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KULI User meeting 2007, Engineering Center Steyr

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Thermal Management Simulation during the Development of the new Porsche Cayenne

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Overview

- Introduction: The New Porsche Cayenne V8 Turbo
- Development of Cooling Systems at Porsche
- KULI Model
- Calibration/Simulation of Variants
- Coupled Thermal and Driving Simulation
- Conclusion
- Outlook

Introduction

The New Porsche Cayenne V8 Turbo

- Market Launch February 2007
- 4,8 l Turbo Engine (Direct Injection)
- Engine Power 500 PS @ 6300 1/min
- Max. Torque 700 Nm @ 2300 1/min
- Maximum Velocity 275 km/h

Introduction

The Cooling System of the Porsche Cayenne V8 Turbo

- Situated in front of Engine
- Main Coolant Radiator
- Automatic Transmission Fluid Cooler
- Air Condition Condenser
- Power Steering Oil Cooling Unit
- Air-cooled Charge Air Cooler

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Development of Cooling Systems at Porsche

Relevant Test Conditions for the Porsche Cayenne

High Speed Test

- Nearly steady Simulation Parameters
- High Air and Coolant Flows in Radiator

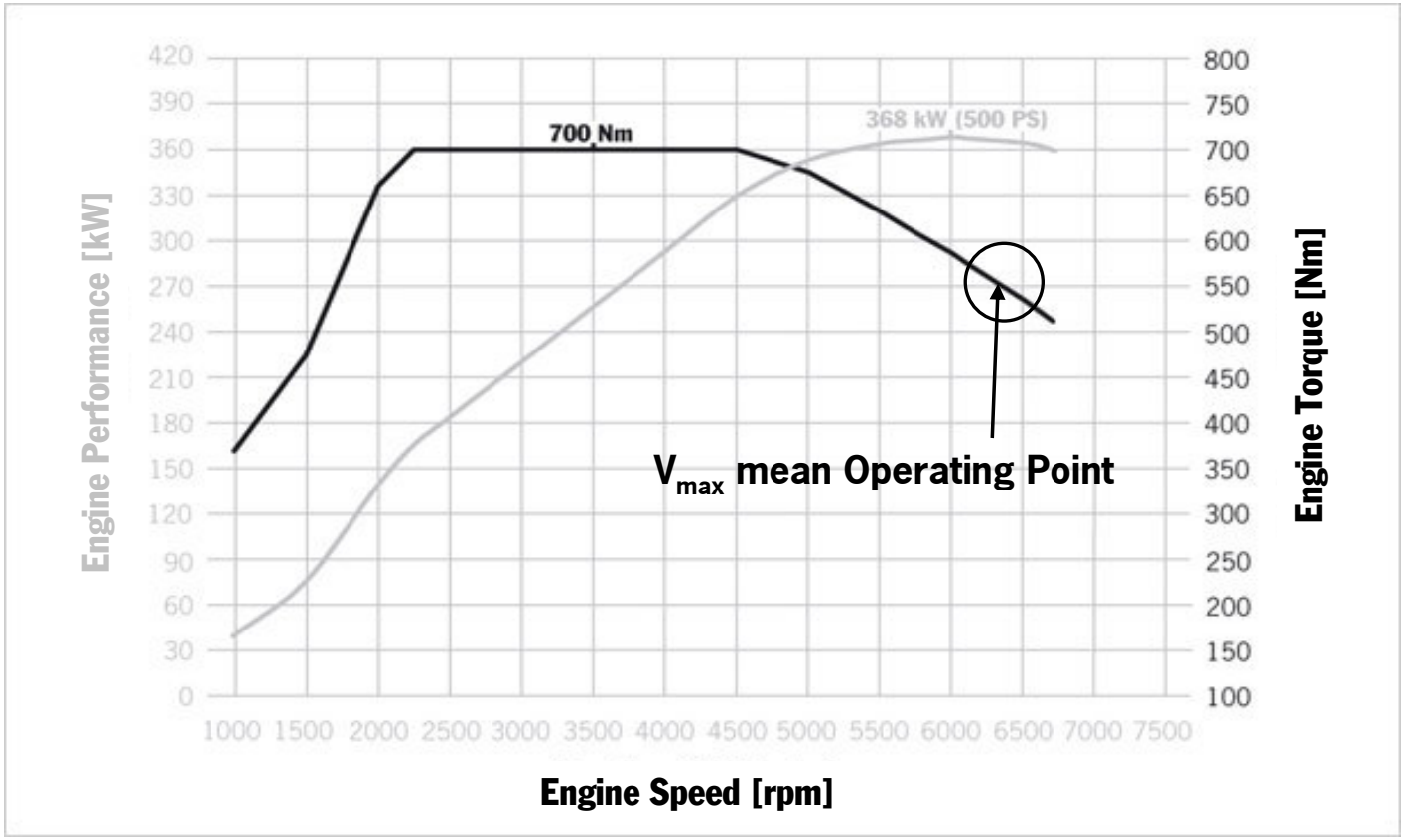
  → Not most relevant Test Condition for Coolant Temperature
- Maximum Engine Speed and Engine Torque

  → Most relevant Test Condition for Gearbox Temperatures

Development of Cooling Systems at Porsche

Relevant Test Conditions for the Porsche Cayenne

High Speed Test



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Development of Cooling Systems at Porsche

