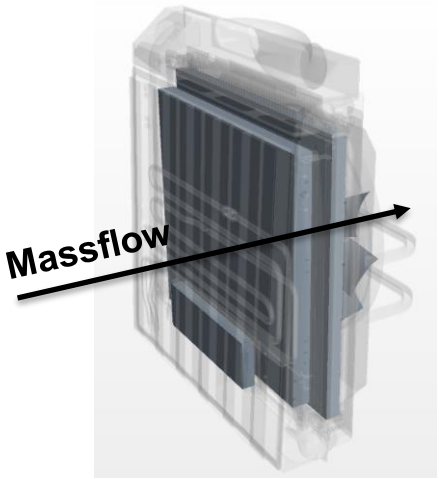


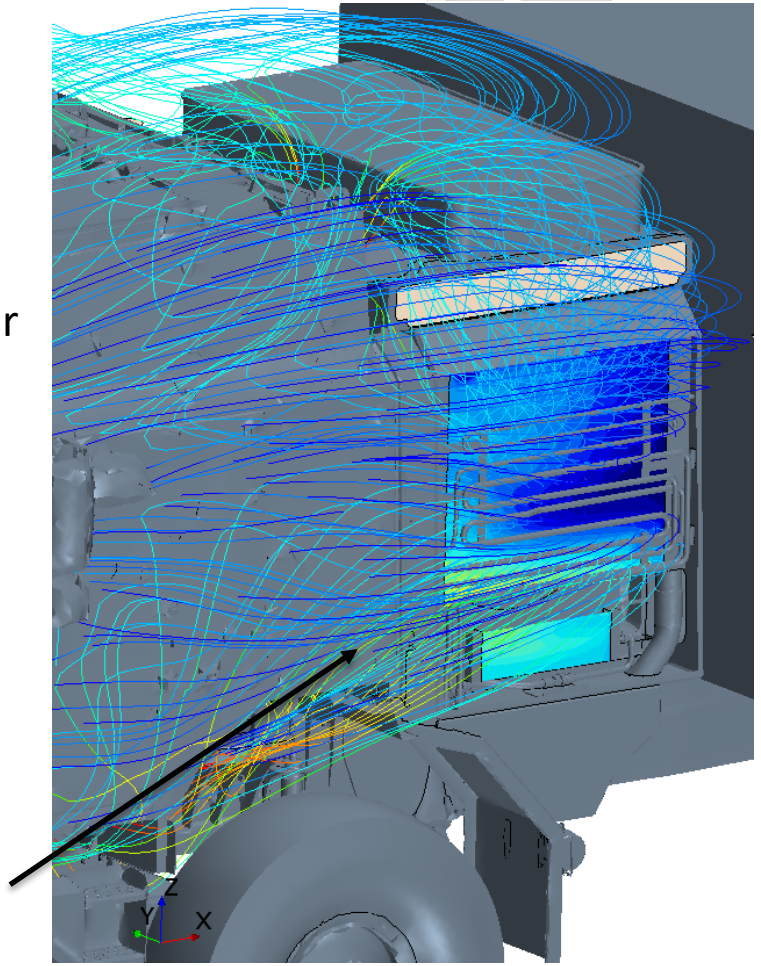
CFD Simulation Cold Flow

- Airflow Simulation without Energy Equation

- Benefit:
  - Find Shortcuts / Backflow -> suggestions for improvements (for example air guides or deflectors to reduce backflow)
  - Values of Backflow and air massflow are used in KULI Simulation



Massflow of air through the Cooling Package is needed to calibrate the KULI Model.



Backflow from Underhood will lead to higher air temperatures at the cooler.

That must be considered in the KULI simulation to get valid results.

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Source: MAGNA Powertrain, ECS Steyr

