The KULI 4 mass engine model on the (engine-) test rig

- a progress report

Kai Gonet

Gesellschaft für numerische Simulation
D-38114 Braunschweig
gonet@gns-mbh.com

Dr. Christoph Lund

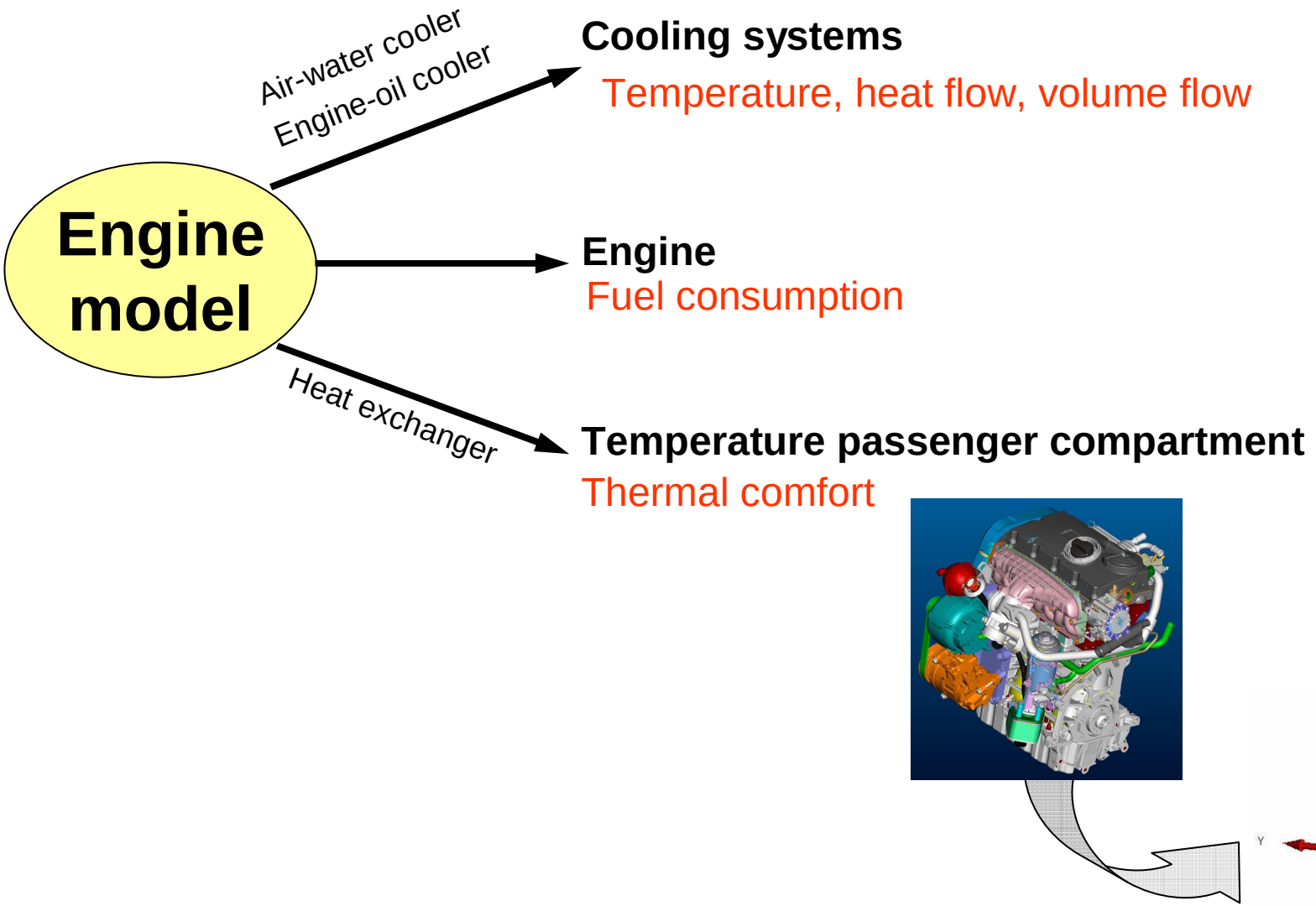
Volkswagen AG
Technische Entwicklung
D-38436 Wolfsburg
christoph.lund@volkswagen.de

Agenda

- Introduction
- The 5 steps to „happiness“ – the engine model
    1. Getting the input data
    2. Engine and test rig equipment
    3. The engine at steady states → the heat map
    4. Driving transient → the load steps
    5. Auto adjustment of the engine model
- Comparison of measurement and simulation data
- Conclusion / Outlook

Introduction

Why constructing an engine model?



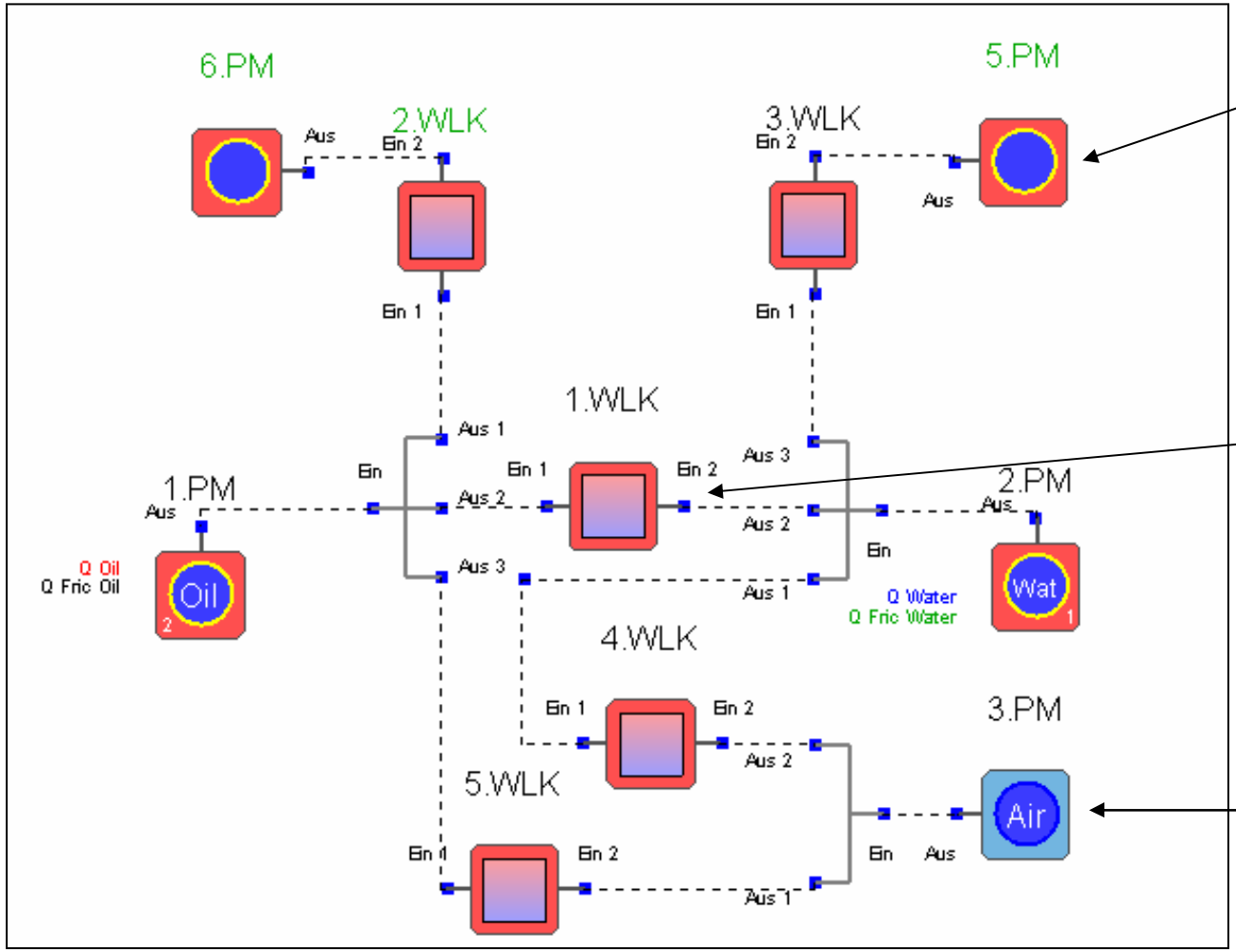
Introduction

Requirements concerning the engine model

- Analysing stationary and transient effects on engine ☐
- Simulation of cold start and warming up ☐
- Prediction of fuel consumption ☐
- Integration / coupling with other models ☐
- Easy calibration ☐

Introduction

The advanced KULI engine model



4 masses

- water direct
- water indirect
- oil direct
- oil indirect

5 „k* A“-values
heat transfer coefficients

ambient air

Getting the input data

The engine / the vehicle

Engine Data:

- Engine power: 103kW
- Cylinder capacity: 1968 cm³
- 4V
- Euro Norm 4
- Unit-injector system (Pumpe-Düse)
- TDI

Car Data:

- Golf, 5th generation
- Without DPF
- Standard components from series production
- Gearbox: DSG ®

Getting the input data

Data for the KULI engine model

Engine general data

– Cylinder capacity, number of cylinder banks

Material data

– Fuel, coolant, oil, air

Enviroment

– Air flow velocity and temperature for engine surfaces

Thermal capacity (k*A)