Relevant Test Conditions for the Porsche Cayenne

Uphill Test – Example Town Pass

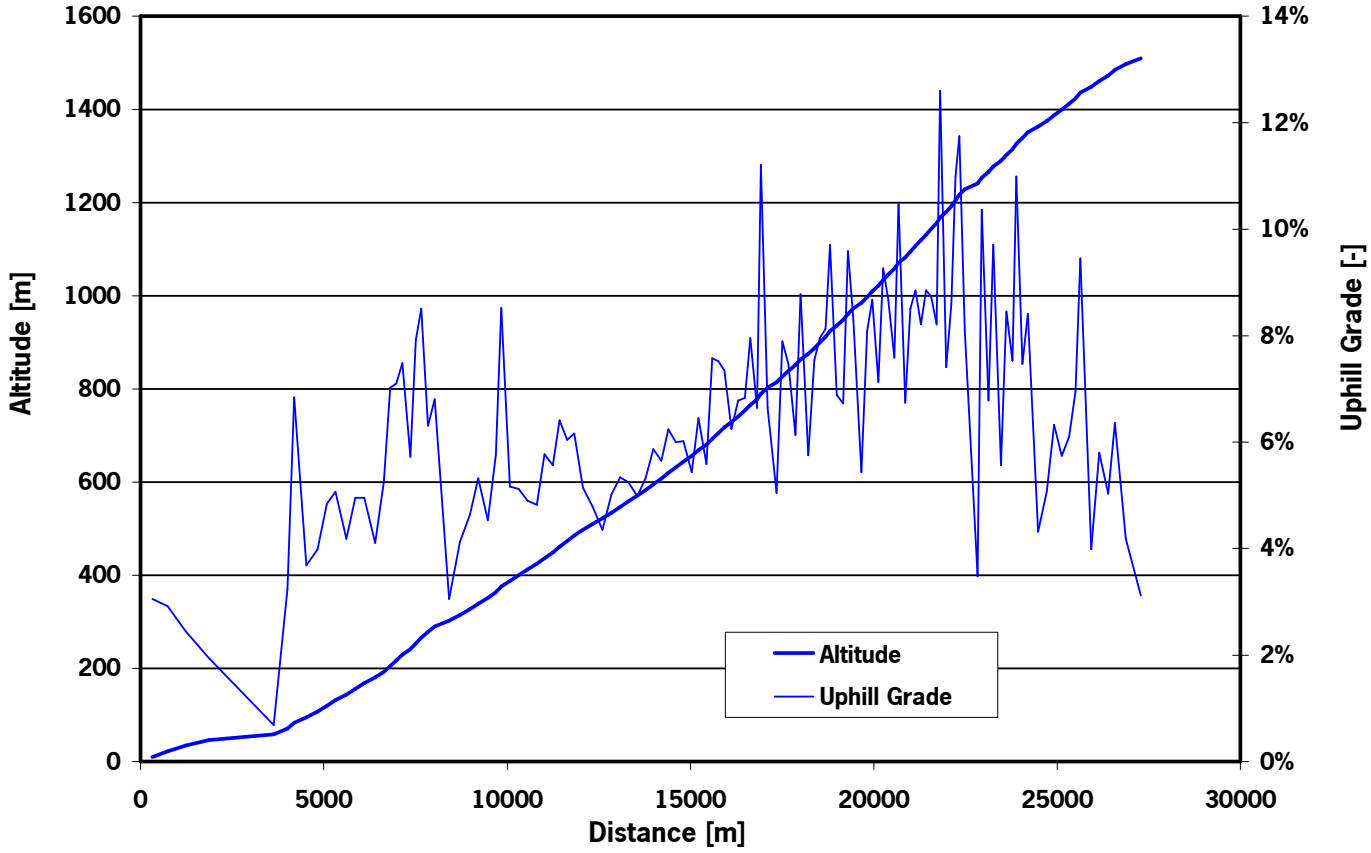
- Test Condition relevant for Cayenne only
- Additional Trailer Load
- High Ambient Temperature (>40°C)
- Air Condition Active
- High variable Uphill Grade
- Dynamic Torque Characteristic due to upgrade and gear variations
- Low Cooling Air Flow due to low Driving Speed

→ Relevant Test Condition for Main Coolant Radiator Layout

Development of Cooling Systems at Porsche

Relevant Test Conditions for the Porsche Cayenne

Uphill Test – Example Town Pass



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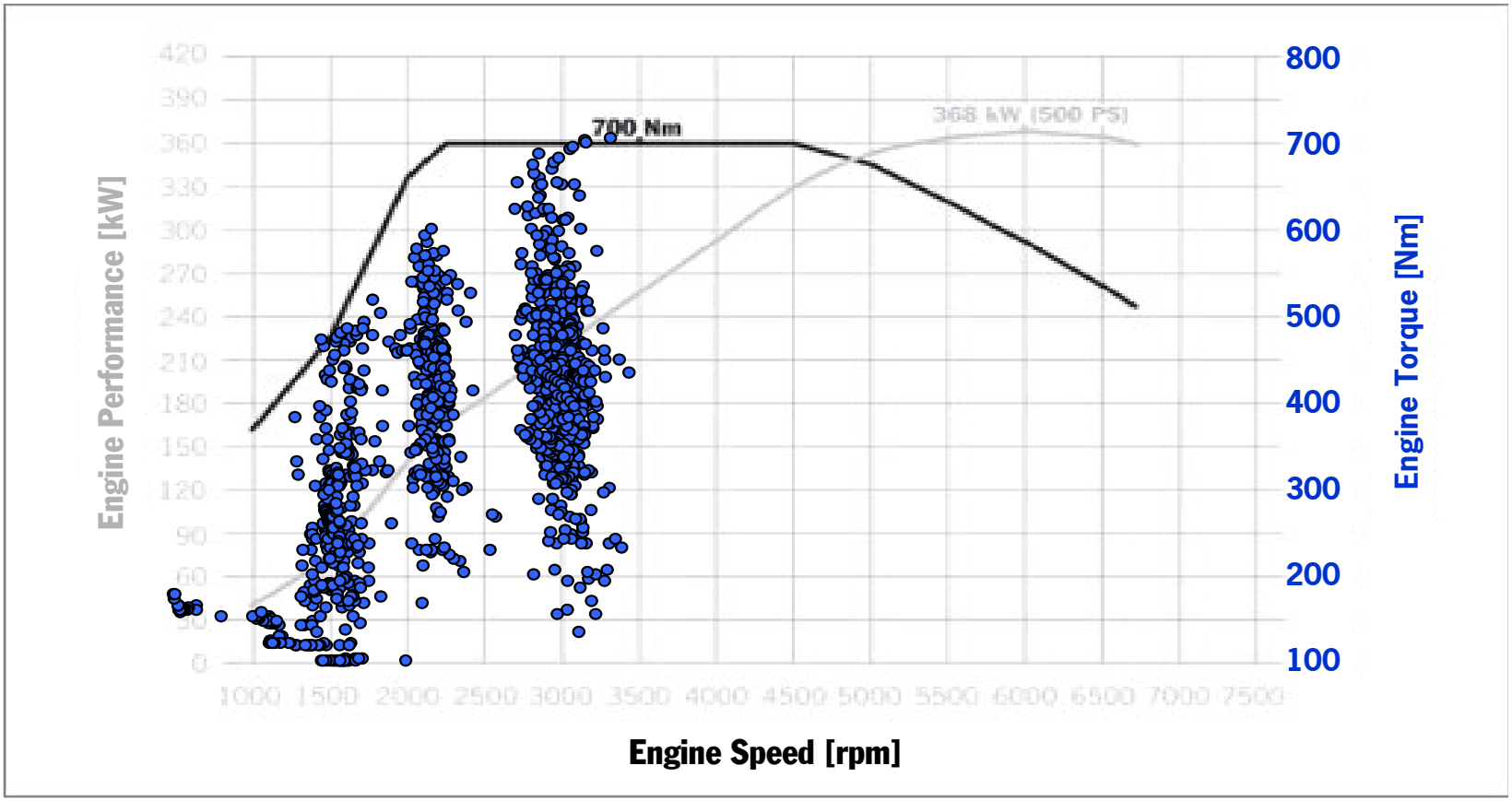
Development of Cooling Systems at Porsche