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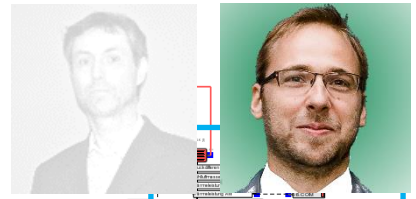
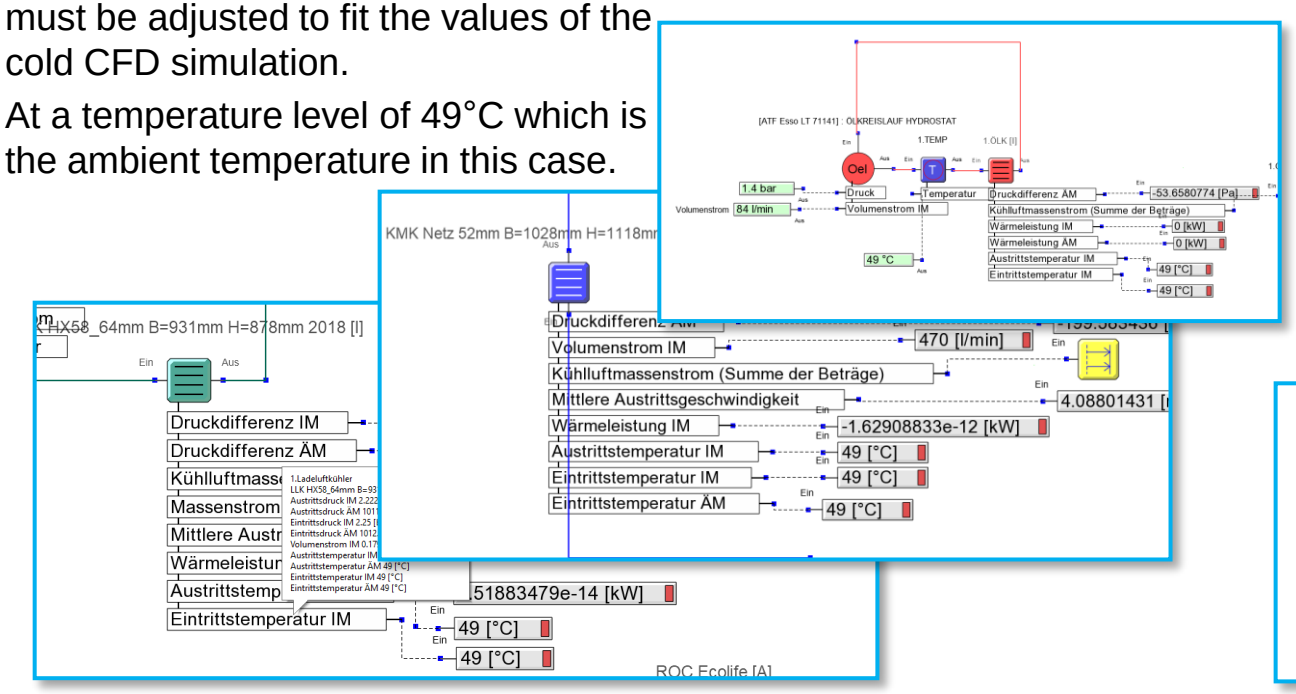


KULI Simulation Cold Flow

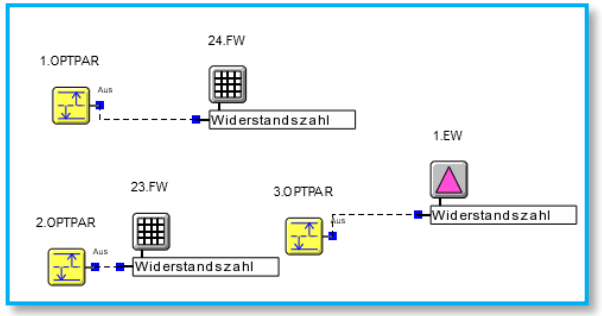
- Airflow Simulation without Energy Input
- Calibration of Airflow with Cold CFD Simulation

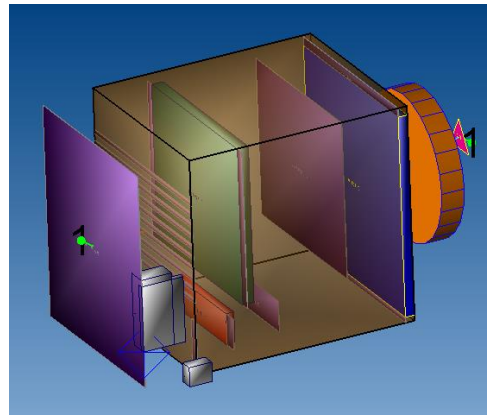
All the massflows through the coolers must be adjusted to fit the values of the cold CFD simulation.

At a temperature level of 49°C which is the ambient temperature in this case.



Resistances have to be adjusted, either manually or by KULI optimization until the air stream / massflow fits the cold CFD.