– Water - oil, water - engine, oil - engine

Coefficient of thermal part of loss

– Drag operation, steady state load points

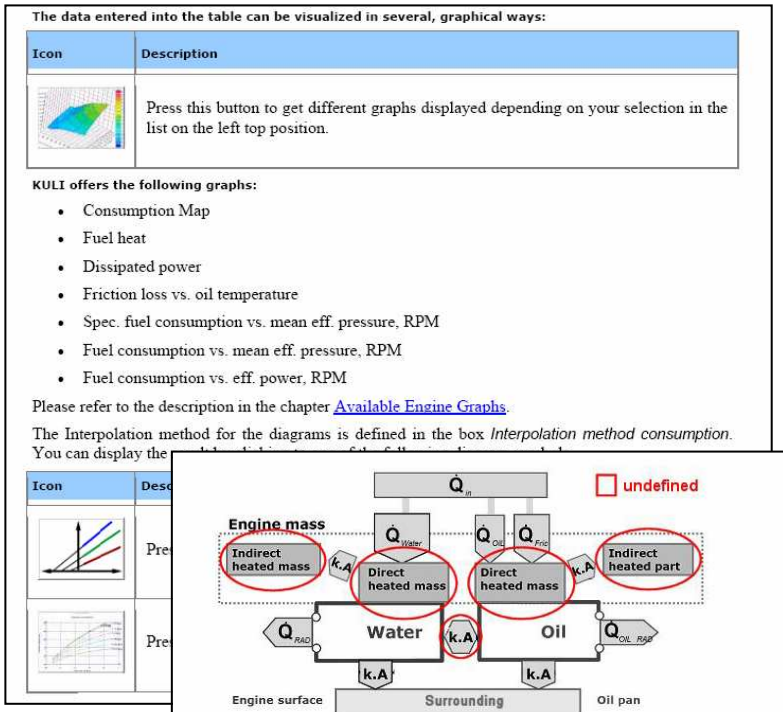
Engine loss

– Fuel consumption maps from Willans characteristics

– Drag torque characteristics

Heat map

– Maps of exported heat and temperature for water and oil



The data entered into the table can be visualized in several, graphical ways:

Icon	Description
	Press this button to get different graphs displayed depending on your selection in the list on the left top position.

KULI offers the following graphs:

- Consumption Map
- Fuel heat
- Dissipated power
- Friction loss vs. oil temperature
- Spec. fuel consumption vs. mean eff. pressure, RPM
- Fuel consumption vs. mean eff. pressure, RPM
- Fuel consumption vs. eff. power, RPM

Please refer to the description in the chapter Available Engine Graphs.

The Interpolation method for the diagrams is defined in the box *Interpolation method consumption*.

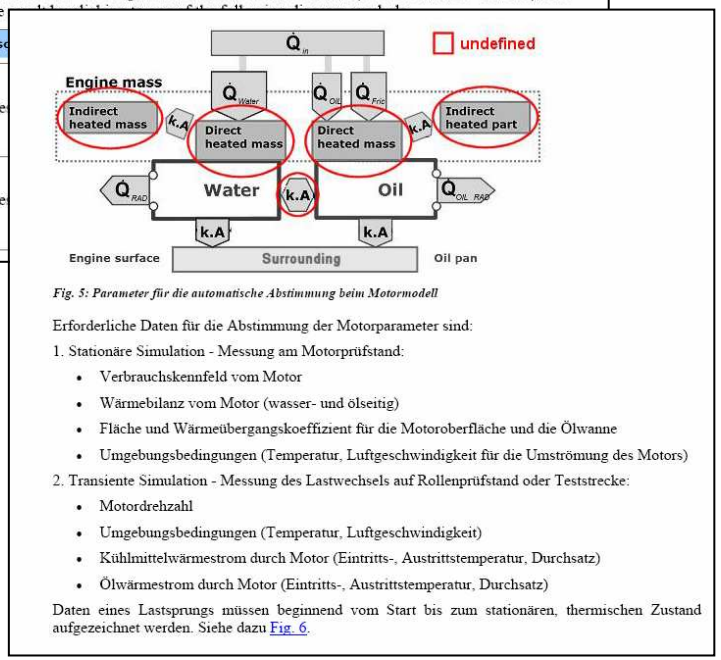


Fig. 5: Parameter für die automatische Abstimmung beim Motormodell

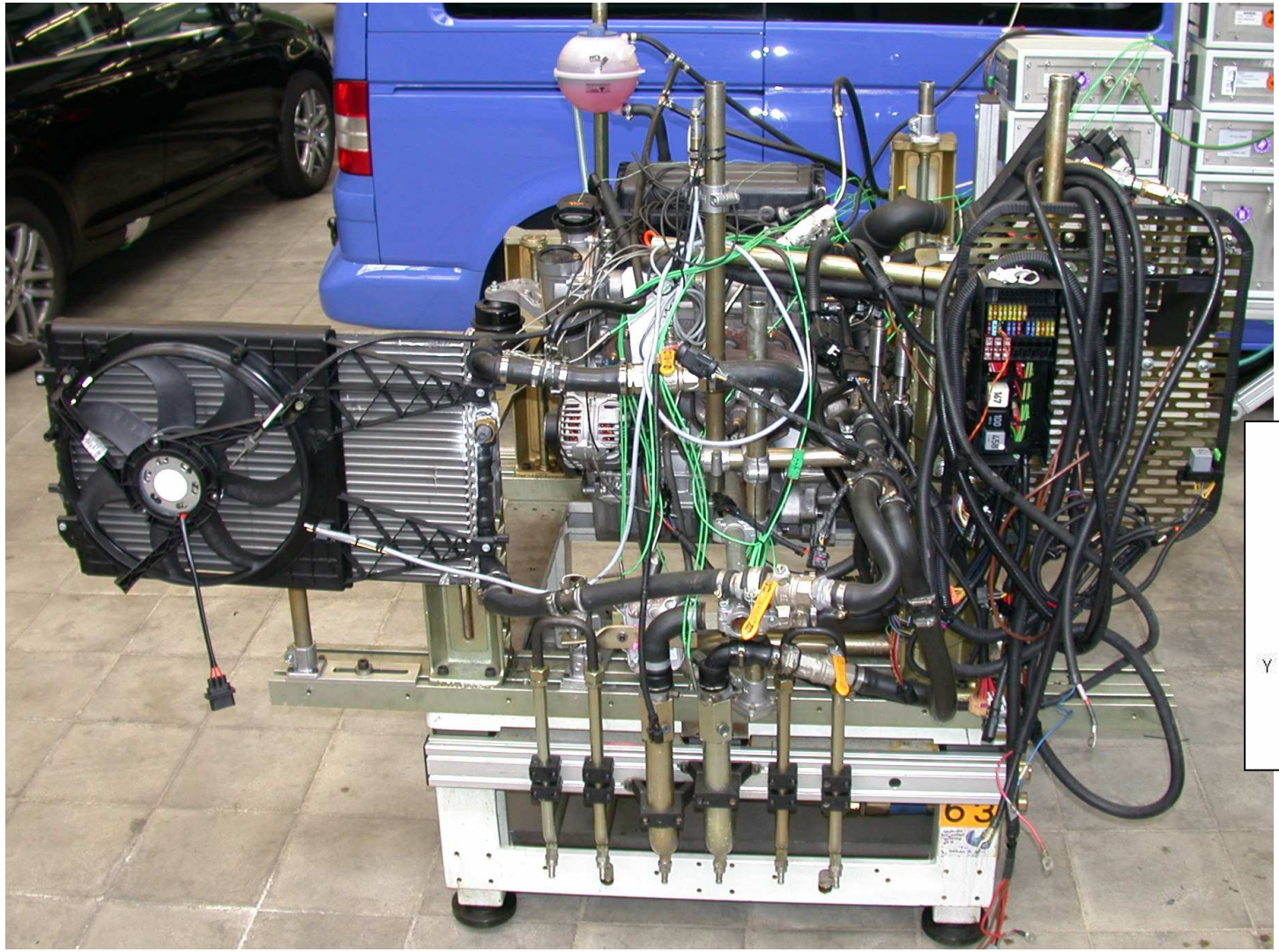
Erforderliche Daten für die Abstimmung der Motorparameter sind:

1. Stationäre Simulation - Messung am Motorprüfstand:
   - Verbrauchskennfeld vom Motor
   - Wärmebilanz vom Motor (wasser- und ölseitig)
   - Fläche und Wärmeübergangskoeffizient für die Motoroberfläche und die Ölwanne
   - Umgebungsbedingungen (Temperatur, Luftgeschwindigkeit für die Umströmung des Motors)
2. Transiente Simulation - Messung des Lastwechsels auf Rollenprüfstand oder Teststrecke:
   - Motordrehzahl
   - Umgebungsbedingungen (Temperatur, Luftgeschwindigkeit)
   - Kühlmittelwärmestrom durch Motor (Eintritts-, Austrittstemperatur, Durchsatz)
   - Ölwärmestrom durch Motor (Eintritts-, Austrittstemperatur, Durchsatz)

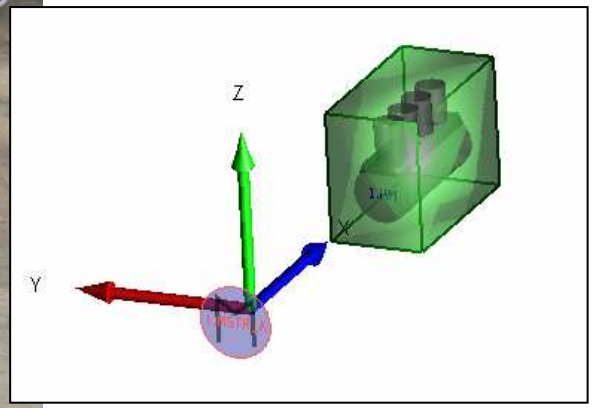
Daten eines Lastsprungs müssen beginnend vom Start bis zum stationären, thermischen Zustand aufgezeichnet werden. Siehe dazu Fig. 6.