Relevant Test Conditions for the Porsche Cayenne

Uphill Test – Example Town Pass



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Development of Cooling Systems at Porsche

Simulation of Town Pass Drive in Climatic Wind Tunnel

Images: Modine Wind Tunnel

Benefits vs. Road-Test:

- Good Reproducibility
- Less Time for Preparation and Loops
- Lower Costs
- More detailed Measurement Information
- No traffic limitations (on public roads)

Simplifications:

- Non-moving Ground
- Constant Ambient Temperature
- No Density Changes due to Altitude

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Steps of Thermal Management Simulation

- Simulation of Town Pass Drive in Climatic Wind Tunnel
- Build-up of the Cayenne KULI model
- Calibration of KULI Model to Wind Tunnel Results
- Variation Simulations / Parameter Studies

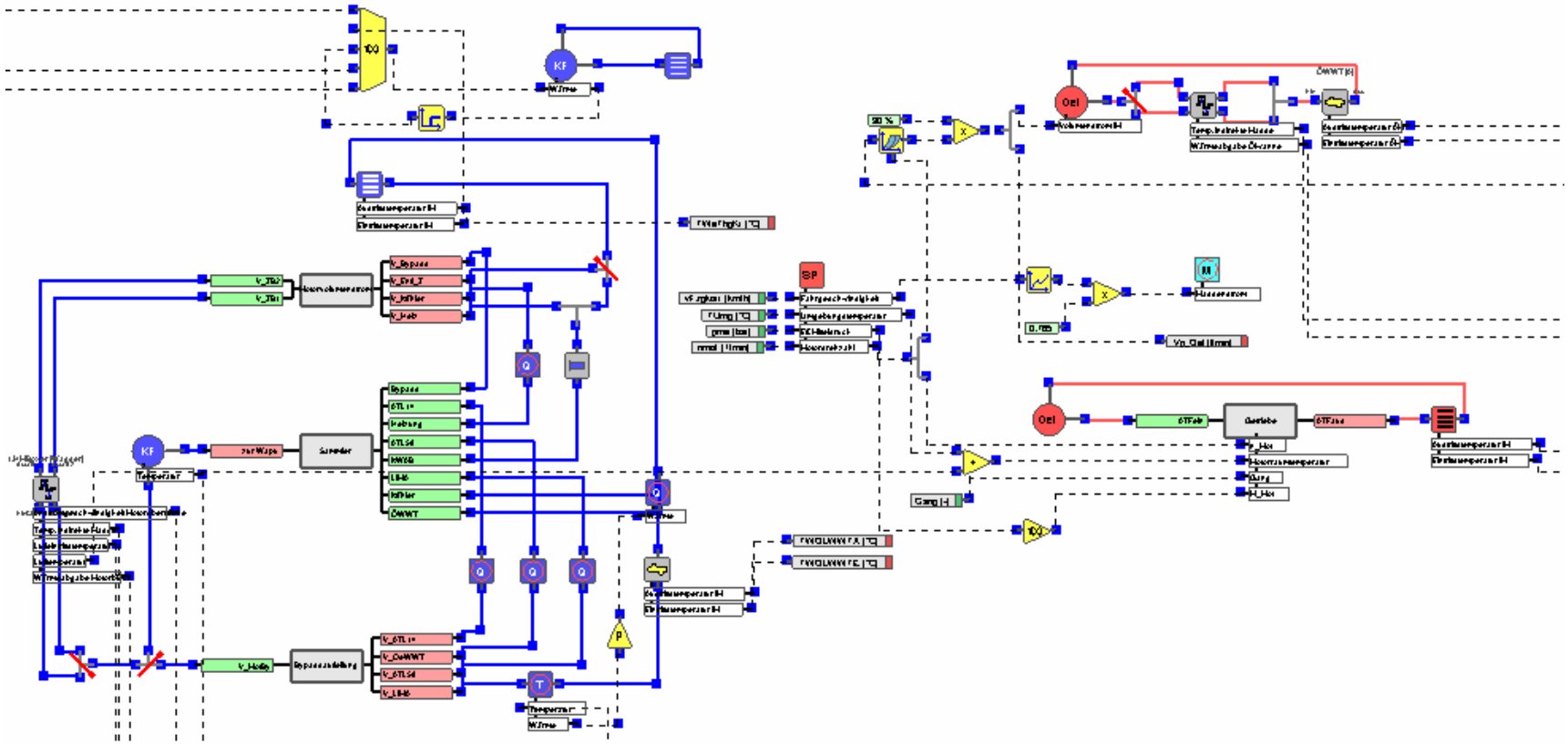
→ Forecast of Temperature Behaviour for new Cooling System Configurations