Source: MAGNA Powertrain, ECS Steyr

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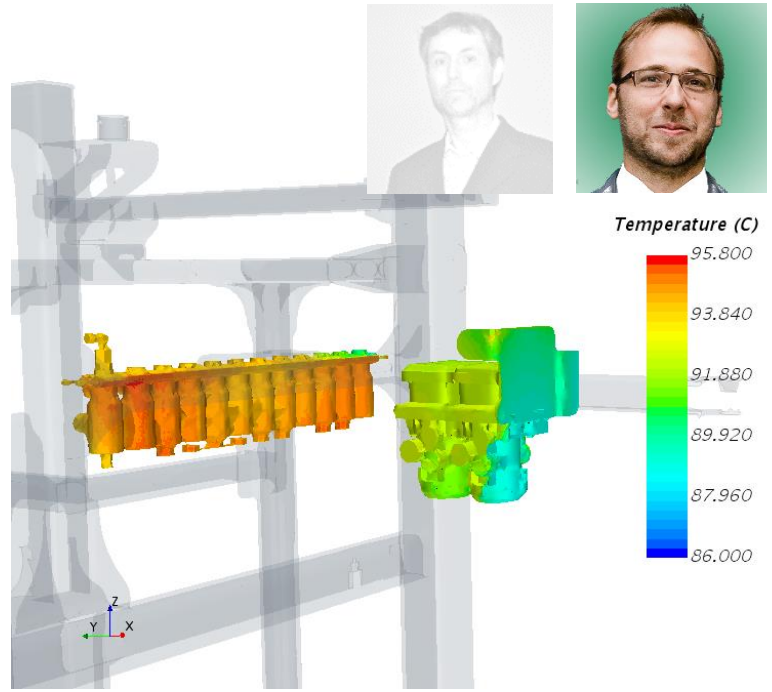
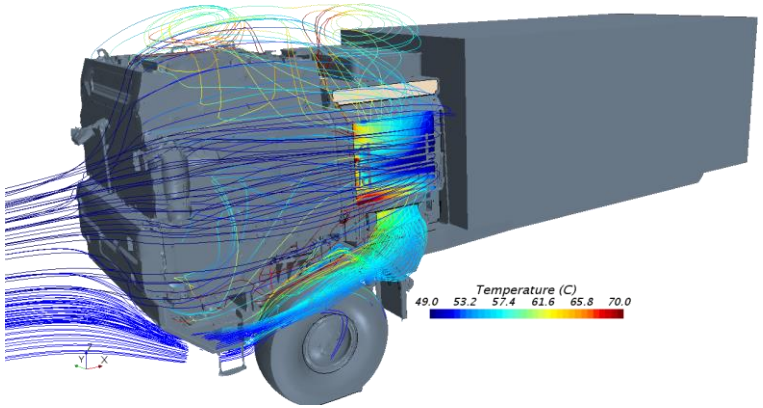
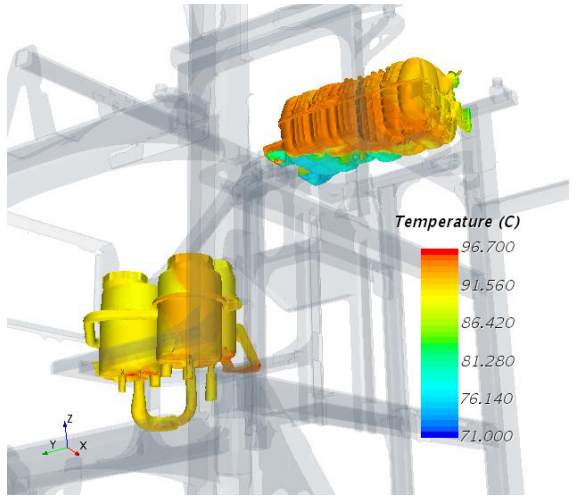
CFD Simulation Warm Flow

- Airflow Simulation with Energy Equation and Radiation Model

- Benefit:
  - Check if pneumatic and hydraulic parts are in proper places or have ot be moved.
  - Suggestions for heat shields or other actions can be handed over to the design engineers
  - Heat up temperature of Airflow into Cooling Package as input for warm KULI







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Source: MAGNA Powertrain, ECS Steyr

