PORSCHE

Contents

Transient Simulation of the Cooling System of a Flat Six Engine

Dr.-Ing. Ralf Häßler, Dr. Ing. h.c. F. Porsche AG, Weissach, Germany

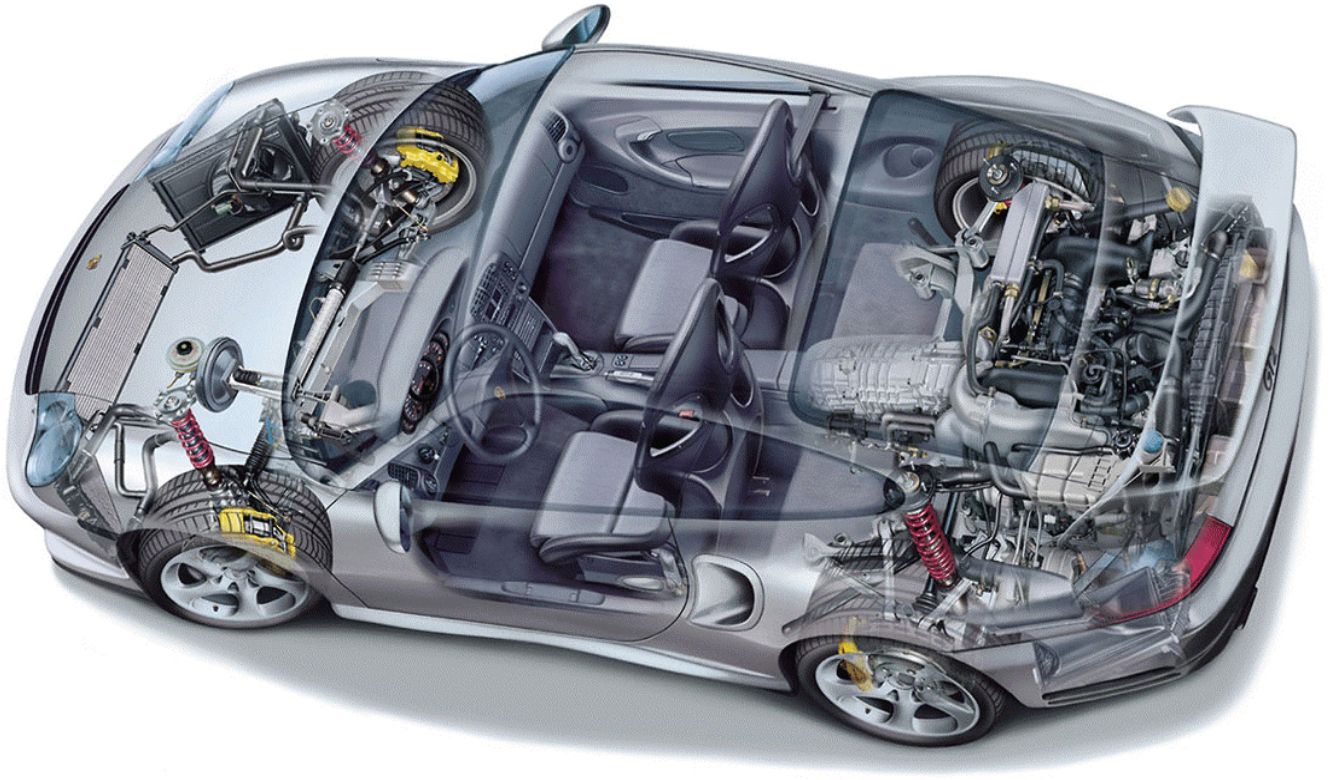
Kuli User Meeting, 25.-26.6.2003, Steyr, Austria

Special Thanks to
Mr. A. Koller and the Members of
Porsche's Simulation Departement

Porsche AG

Introduction

Overview of Cooling System

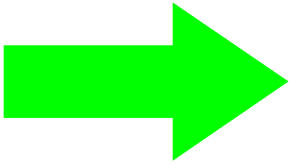


Porsche AG

Introduction

Test Conditions (Fluid Temperatures less than given Limit!)