Engine and test rig equipment

Engine palett for test rig



A typical real engine on a palett

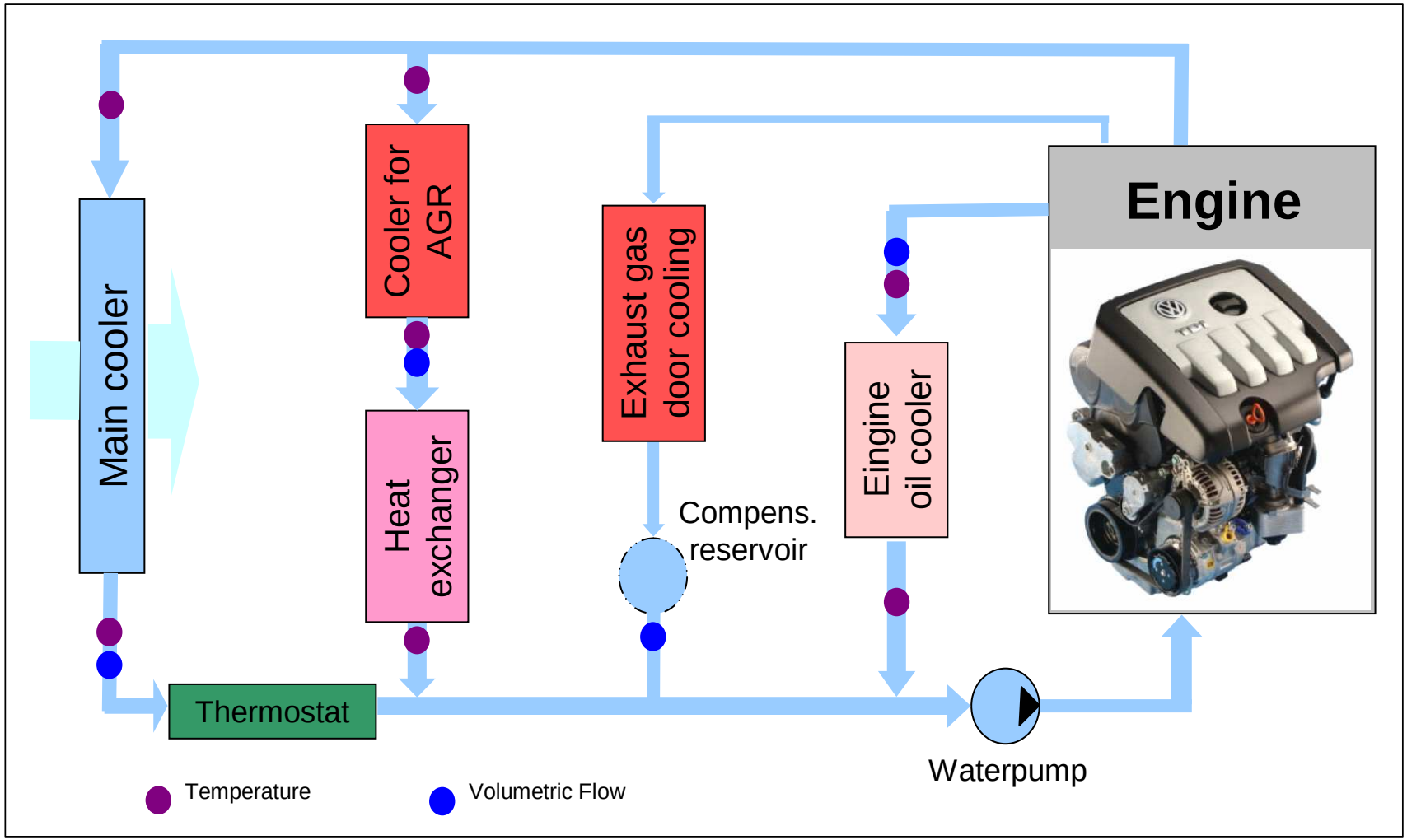


The real engine model

Engine and test rig equipment

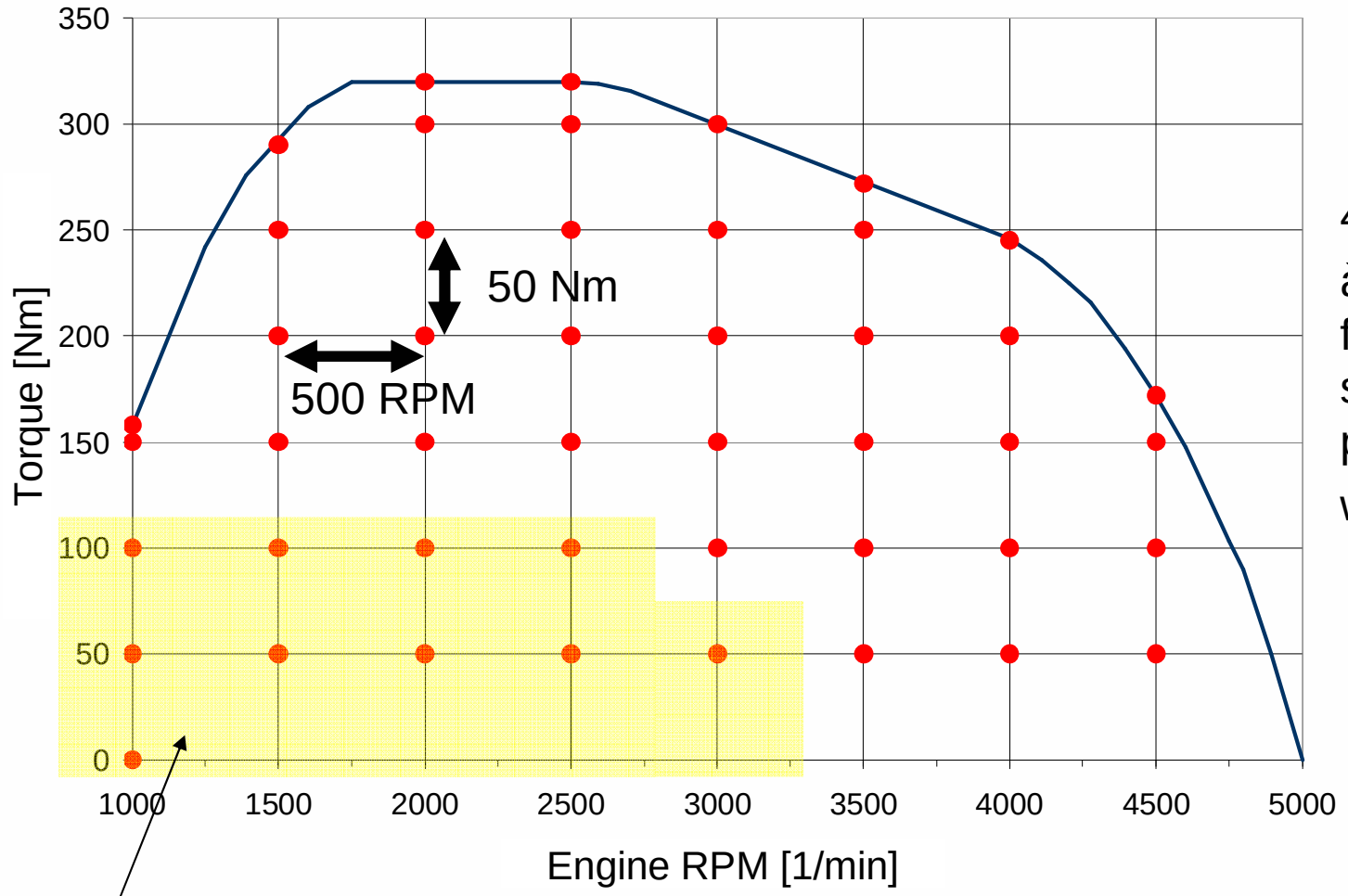
Equipment - the water circuit

:



The engine at steady states

Used load cases for steady states



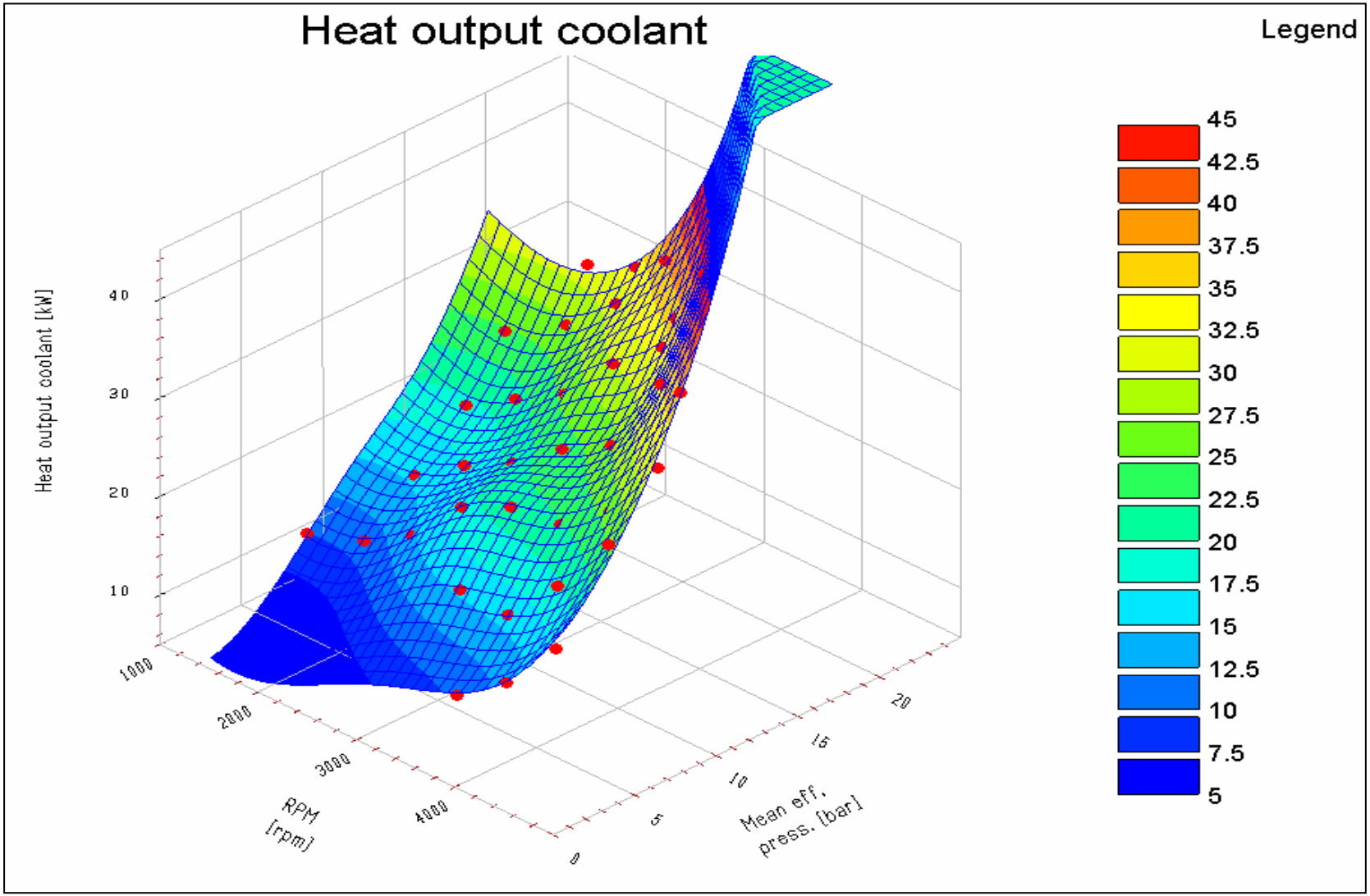
46 points;

à 30 min for steady state with preconditioned water-water-cooler

data we excluded due to failed measurement; uncertain temperature difference on oil side