→ Optimization of Cooling System Components

→ Development of Automatic Control Algorithms

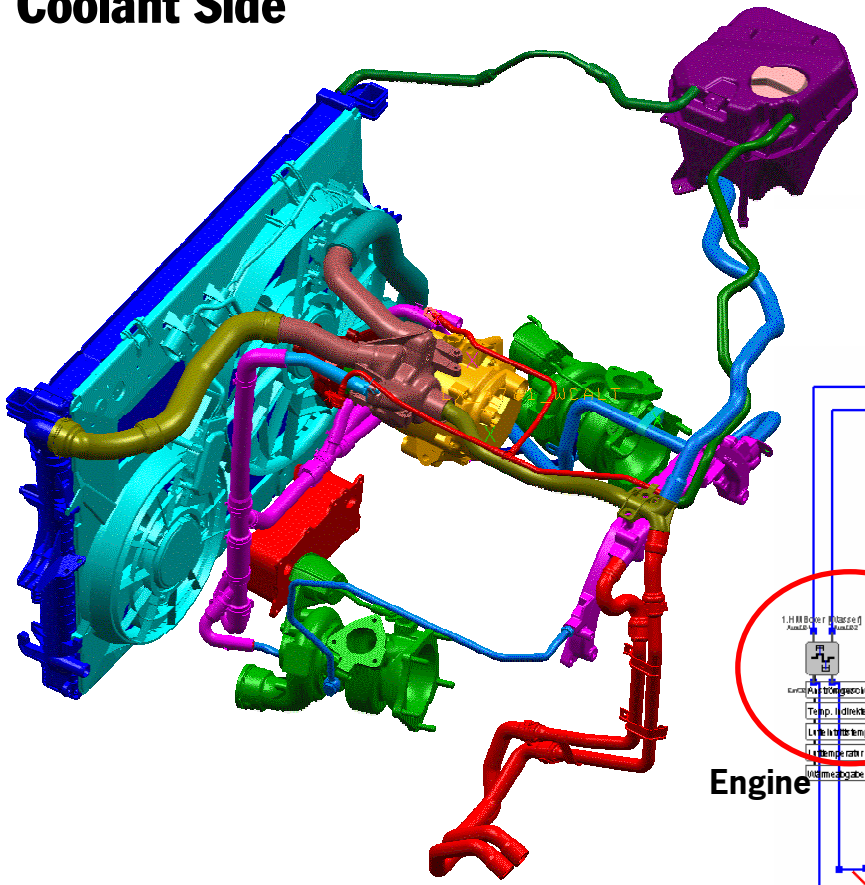
→ Transfer to real Town Pass Conditions (Temperature and Density)