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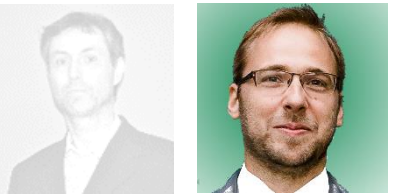
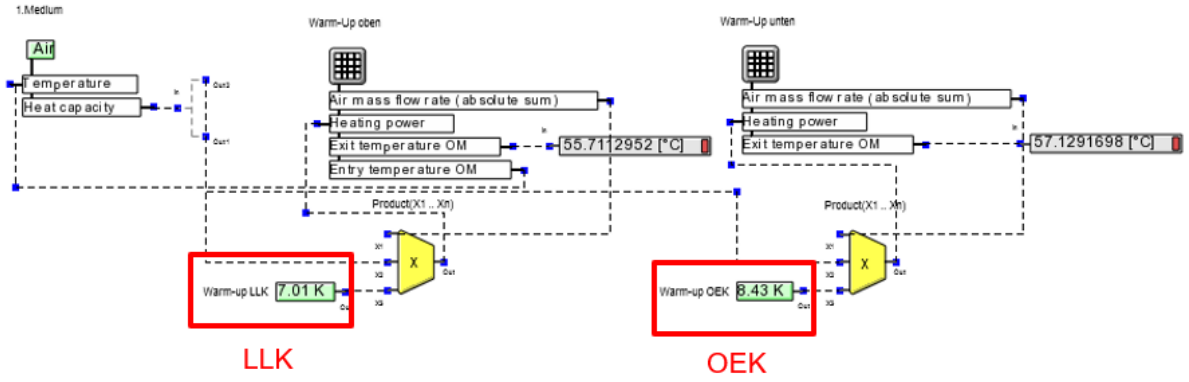


KULI Simulation Warm Flow

- Airflow Simulation with Energy input / Temperatures
- Simulation of inner and outer fluid Temperatures
- Optimization loops can be performed to find out proper settings for cooler size and fan speed.
- Power of Heat Exchanger for warm CFD (iterative loops)



Source: MAGNA Powertrain, ECS Steyr

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Workflow Overview

First Simulation Loop

Cold CFD → Air flow Data for design optimizations

Massflows
Backflow percentage

Cold KULI

Calibrated model

Part Temperatures for design optimization or replacement
Outer fluid Data
Massflow, temp., …

Warm CFD

Heat up temp. cooling package
Power Input for warm cfd

Warm KULI → Inner fluid Data
Massflow, temp., …

Second Simulation Loop

Cold CFD

Cold KULI

Warm CFD

Warm KULI

Further Loops…

In the Euro 6 case, there was performed 5 simulations loops.

A 6th loop was done to validate the KULI/CFD Simulation with the measurements

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Source: MAGNA Powertrain, ECS Steyr

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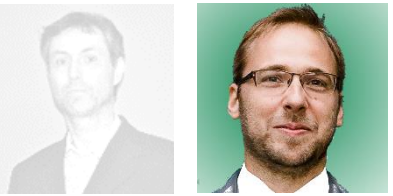

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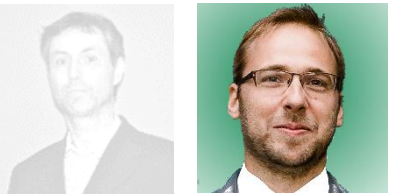

RMMV Test bench setup (at MAN test site Munich)

Topics of the test bench measurements:

- Pmax at 49°C analog ECS simulation
- Mmax at 49°C analog ECS simulation
- Customer-specific test cycle at 49°C

Therefore 72 measuring points (temperature, pressure, flow rate) were installed (e.g. to measure the temperature and the flow rate of the coolant before and after the radiator; to measure the surface temperature of the air dryer in the cooling rig, etc…)

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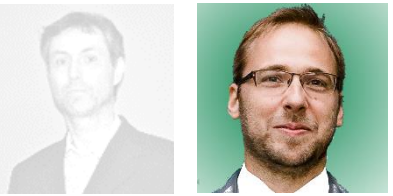

Boundary Conditions

Boundary conditions from measurements

Ambient temperature 49°C
Ambient pressure 1013hPa
Fan RPM 1950 1/min
Water volume flow total 446.7 l/min
Water Volume Flow VGOC 25.8 l/min

Additional measurement data:

T_KMK_water_inlet 99.9°C
T_KMK_water_outlet 92.2°C
T_TOC_water_inlet 97.2°C
T_TOC_water_outlet 97.8°C

T_CAC_chargeair_inlet 225.1°C
P_CAC_chargeair_inlet 3.13 bar
M_CAC_chargeair_inlet from previous KULI model
T_CAC_chargeair_outlet 54.4 °C

For further improvement there was executed a sixth loop to validate Measurement and Simulation.