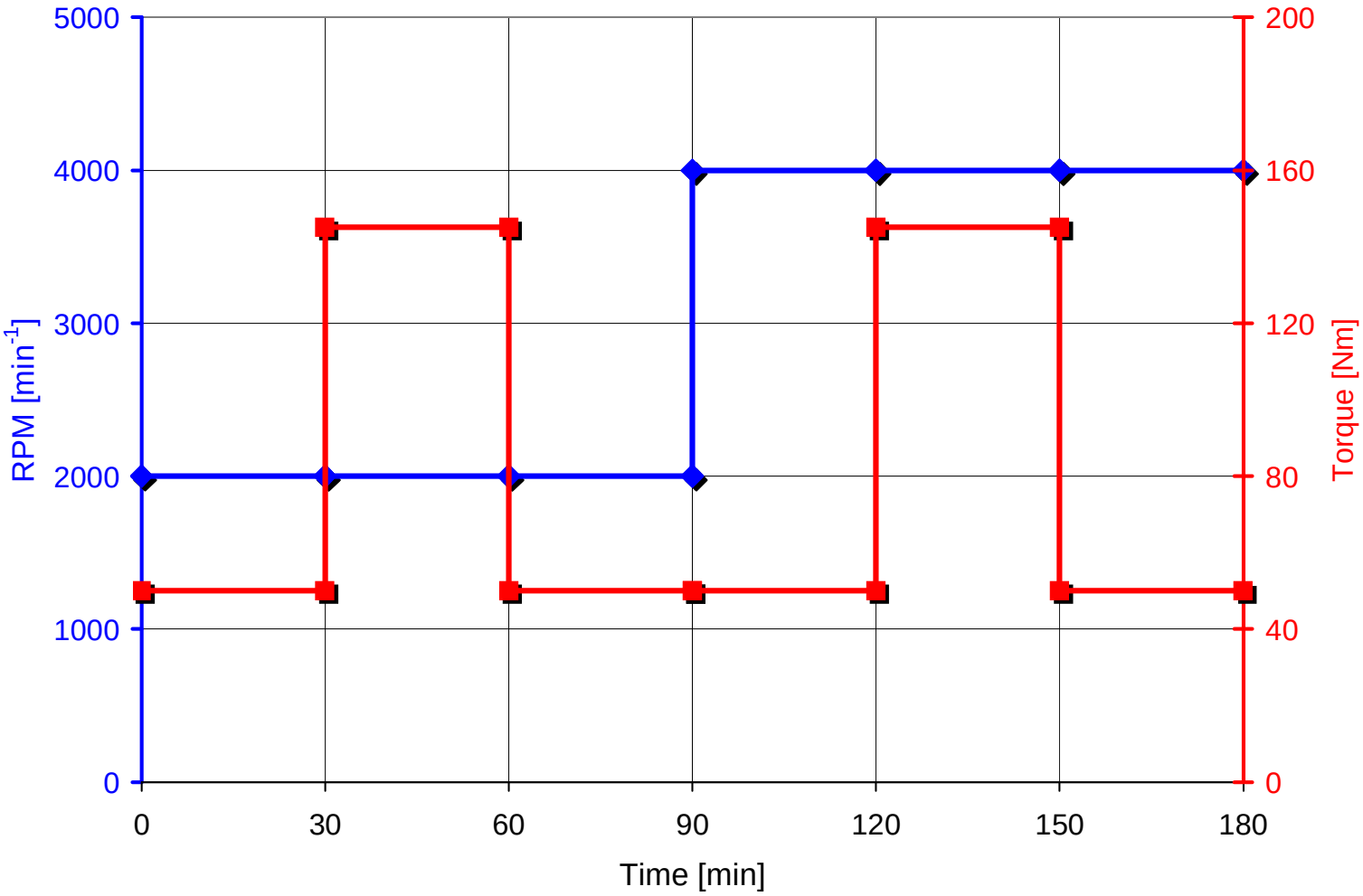
The engine at steady states

Heat map for steady state condition



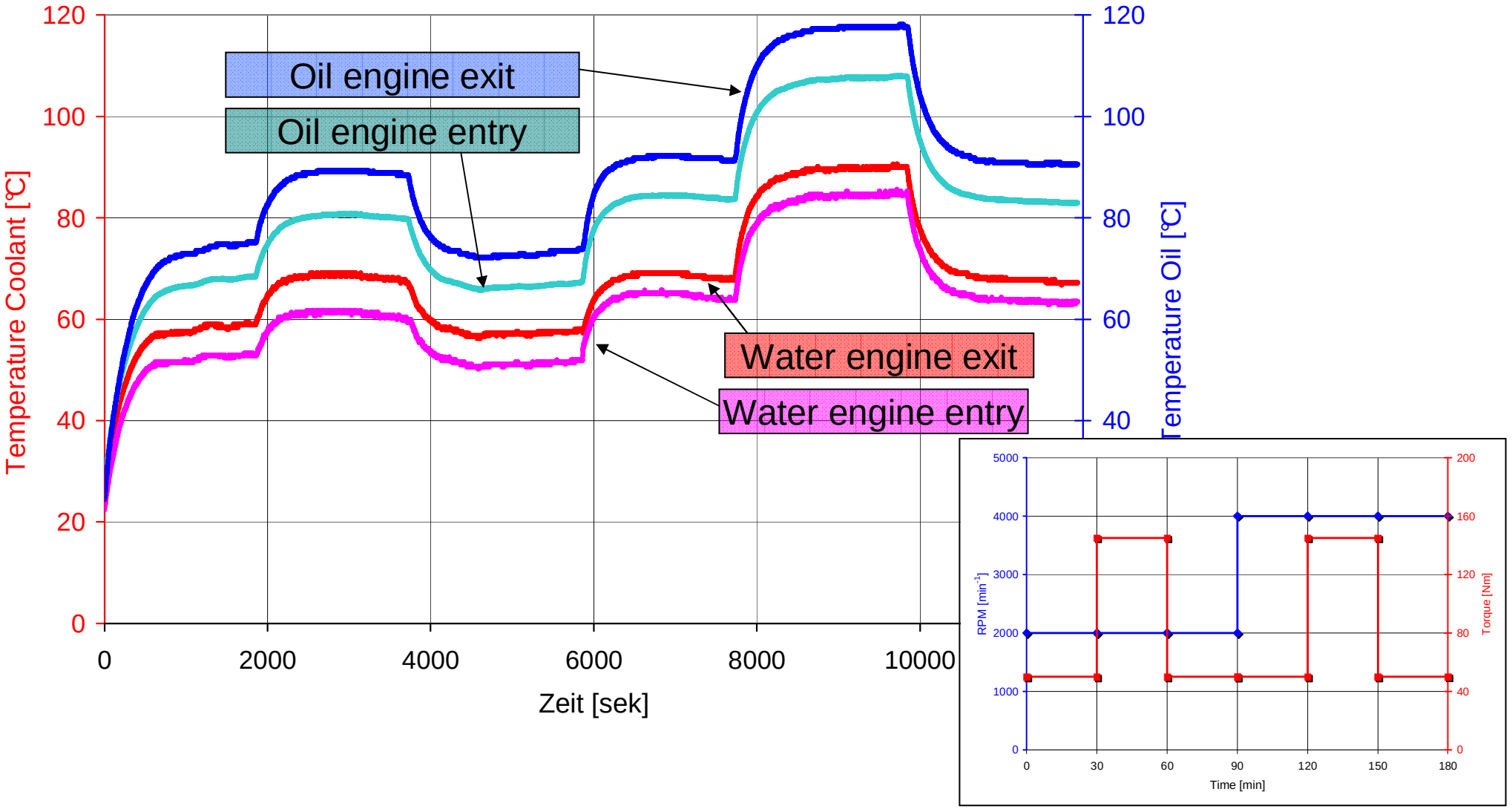
Driving transient

Transient loadcases



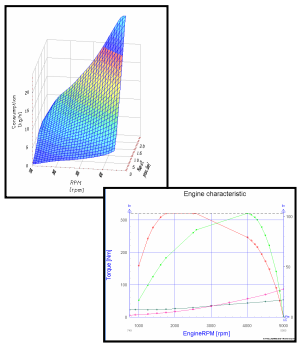
Driving transient

Characteristic curve for coolant and oil temperature of engine



Auto adjustment of the engine model

How to auto adjust – a flowchart



General engine data
General data load step

Consumption map

Engine characteristics:
-Max. engine torque
-Drag torque

Heat map: Oil and water

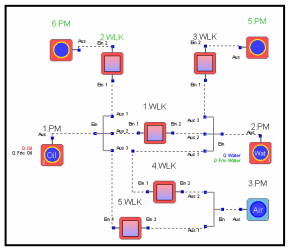
Interpolation Method okay?

no

yes

Measured data from load step

Creating: advanced engine model



Setting masses

Setting heat coefficients

Setting components for autoadjustement

Auto Adjustment okay?