Idle, Stop & Go, Grade	Low Speed, High Load	Climatic Wind Tunnel
High Speed	High Speed, Max Load	High Speed Test Track
Race Track	Medium Speed, High Load	Weissach, Hockenheim …

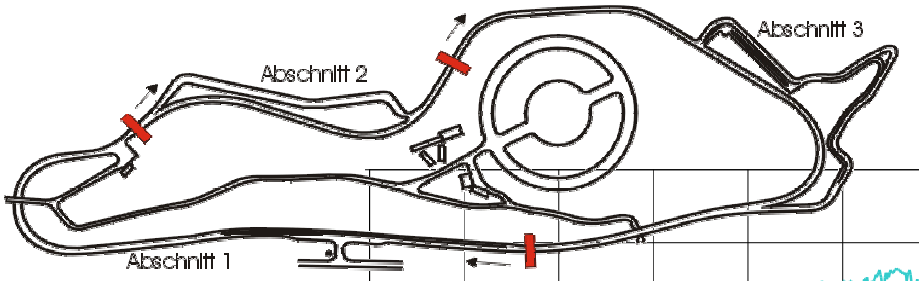


- Race track most severe for fluid temperatures
- Steady state not achieved in general
- Parameter studies require transient simulation
- Real-time simulation requires high complexity

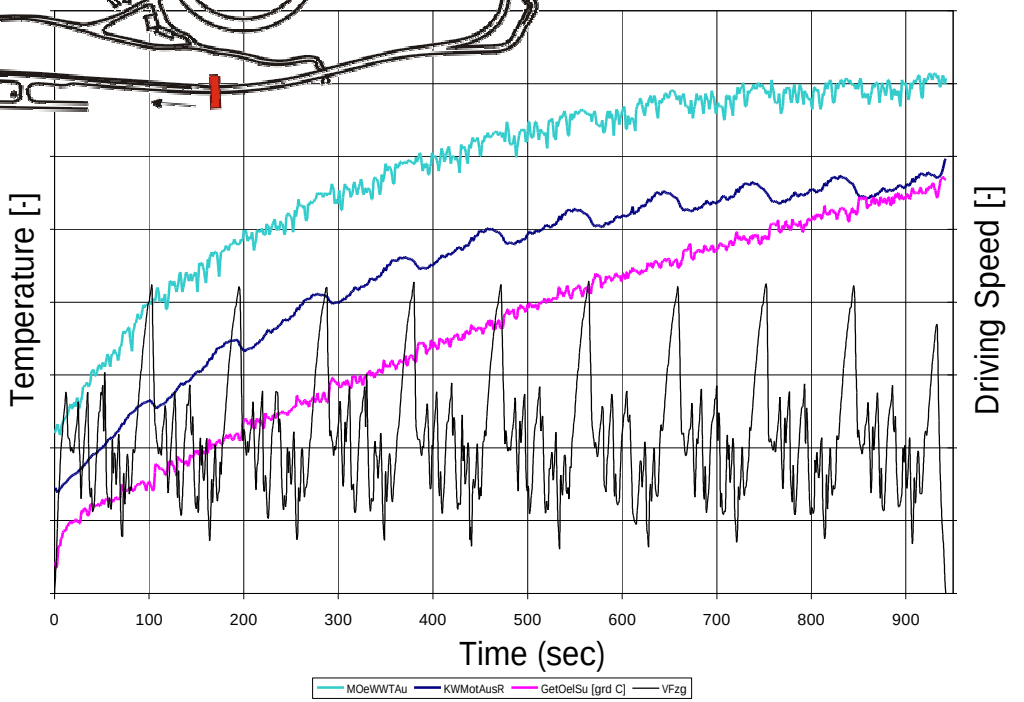
- Average operating conditions are kept constant in quasi transient simulation
- Warm-Up behavior is simulated