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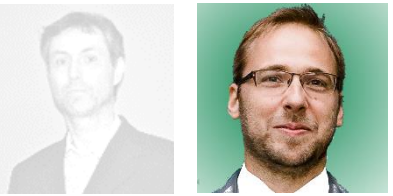

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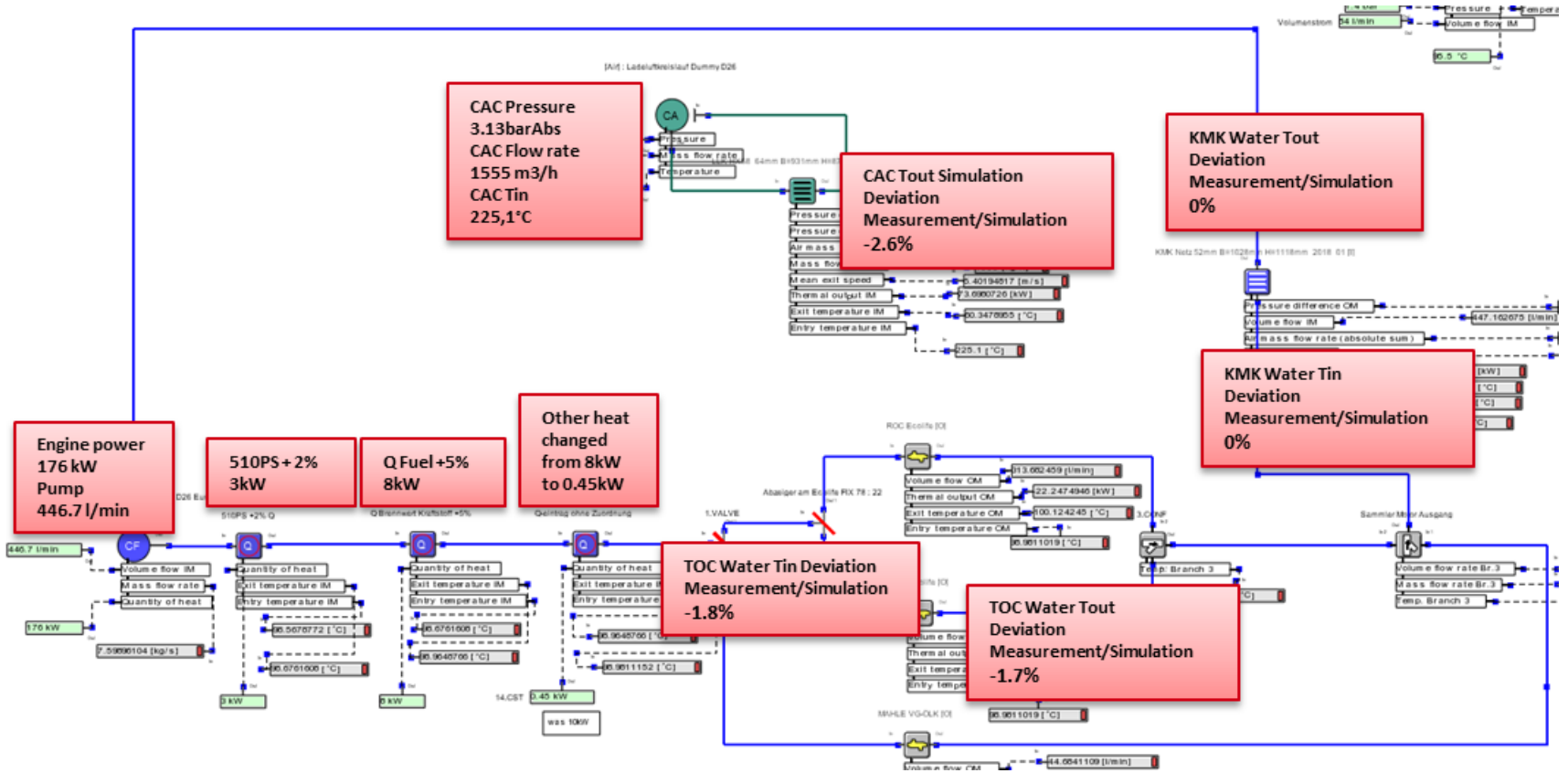
Validation temperatures inner Medium (Charge Air, Water)



Heat Input value was adopted to the measurement conditions.