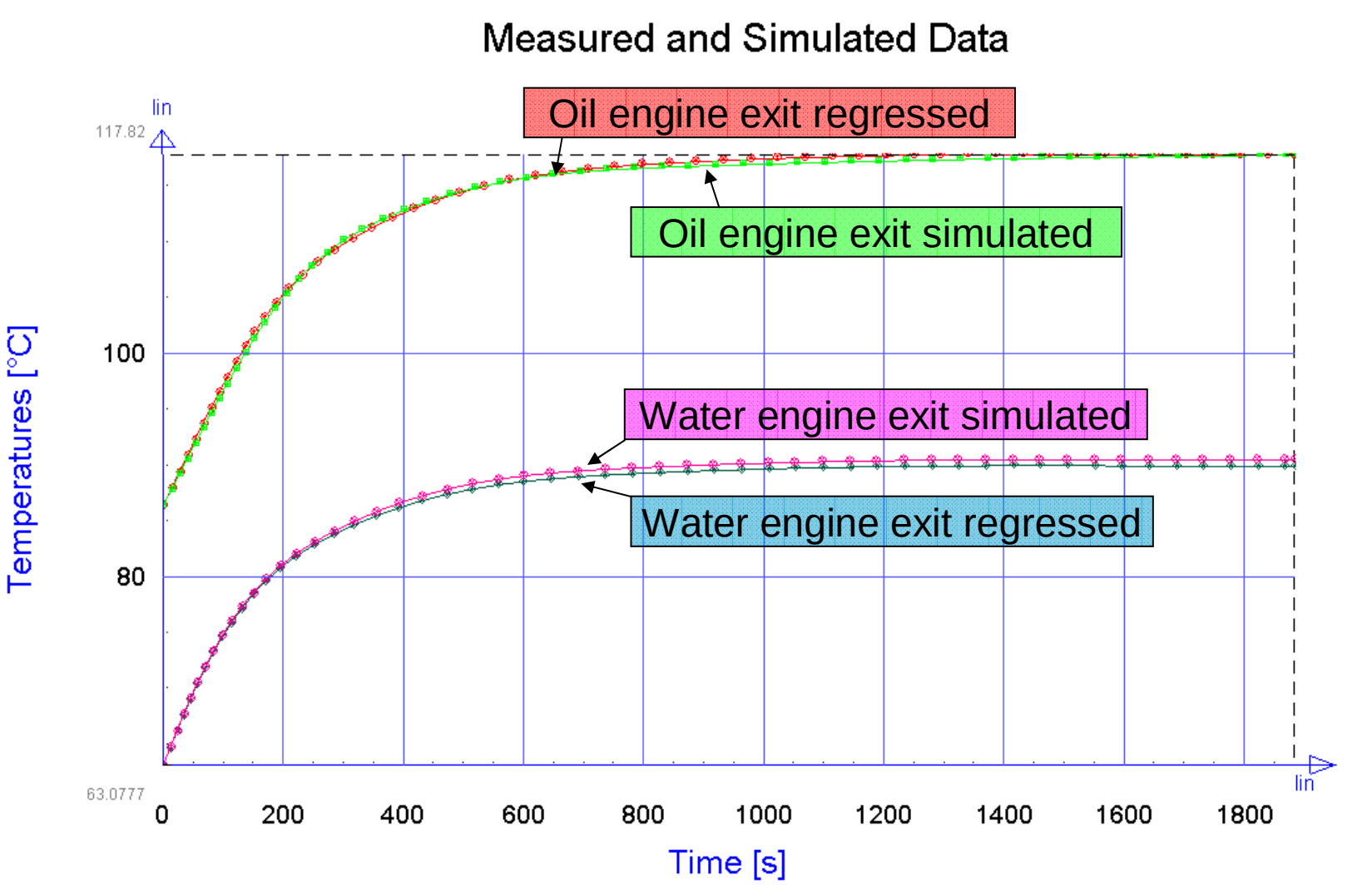
no

yes

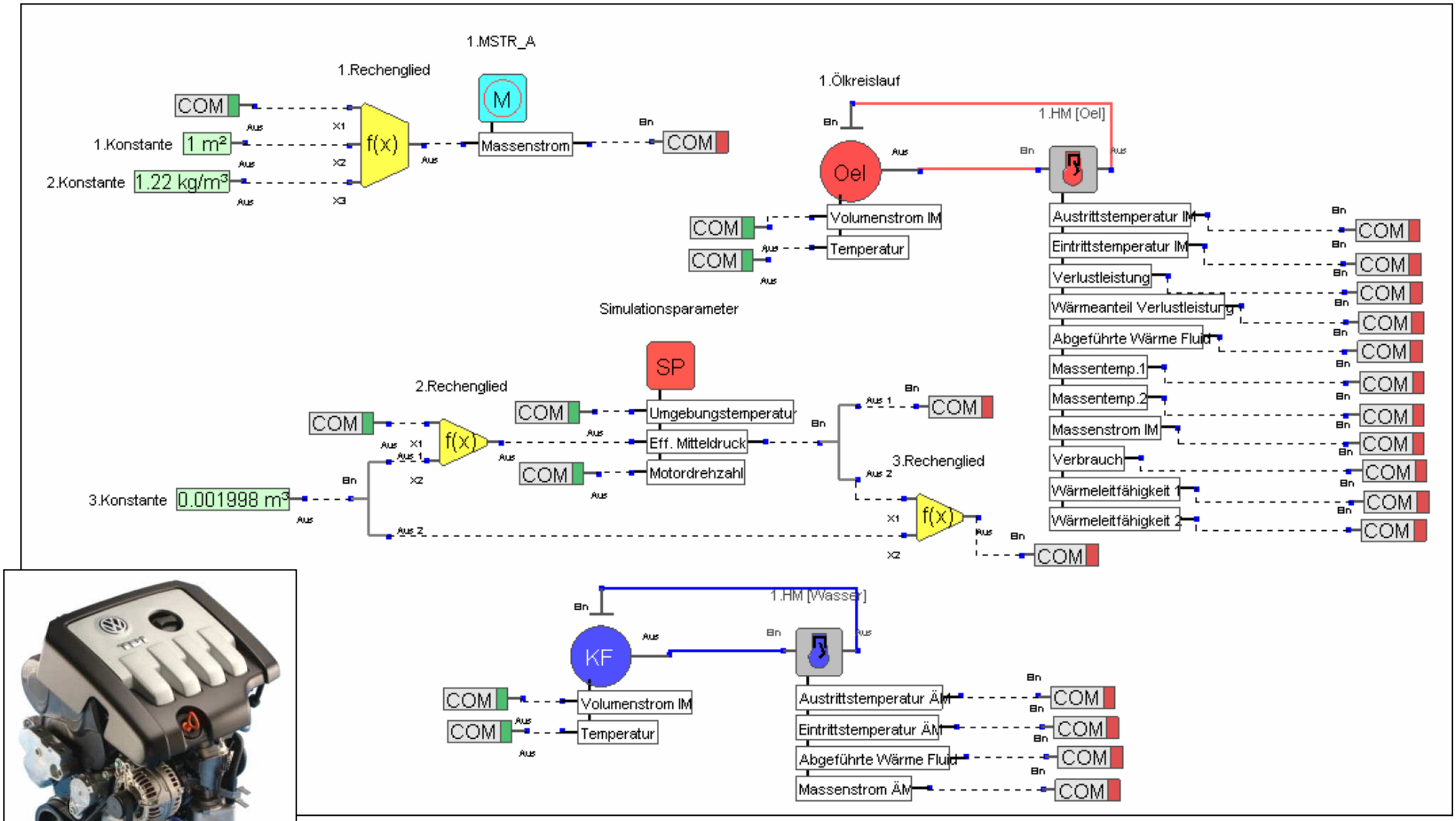
engine model ready to use ☺

Auto adjustment of the engine model

Data after calibration (temperature)



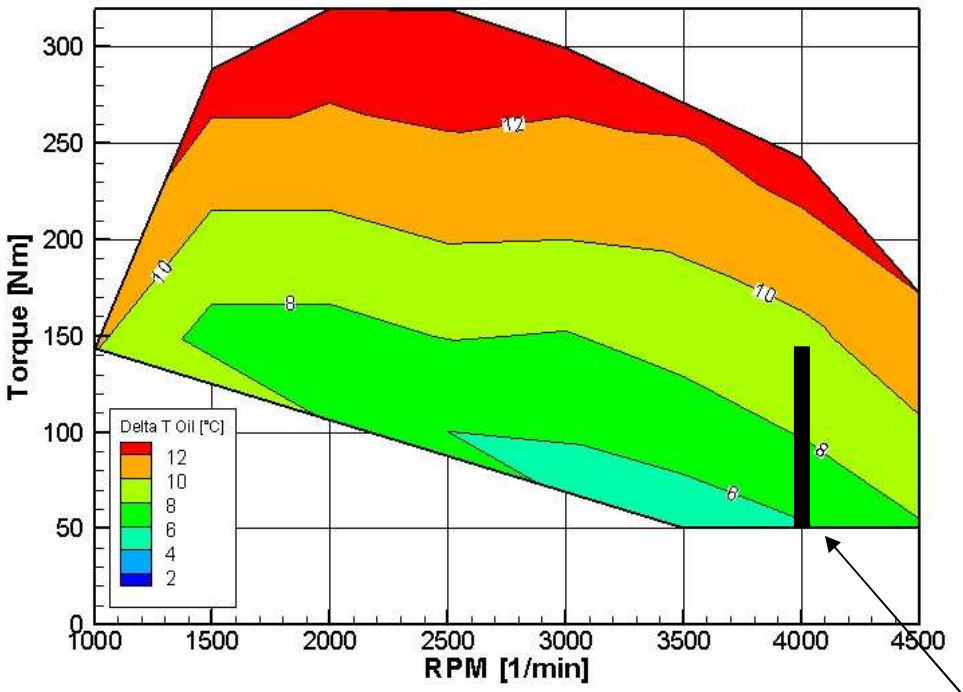
Finally – a simulation model for the 2.0l 103kW engine



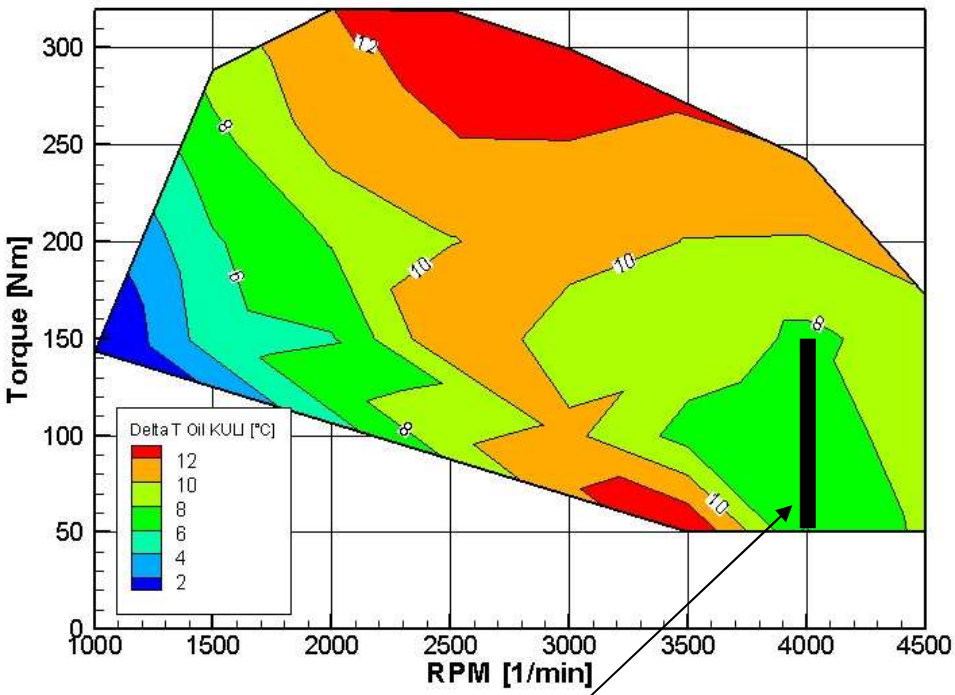
Comparison of measurement and simulation data