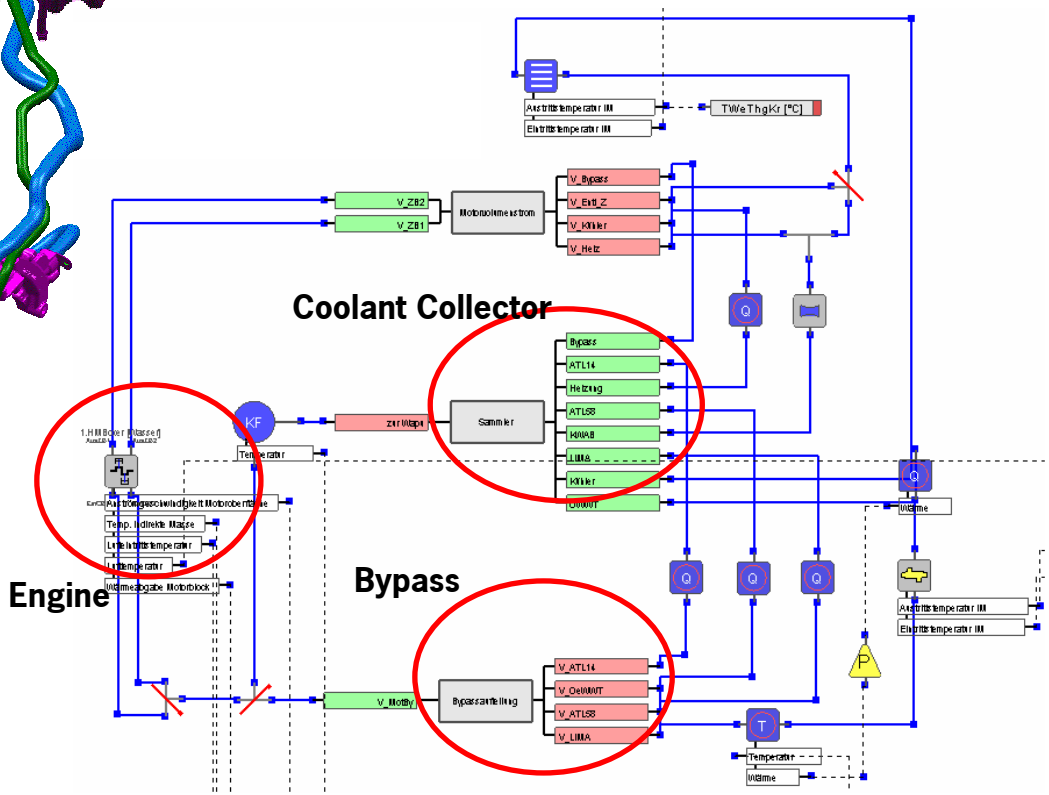
Kuli Model of the Cayenne V8 Tiptronic



Kuli Model of the Cayenne V8 Tiptronic

Coolant Side

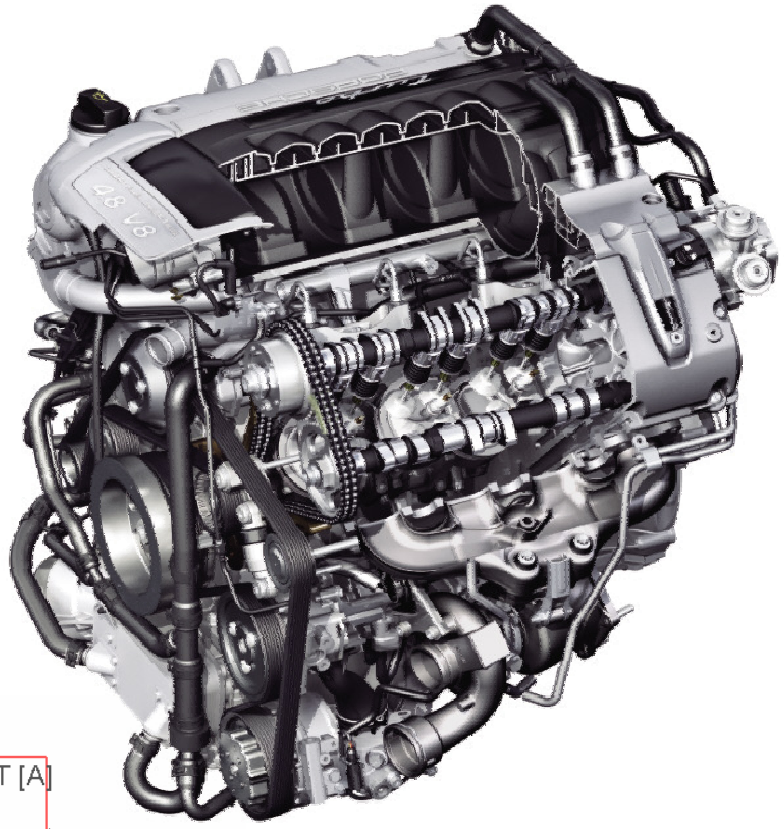


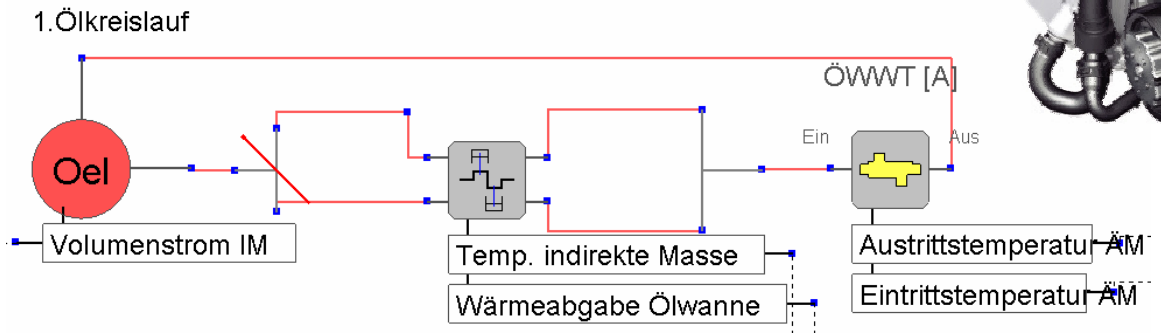


Kuli Model of the Cayenne V8 Tiptronic

Engine Oil Side with Engine Model

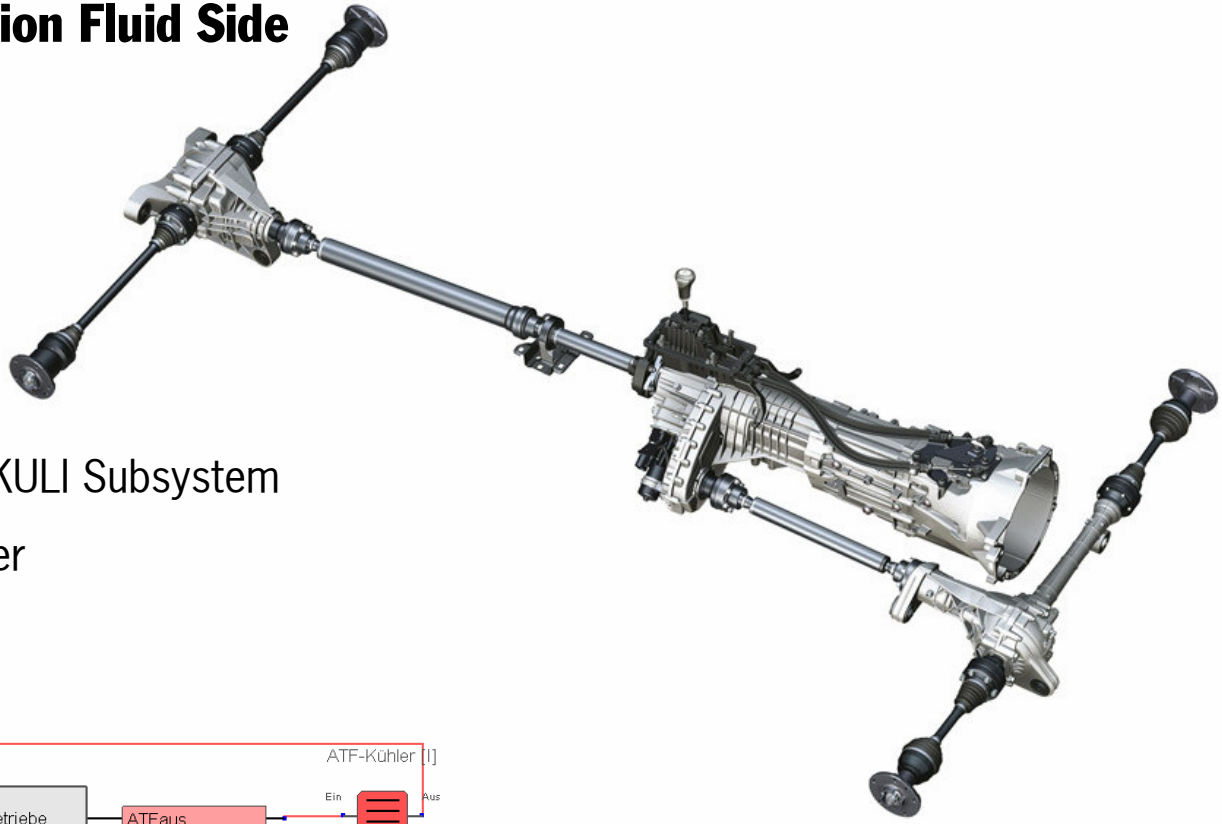
- 2 Cylinder Bank Engine Model
- Regulated Oil Pump
- Oil/Water Heat Exchanger