Introduction

Test Conditions: Test Track, Typical Temperature Curves



Length 2.8 km
3 track variants

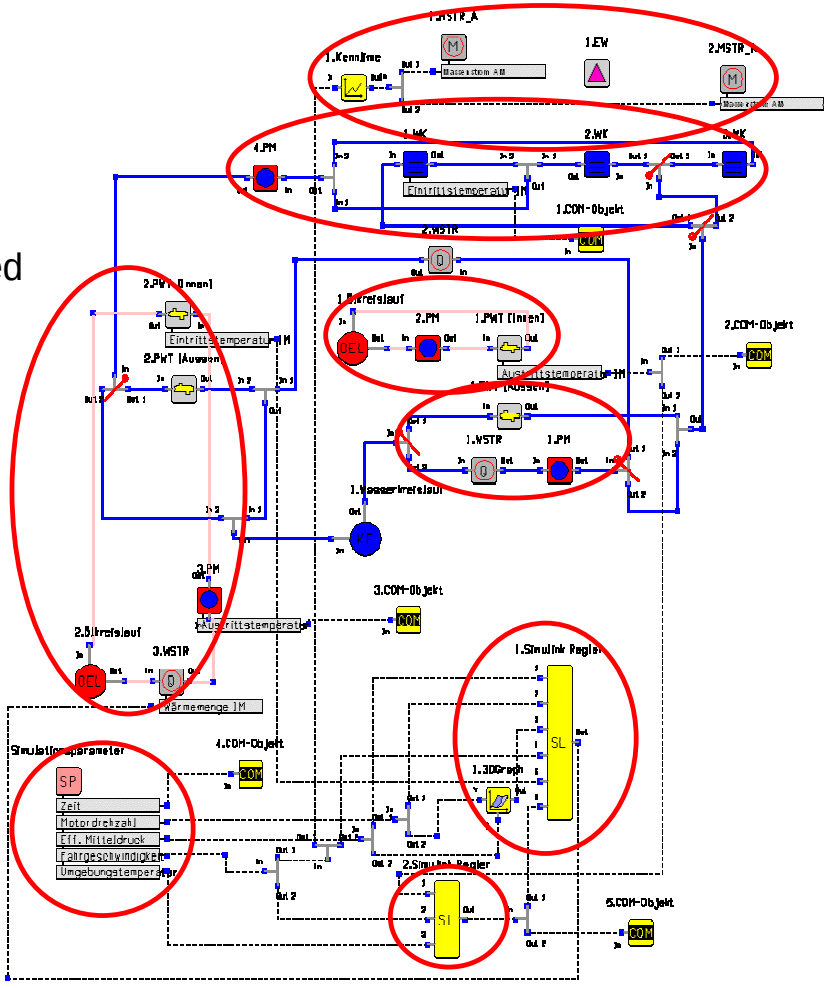


Porsche AG

Kuli Model

Coolant Side

- Radiators
- Cooling Air Flow vs. Driving Speed for Side Radiators
- Middle Radiator with CP and BiR
- Engine Oil Circuit
- Engine as Heat Source
- Automatic Transmission Fluid
- Automatic Gearbox as Simulink Controller
- Engine Compartment as Simulink Controller
- Simulation Parameter (constant)