KULI engine model computes steady state heat map / temperature difference

Measurement



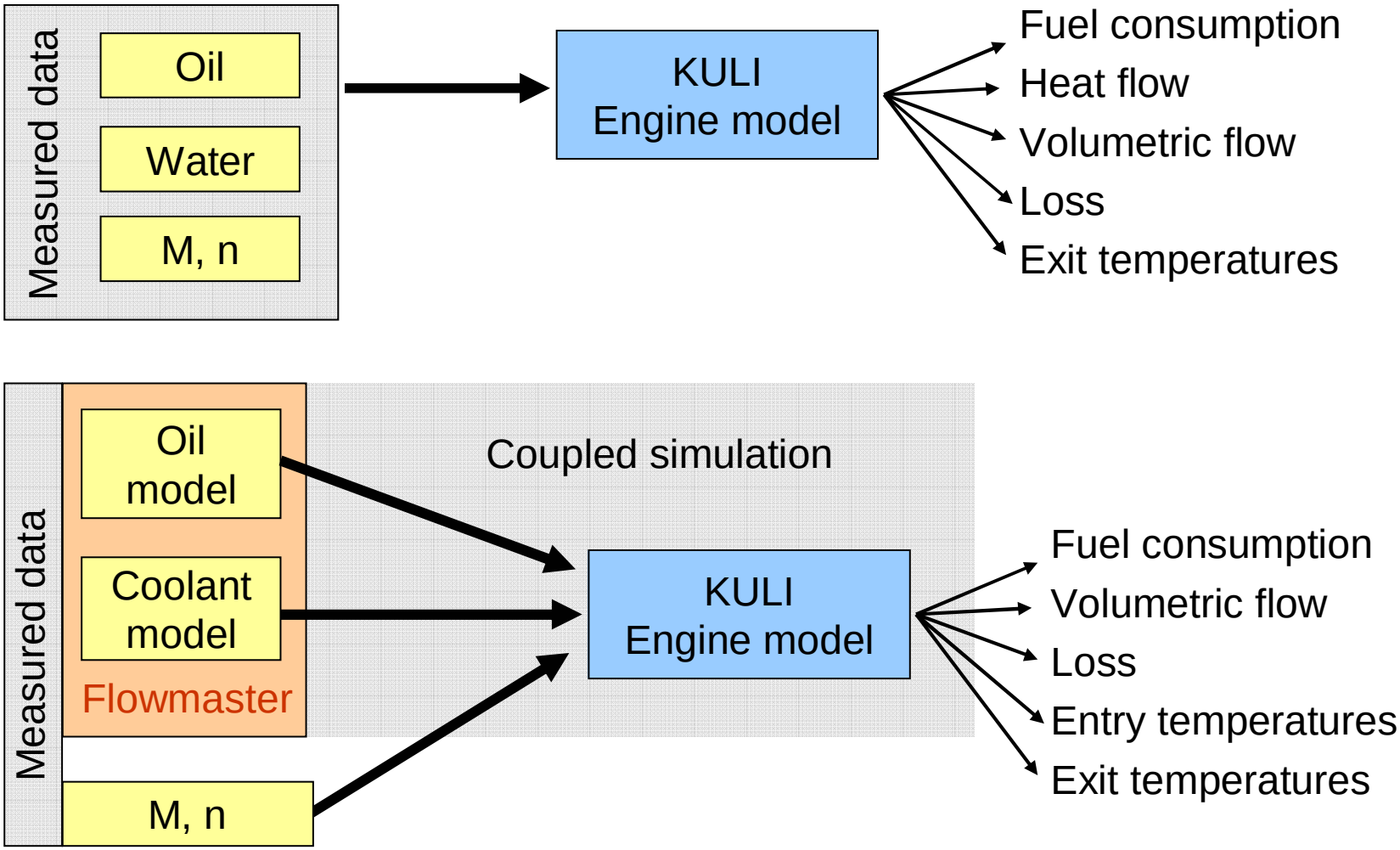
Simulation



Section, where engine model was calibrated

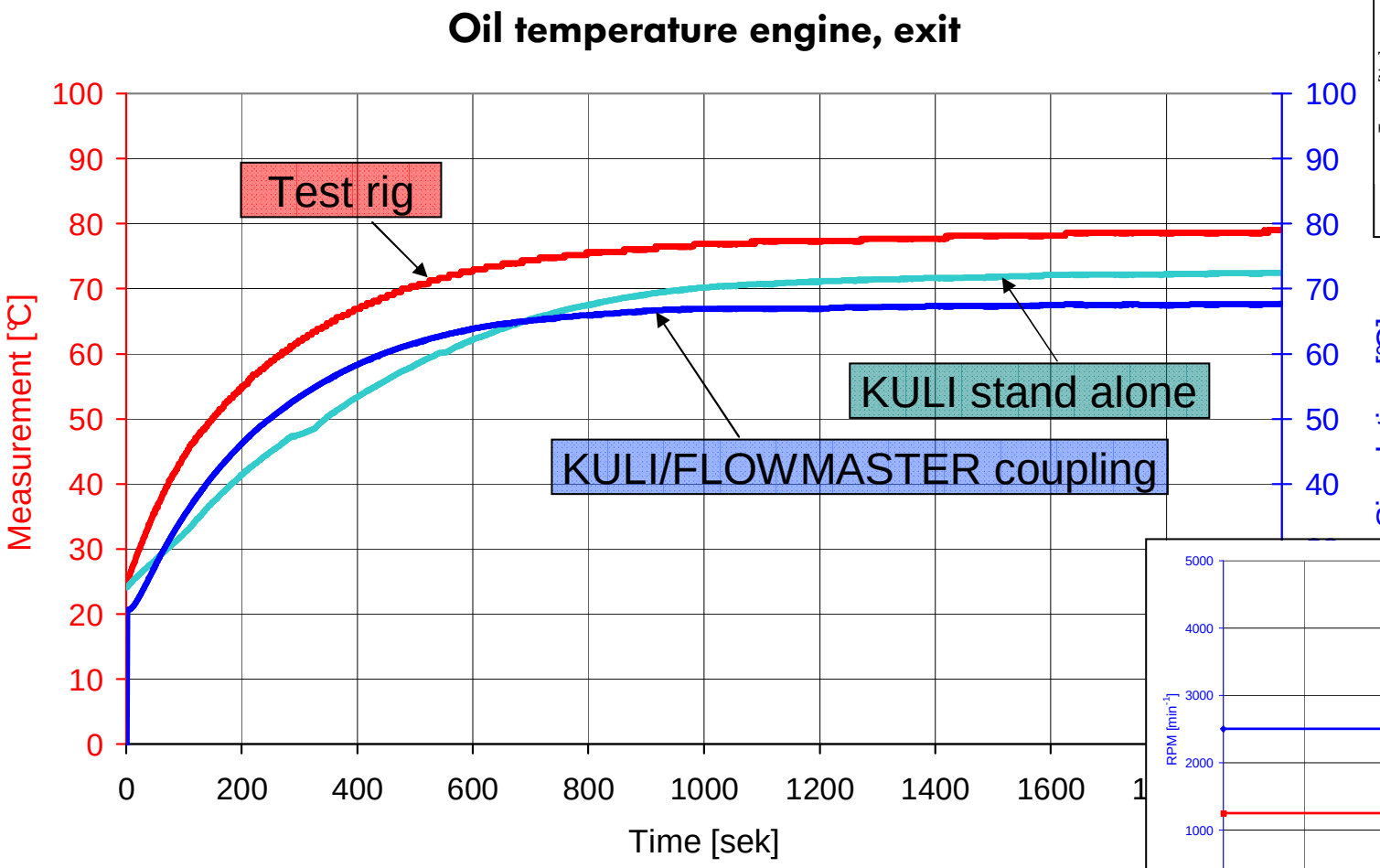
Comparison of measurement and simulation data

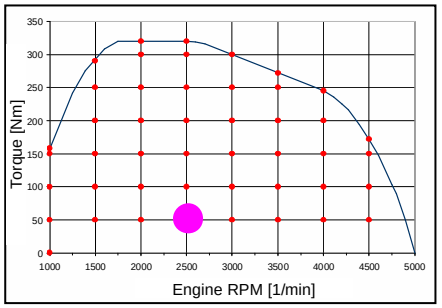
KULI engine model computes transient load case