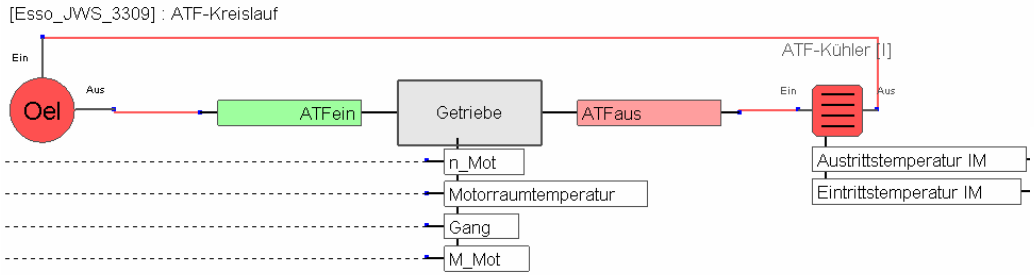


Kuli Model of the Cayenne V8 Tiptronic

Automatic Transmission Fluid Side



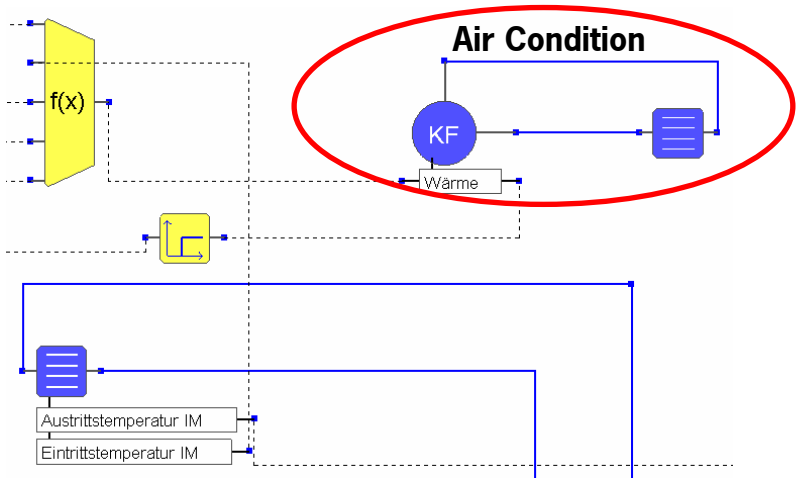
- Gearbox modelled as KULI Subsystem
- ATF/Air Heat Exchanger
- ATF Pump



Kuli Model of the Cayenne V8 Tiptronic

Air Condition Side

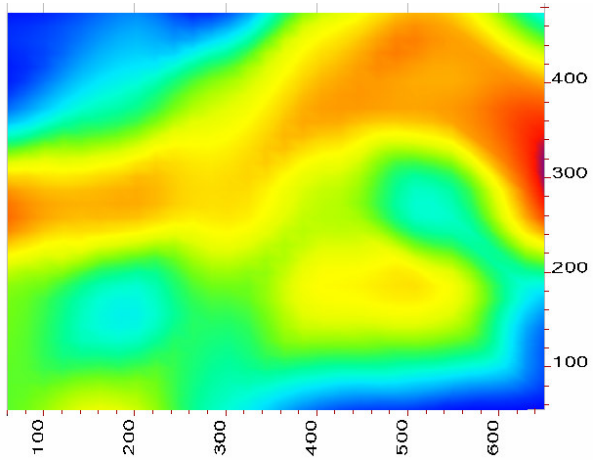
- Required for Town Pass Simulation
- A/C System Status depends on Operating Point
  - enabled
  - disabled
- Heat Input into Air from Condenser
- No detailed Modelling of Refrigerant Circuit
- A/C Condenser modelled as Radiator
- Values from Climatic Wind Tunnel Testing