Kuli Model

Air Side

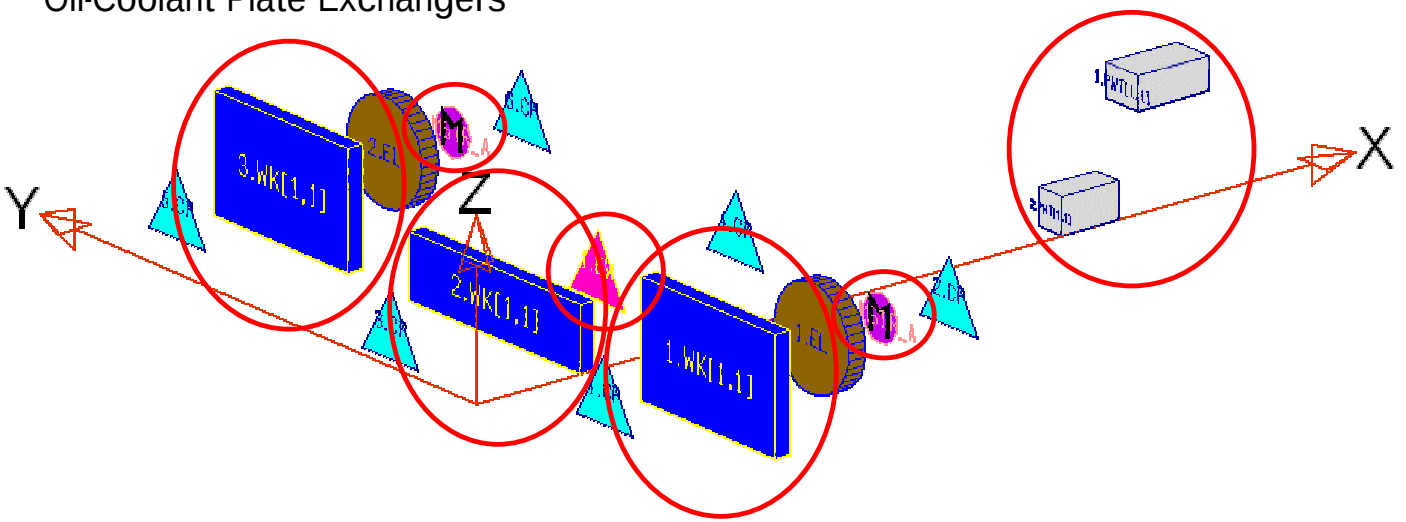
Side Radiators 44 mm i-flow, down-flow

Middle Radiator 44 mm i-flow, side-flow

Cooling Air Flow vs. Driving Speed for Side Radiators

Middle Radiator with CP and BiR

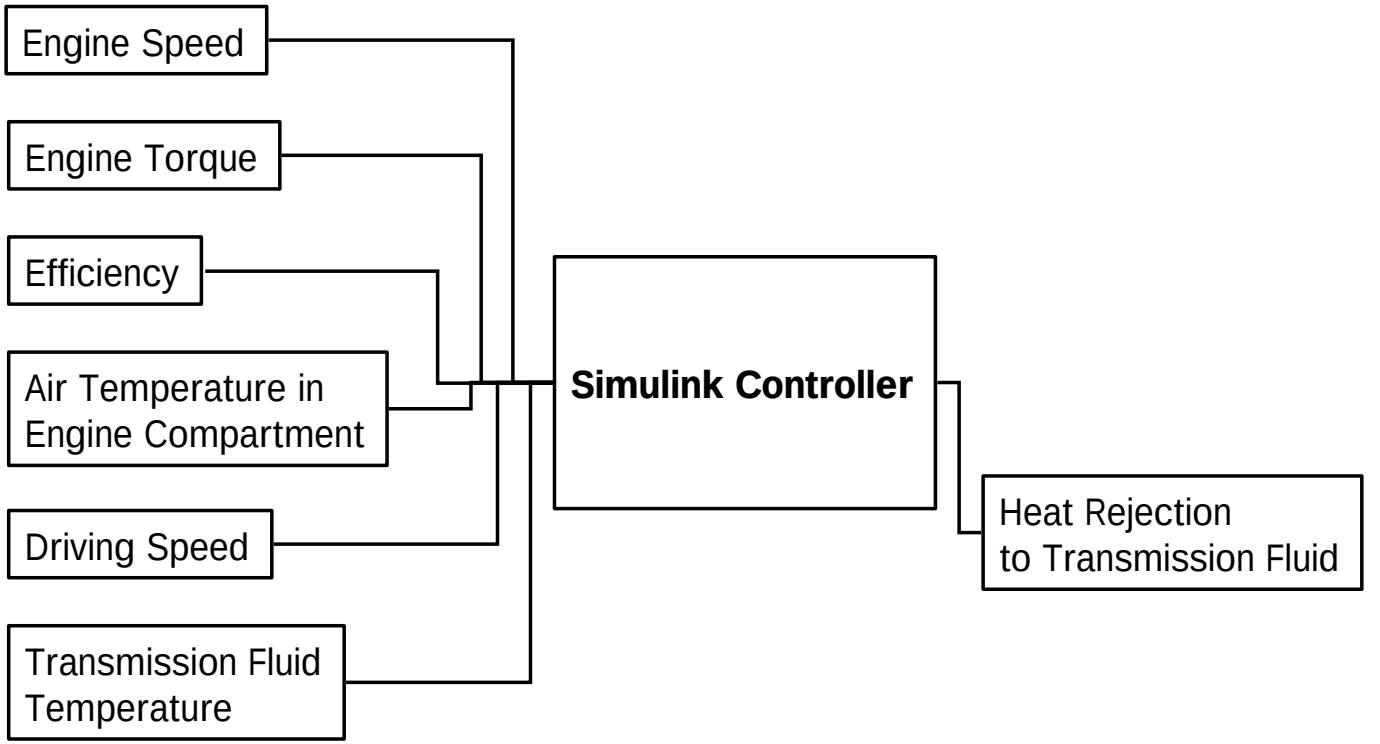
Oil-Coolant Plate Exchangers



Porsche AG

Kuli Model

Automatic Gear Box as Simulink Controller

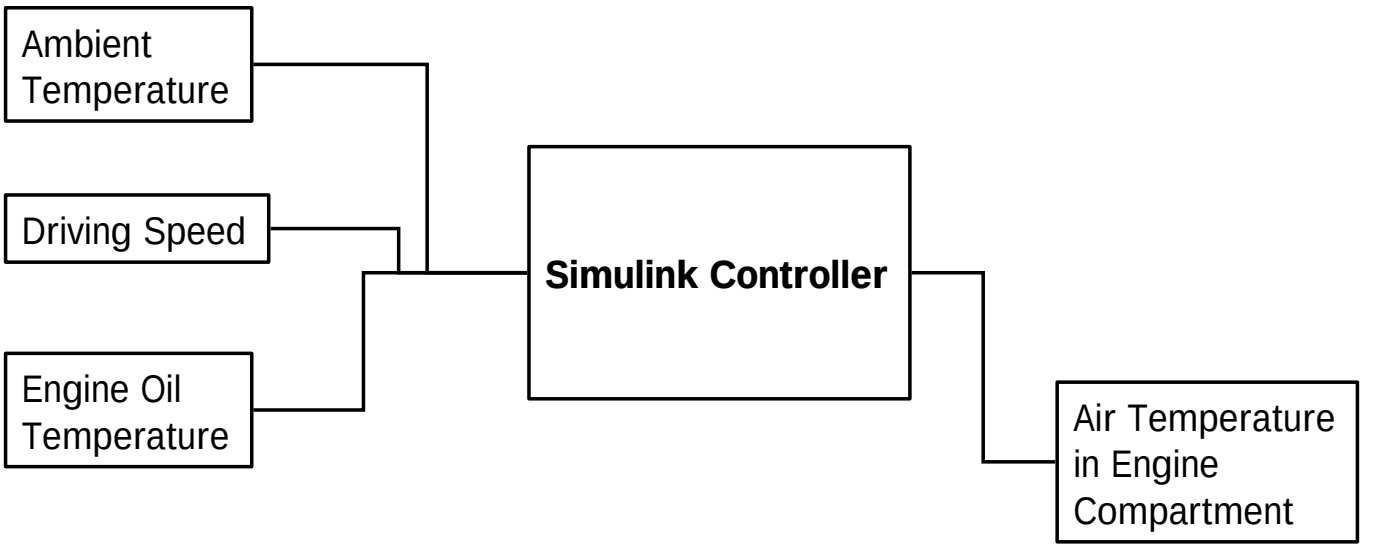


Data Exchange Kuli -> Simulink

Data Exchange Simulink -> Kuli

Kuli Model

Engine Compartment as Simulink Controller



Data Exchange Kuli -> Simulink

Data Exchange Simulink -> Kuli

Porsche AG

Calibration

Initial Conditions

Unknown:

Starting Temperature at each point of the system

Temperature gradient at initial state

Solution:

Different starting temperatures of engine and coolant

Temperature gradient at initial state equal to measurement

Fine tuning done manually

Calibration

Heat Fluxes

Unknown:

Heat rejection to engine oil and coolant

Solution:

Sensitivity analysis of influences of heat fluxes on temperatures

3 simulations with varying heat fluxes lead to functions

4th simulation using results from above yields satisfactory results

Masses

Unknown:

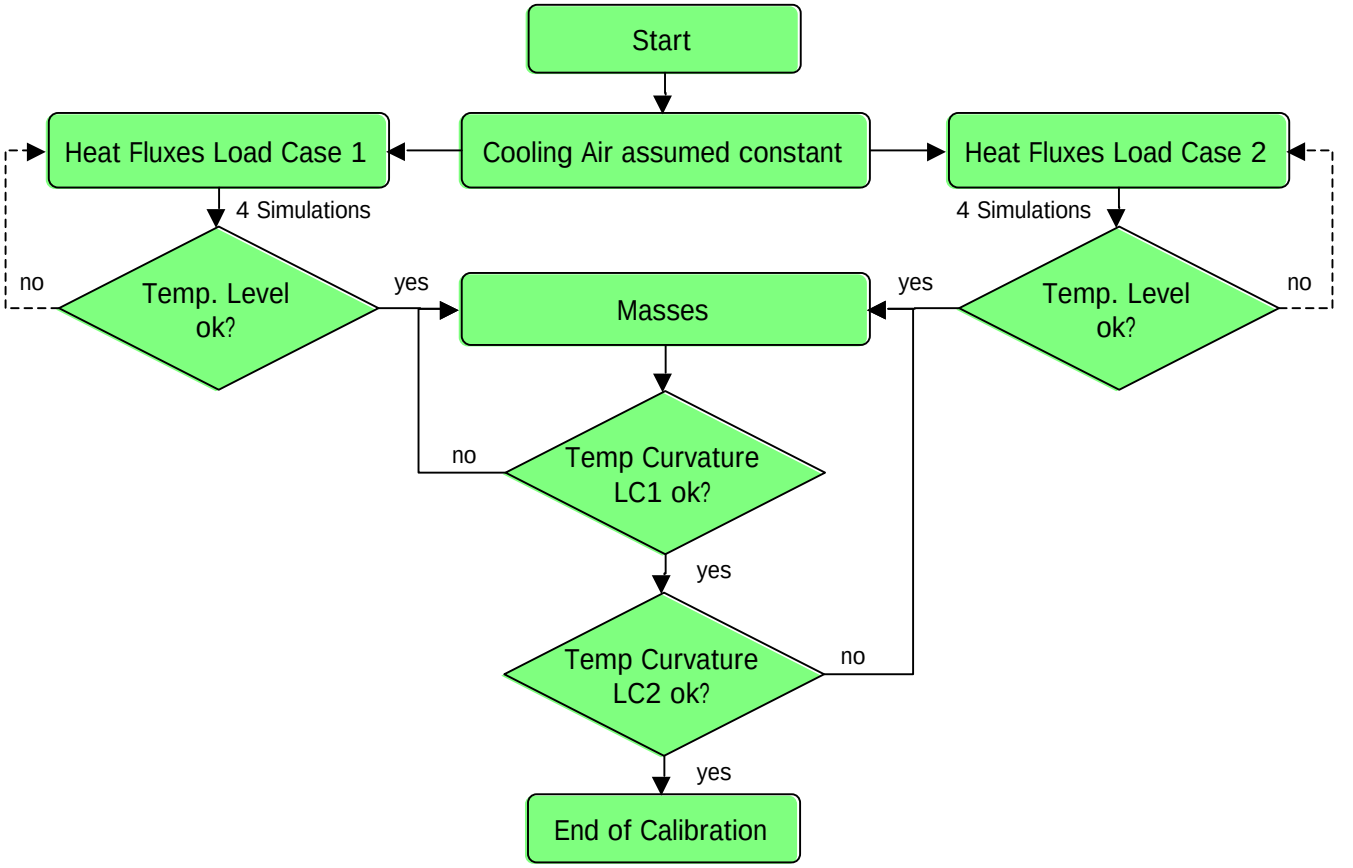
Heat capacities influencing curvature of temperature behavior

Solution:

1- 3 simulations with varying masses (based on experience) lead to correct curvature