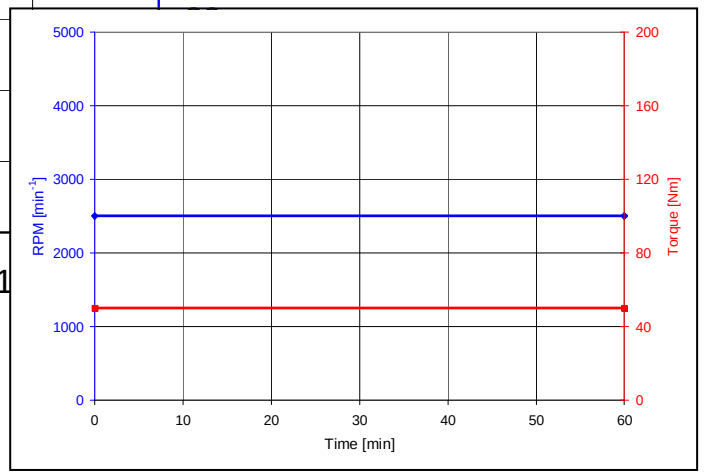


Comparison of measurement and simulation data

Comparing model and reality – Oil temperatures

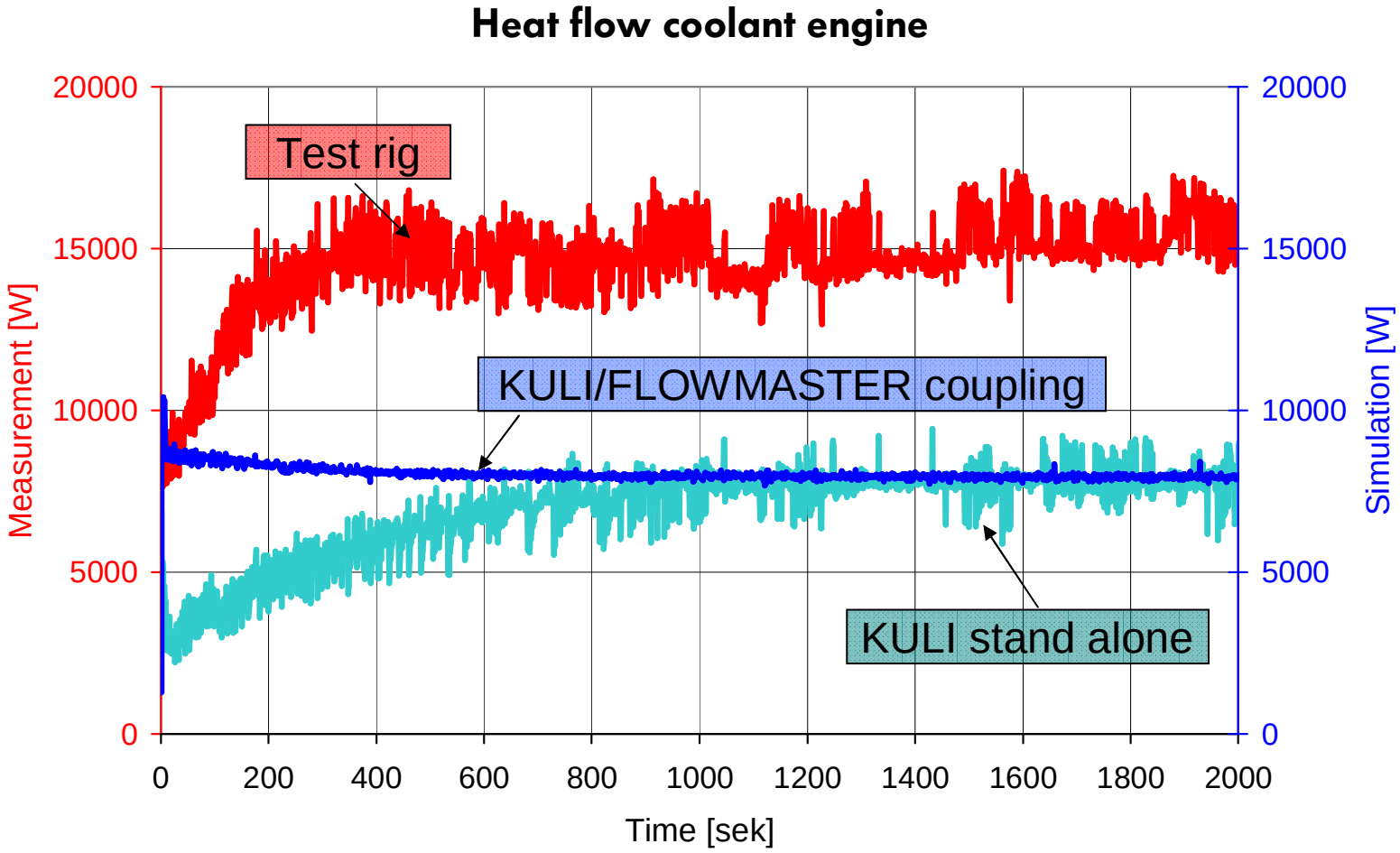






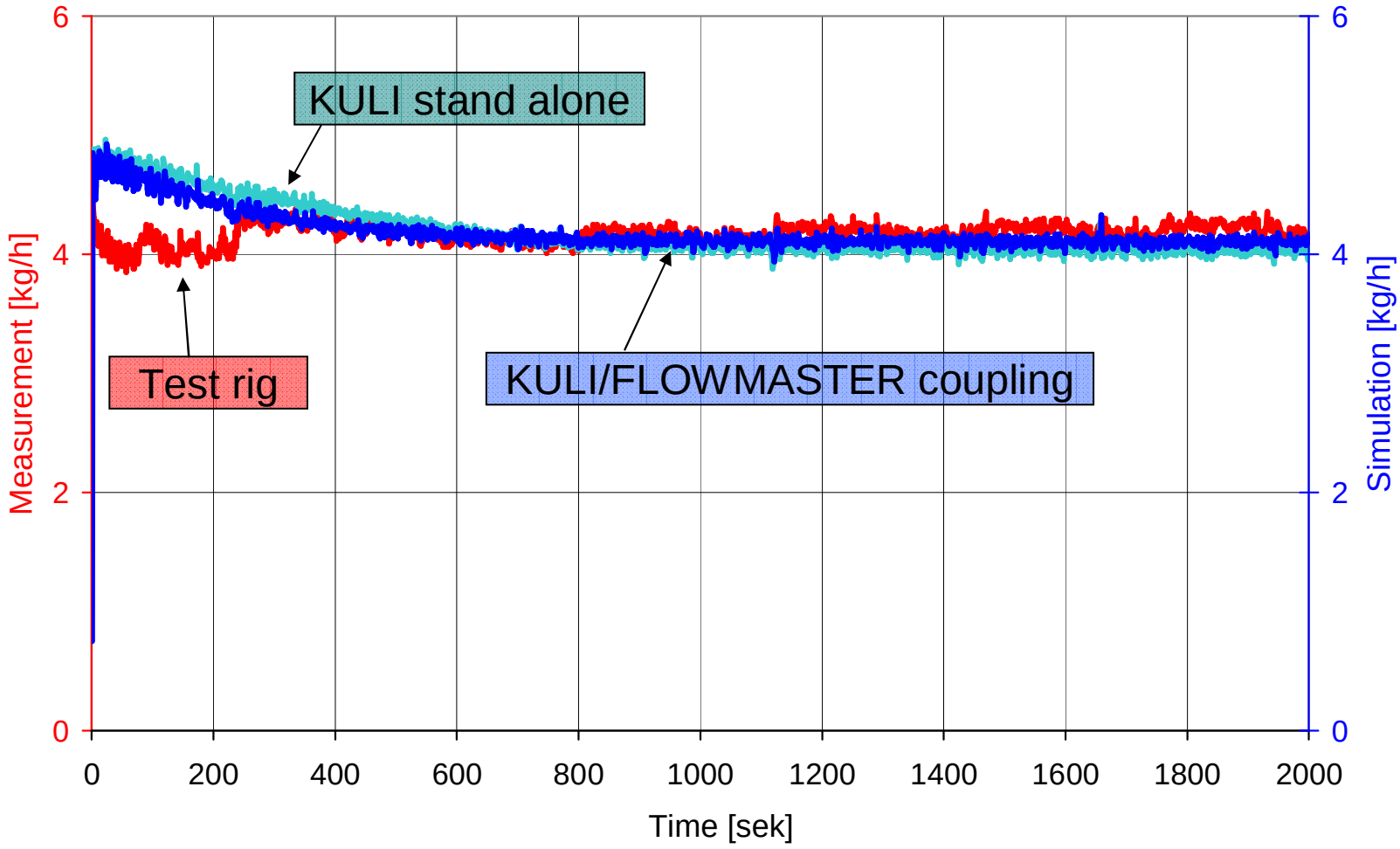
Comparison of measurement and simulation data

Comparing model and reality – Heat flow coolant



Comparison of measurement and simulation data

Comparing model and reality – Fuel consumption



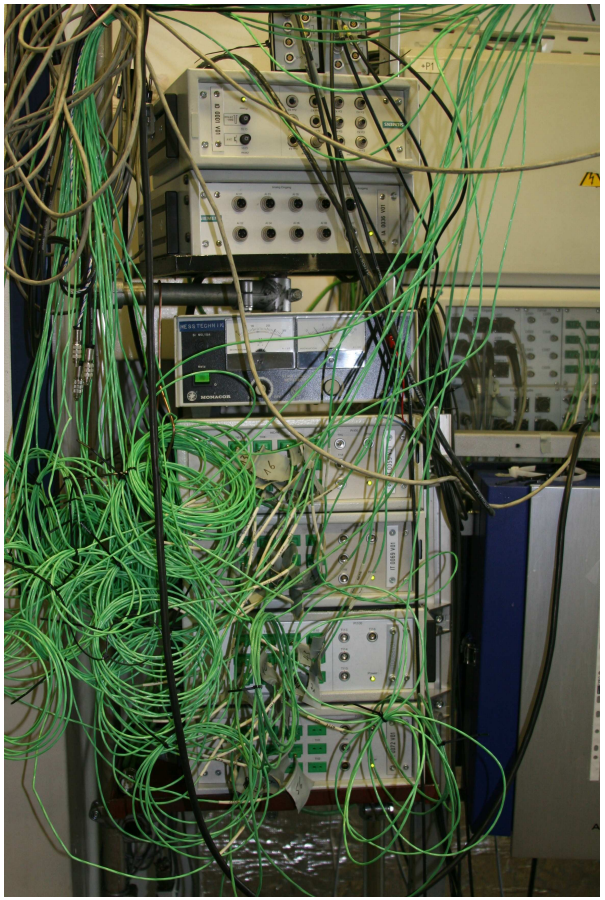
Conclusion

Our requirements concerning the engine model – and our experience

- Analysing stationary and transient effects on engine 
- Simulation of cold start and warming up 
- Prediction of fuel consumption 
- Integration / coupling with other models 
- Easy calibration 

Conclusion

Our experiences while woking with the engine model



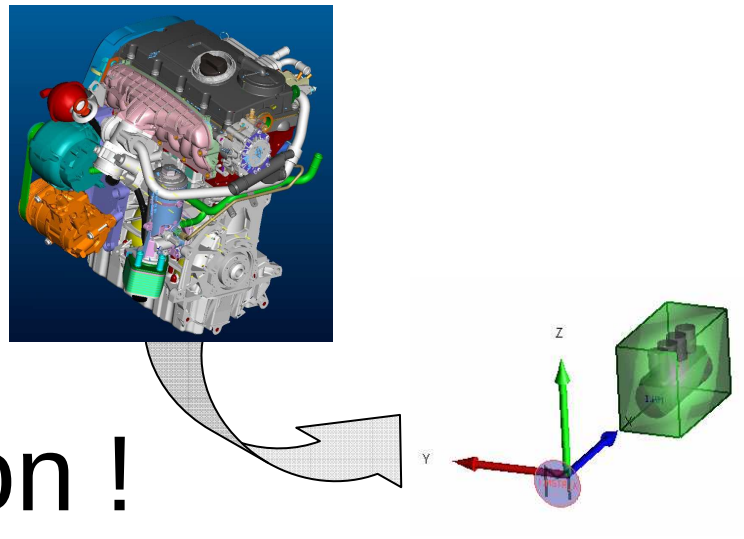
- The technical effort is greater than expected
- Temperature measurement for engine parts complicated
- PT100 1/10 DIN thermal sensors not applicable everywhere
- Volumetric flow for oil could not be measured directly
- The heat map / heat balance has to be calculated by user to fit KULI input
- interpolation method of heat map has no influence on calibration
- user has to refine the automatic adjustment

Outlook

KULI air side successful – KULI engine model needs to be improved.

Suggestions

- Auto-adjustment should accept more than a single load step
- Engine model should use „real“ masses (e.g. cylinder head)
- Engine fluid masses should be separated from engine metal masses
- Can an engine model be scaled?



No thermal management without an engine model!

Everybody needs one ☺

Thank you for your attention !