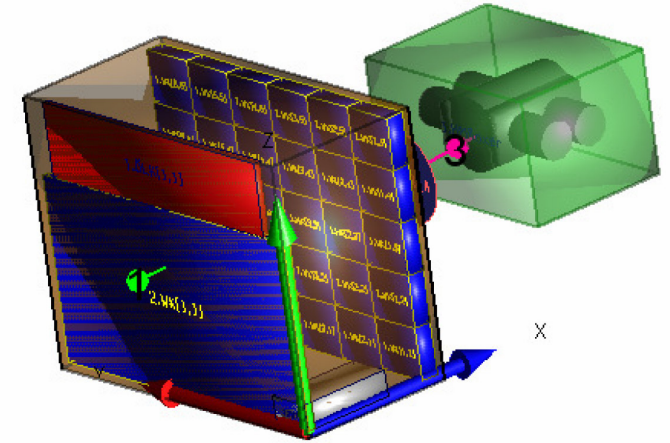


Kuli Model of the Cayenne V8 Tiptronic

Air Path

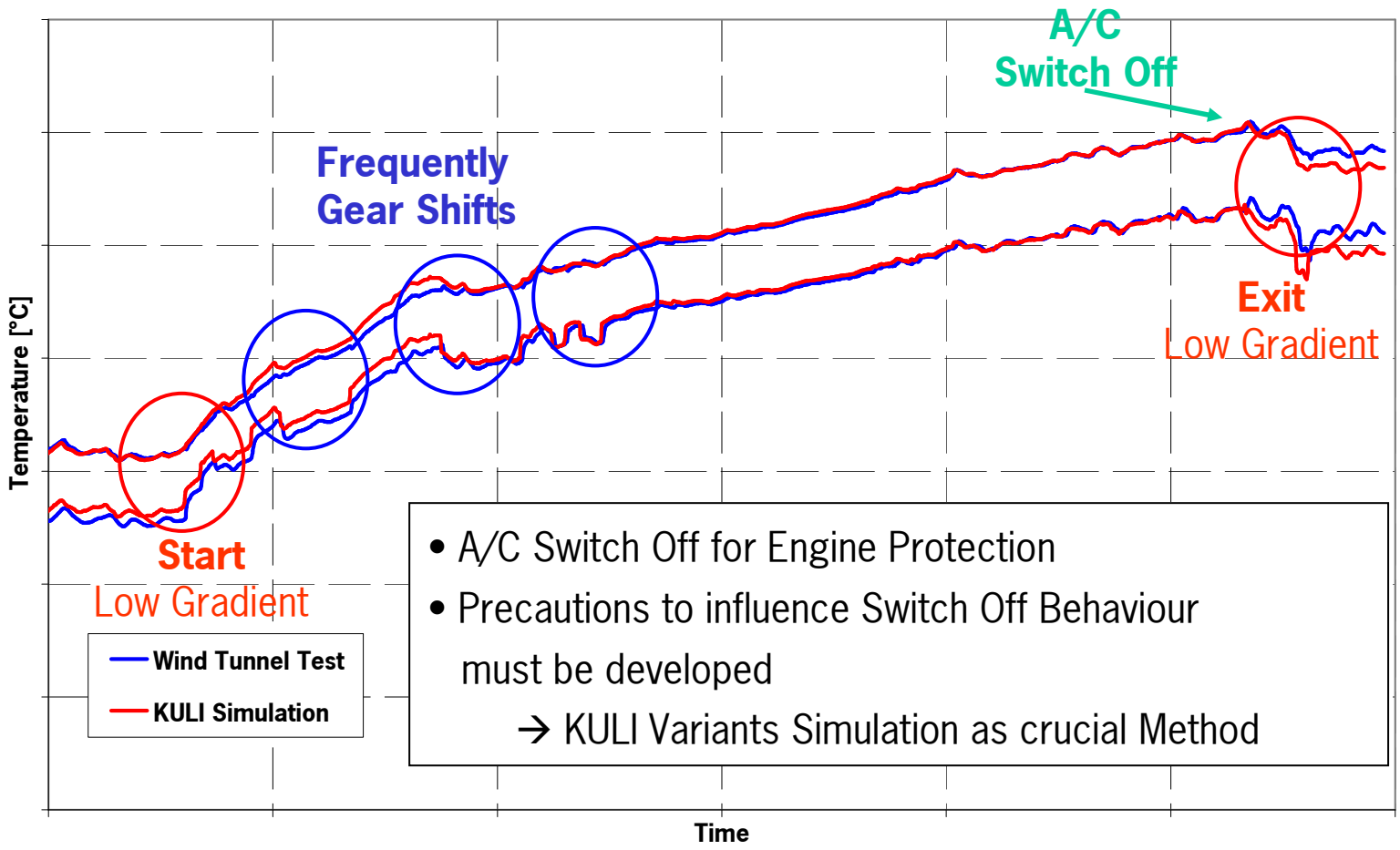
- Engine Model integrated in Cooling Air Path
- Air Flow controlled by Flow Source
- Realistic Geometry through Block Formation
- Segmentation and Resistance Matrix for Heat Exchangers
- Air Mass Flow and Distribution from Wind Tunnel Tests
- No Use of KULI Fan Component
- No Modeling of Charge Air Coolers





Result of Calibrated KULI Model

Coolant Temperatures at Radiator Inlet/Outlet



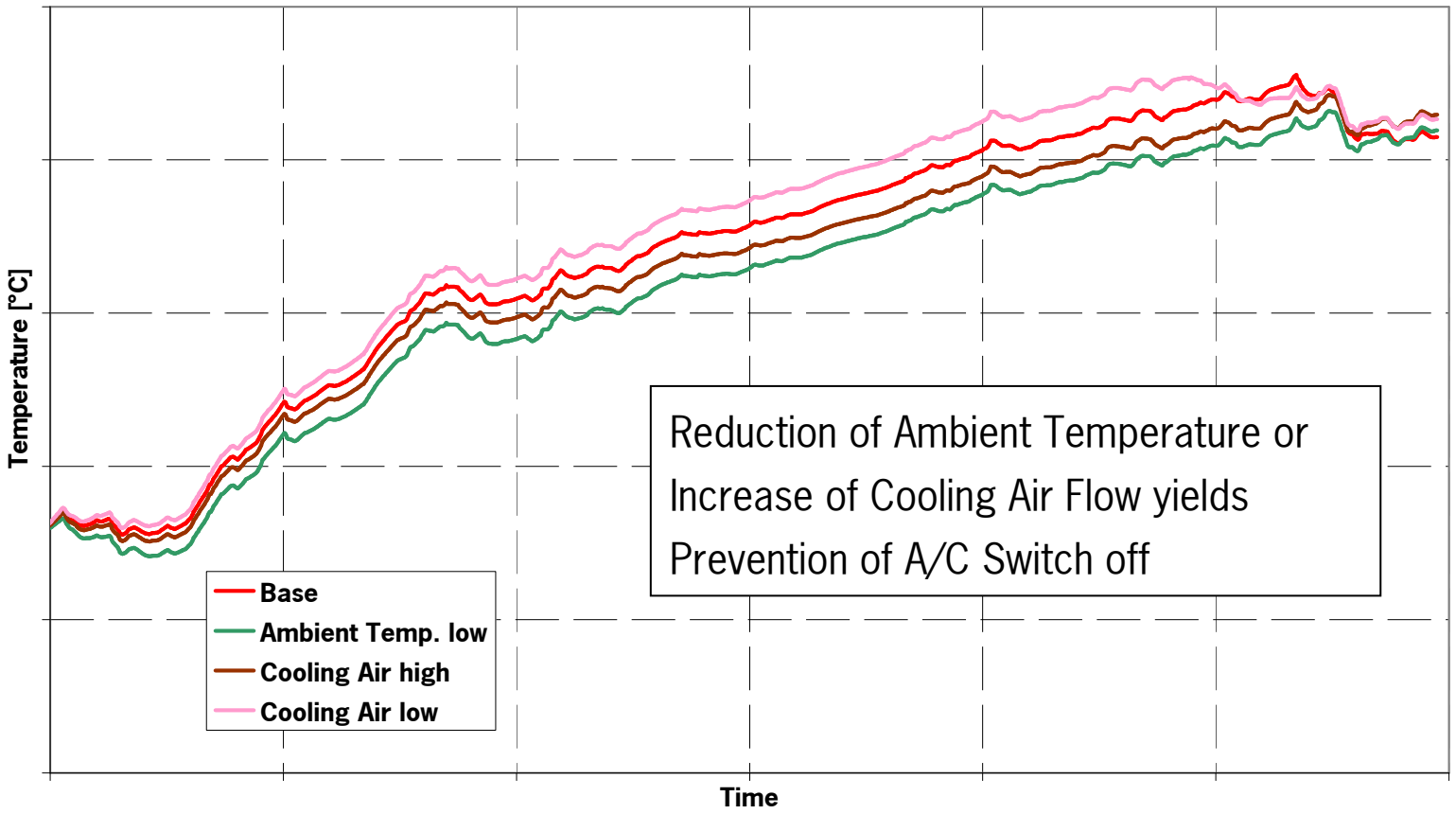
Simulation of Different Variants

Potential Variants

• Ambient Temperature • Increased Air Flow • Coolant Flow	• Different Engine Power	• Modified Gear Shift Strategy
	Changed Simulation Parameters as Input for KULI	Changed Simulation Parameters as Input for KULI KULI Fluid Temperatures do influence Driving Simulation
KULI Standalone Simulation sufficient	Offline Coupling KULI-CRUISE necessary	Online Coupling KULI-CRUISE necessary