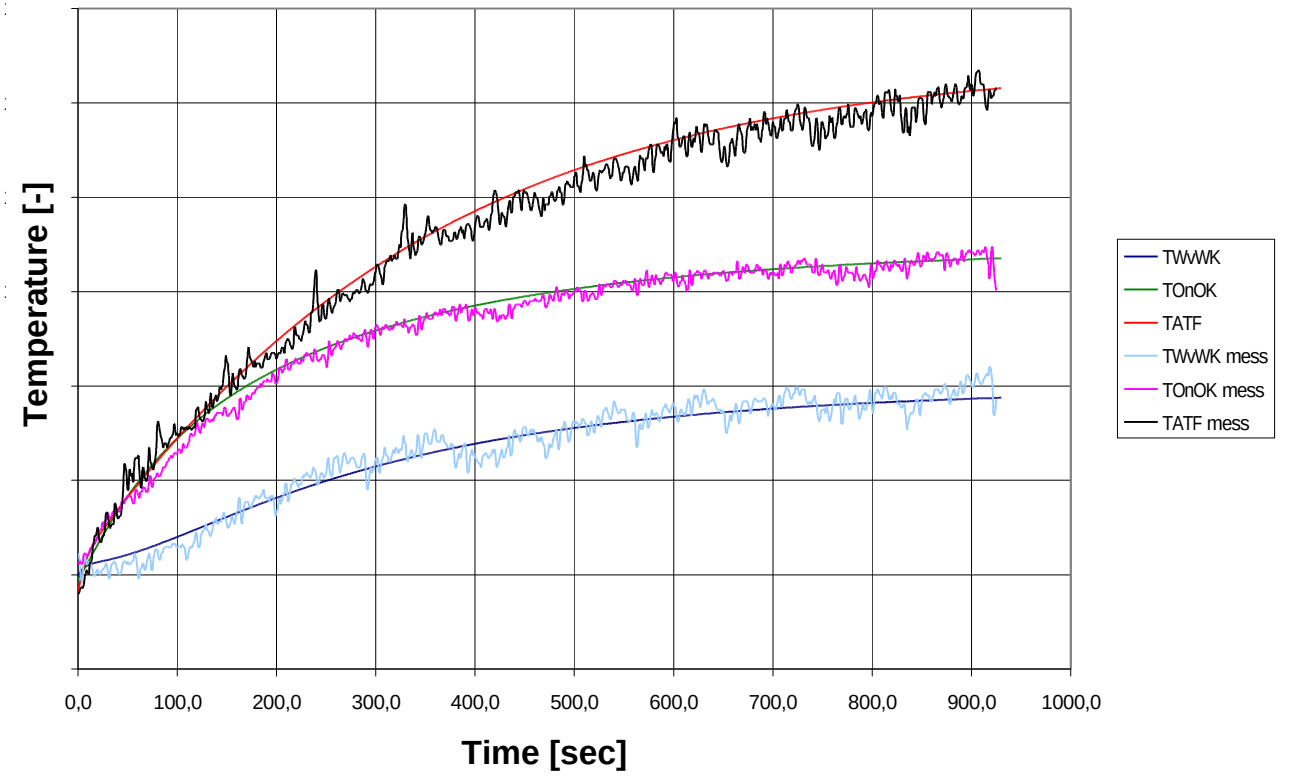
Calibration

Flow Chart of Calibration Method



Results

Result after Calibration



Porsche AG

Results

Application

- Data collection
- Adjustment of coolant flow rates per measurement (flow lab)
- Calibration of model via measured temperature data
- Maximum temperature of simulation is corrected by offset from measurement scattering
- Resulting temperature is corrected for different ambient temperature (30°C, 35°C ref.)

Simulated Cases

- Modification of engine performance / engine torque
- Variation of air flow data from windtunnel tests or CFD
- Variation of coolant flows from experiments / FlowMaster simulation
- Variation of radiator core with approximation to air flow data
- Variation of oil/coolant heat-exchangers
- Parameter studies

Constraints

Coolant Flows:

The actual model requires data of coolant flows by component.
These are adjusted by valves and thus represent input parameters.

Air Flows:

The side radiators air flow must be known as a function of driving speed.
The effect of modified cooling air paths require new measurements or CFD simulations

Drivers Impact:

Different drivers require recalibration

Driving Cycles:

Results cannot be transferred to different tracks (driving cycles)

Engine Model:

Influence of forced convection and radiation are neglected in engine model

Outlook

Coolant Flows:

Adjustment of coolant side pressure drops will be done using measurement data

Air Flows:

An aerodynamic model allowing the input of windtunnel or CFD data
is currently developed

Driver Impact / Cycle Impact:

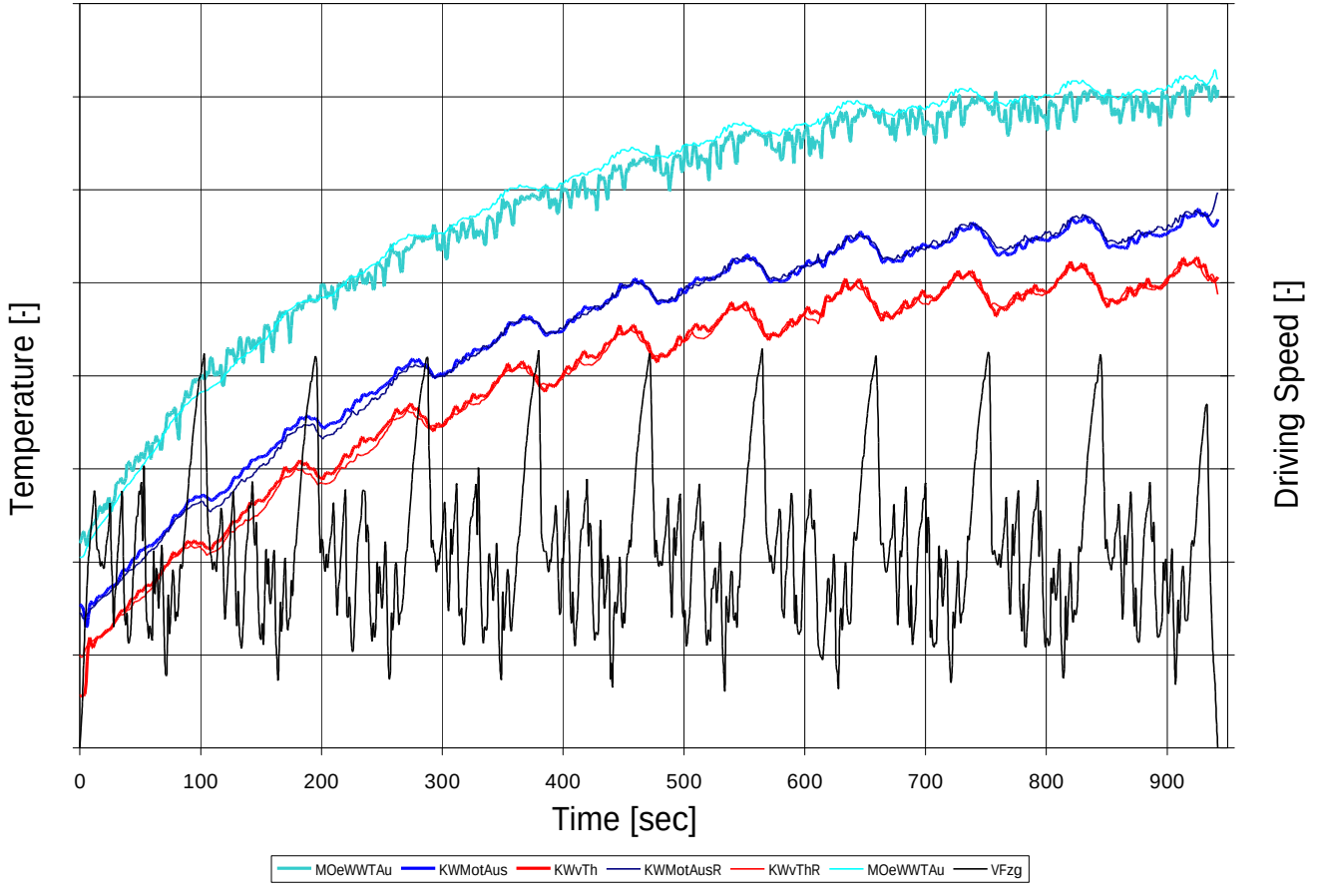
Real transient simulation allowing the input of driving simulation or measured data first for manual transmission, second automatic transmission
is currently developed

Engine Model:

Influence of forced convection and radiation can be integrated in new engine model developed by Magna Steyr

Outlook

Real Transient Simulation:



Contents

- Introduction
- Kuli Model
- Calibration
- Results
- Constraints
- Outlook

Thanks for your Attention!

Porsche AG