Values in a range of 3%

Measurement slightly cooler than simulation.

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Source: MAGNA Powertrain, ECS Steyr

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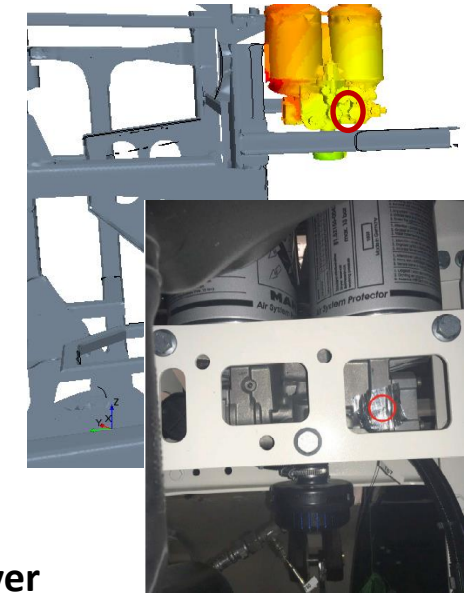
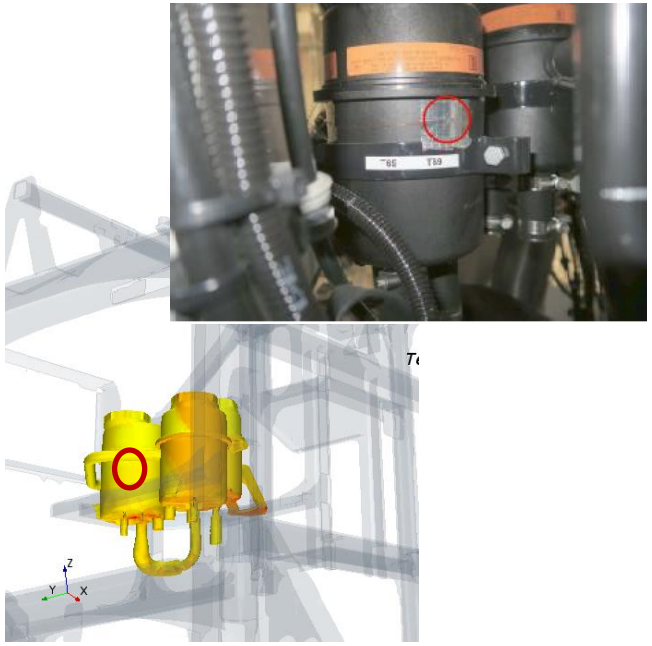
Validation Parts

Good fitting of Part temperatures

Values in a Range of 2%

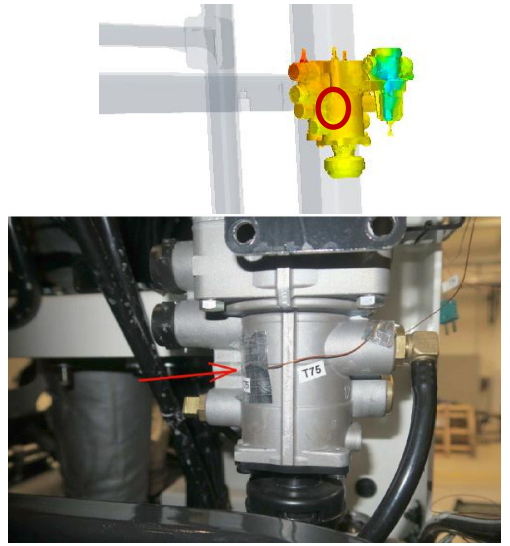


Air dryer
Deviation
Measurement/Simulation -0.3%



Oil Tank
Deviation
Measurement/Simulation -1,3%

Control Valve
Deviation
Measurement/Simulation -0.5%



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Conclusion / useful benefits for RMMV

- ✓ The combined CFD / KULI workflow helps RMMV to find the right solutions for the cooling system and the optimized placement of components in the cooling rig in new projects before hardware (the truck) will be built.

- ✓ The real vehicle test validates the theoretical simulation results and leeds to an official confirmation – big design changes in advanced project phases can be avoided.

- ✓ The combined CFD / KULI workflow helps RMMV to reduce the loopbacks at the test bench.

- ✓ Due to the calibration of the ECS Simulation regarding to the test bench results (especially in the Euro VId project) the following CFD / KULI simulations for other projects will be more proper.

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PASSION FOR **TECHNOLOGY.**