Simulation of Different Variants

KULI Standalone Simulations sufficient



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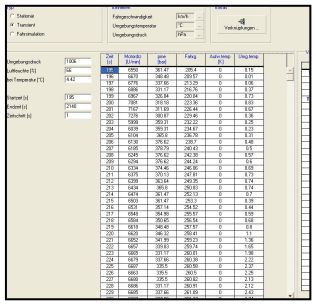
Simulation of Different Variants

Offline Coupling KULI-CRUISE necessary

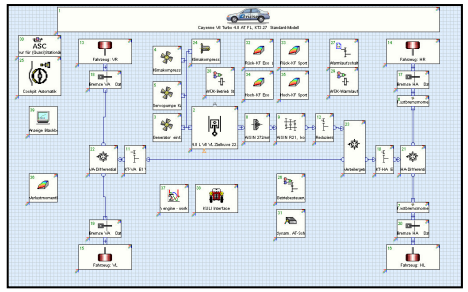
1. Cruise Simulation for new Variant (e.g. increased Engine Power)
2. Generation of new Set of Simulation Parameters for KULI using the Cruise Results
3. KULI Standalone Simulation with new Set of Parameters

Simulation Parameters

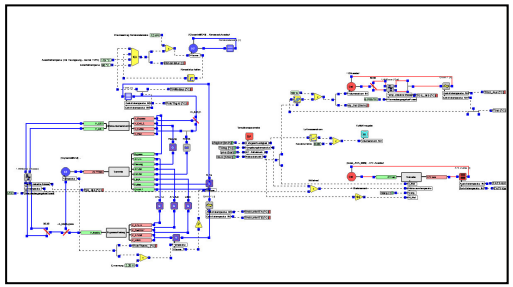


Transfer via ASCII-File or Excel-Table

Cruise Model Cayenne V8 Turbo



KULI Model Cayenne V8 Turbo



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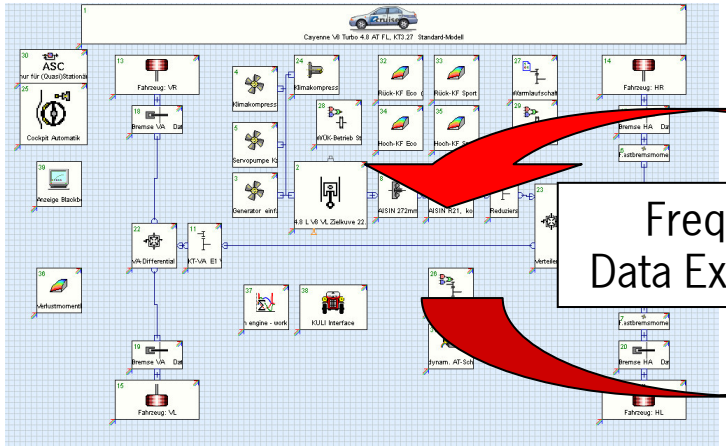
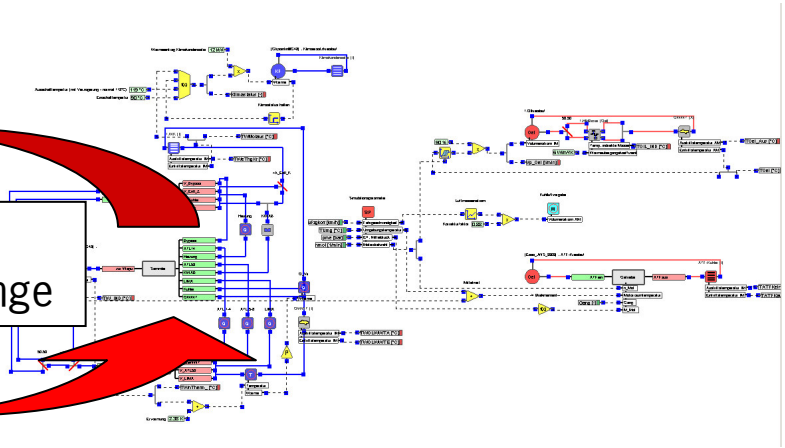
Simulation of Different Variants

Online Coupling KULI-CRUISE necessary

Cruise Model Cayenne V8 Turbo



KULI Model Cayenne V8 Turbo



Frequent Data Exchange

Output:

- Engine Speed
- Engine Torque
- Velocity
- Gear
- Ambient Temperature

Output:

- Coolant Temperature
- Engine Oil Temperature
- ATF Temperature
- A/C Status (enabled/disabled)

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Conclusion / Experience

- Cooling System Development for the New Porsche Cayenne was supported by Thermal Simulation with KULI
- Most relevant Test Condition for Coolant Temperatures: Uphill Test (e.g. Town Pass)
- Use of Climatic Wind Tunnel Tests in Combination with KULI Simulation proves as an efficient Development Method
- KULI Thermal Model shows good Correlation to measured Coolant Temperatures
- Some Variant Simulations show Need of Coupled Driving and Thermal Simulations
- Fixed Cruise-KULI Coupling was built up
- Potentials and Limitations were identified

Outlook

- Upgrade of further existing Standalone Simulation Models (KULI and Cruise) as a Requirement for Coupling
- Further Coupling Activities applying a Middleware Approach scheduled
- Comparison of the different Coupling Approaches (Process, Simulation Results)
- Implementation of coupled Driving and Thermal Simulation Systems as a fixed Development Tool at Porsche
- Extension of Method to Fuel Consumption Test Cycles (e.g. NEDC)

  → Quantification of Fuel Consumption Benefits as a Result of Thermal Management Features


Thank you for your
Attention!
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