Holistic 1D-Model for Cooling Management and Engine Analysis of a Heavy-Duty Truck

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Agenda

1 Introduction

2 Model Description and Results

3 Summary and Outlook
Introduction
Simulation Tools and Methods

3D -CFD Underhood | Engine Data and Models | Boundary Conditions | Cooler and Fan Data

Thermal Hydraulic Simulation (GT-SUITE®)

Characteristics of Cooling System | Fan Speed | Maximum Engine Heat Flow
**Introduction**

New Work Flow → Software Platform GT-SUITE® (POWER®)

### Previous Cooling Circuit

- **PTM**
- **EDC**

**Engine as heat source**

- One-way interface
- Cooling Circuit
- Engineering System

**Validated engine model**

- Fluid dynamics, injection, mechanics, closed-loop control (EDC) and the heat transfer are considered in one model
- Coupling of the cooling circuit and the engine model in one software
- Cooling circuit (water jacket, heat source, pipes, components) is modeled with calibrated heat transfer
- Detailed numerical engine analyses are possible
- Steady-State as well as transient simulation possible

**Up-to-date Powertrain Simulation**

**GT-SUITE®**

- **Injection System**
- **Physical engine model**
- **Gas Dynamic**

- **PTM**
- **EDC**

- Simple cooling circuit for cooling design in steady-state full load engine operating points
- No influence of cooling power on engine behaviour
- Physical heat transfer between heat source and fluid are not considered
- No accurate transient simulation possible
- Robust model for a rough estimation of required cooling size in the predevelopment phase
Introduction

Work Flow → Software Platform GT-SUITE® (POWER®)

- Engine Model
- Cooling Circuit
- Water Jacket Model
- FE Cylinder Structure

Software Platform GT-SUITE® (POWER®)
<table>
<thead>
<tr>
<th></th>
<th>Agenda</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
</tr>
<tr>
<td>2</td>
<td><strong>Model Description and Results</strong></td>
</tr>
<tr>
<td>3</td>
<td>Summary and Outlook</td>
</tr>
</tbody>
</table>
Model Description and Results
Detailed Engine Model

Charge Air
Exhaust Gas

LP-Stage
HP-Stage
CAC-LP
CAC-HP
Model Description and Results
FE Cylinder – Water Jacket

Heat transfer coefficient for heat flux in Intake-/Exhaust Ports, cylinder head

Heat transfer coefficient for heat flux in crank case

Thermal Mass Cylinder Head
Cylinder Head Flow
Crank Case Flow
Thermal Mass Crank Train
Model Description and Results
Cooling Circuit

- EGR
- Main Thermostat
- LT - Cooler
- HT - Cooler
- Water Jacket Model
- Water Pump
- CAC-LP
- CAC-HP
- Cooler Fan

- Charge Air
- High Temp. - Circuit
- Low Temp. - Circuit
Goal of steady-state operating point investigation:

- Comparison of direct and indirect cooling concepts for engines with single-stage and two-stage turbo-charger
- Verification of thermal load of different cooling components and cooling circuits
- Optimization of the max. fan speed for different cooling systems
Model Description and Results
Engine Concept Comparison

@1200rpm full load:

Heat Transfer - D2676 Euro VI 2WG iCAC
- iCAC: 35.8%
- RAD: 64.2%

Heat Transfer - D2676 Euro VI 1st dCAC
- dCAC: 30.1%
- RAD: 69.9%

Intake pressure
- Engine Speed [RPM]: 1200, 1400, 1600, 1800, 1900
- Intake Pressure [bar]: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

Fan Speed
- Engine Speed [RPM]: 800, 1000, 1200, 1400, 1600, 1800, 1900
- Fan Speed [rpm]: 1000, 1200, 1400, 1600, 1800, 2000

Engine Concept Comparison
Agenda

1. Introduction
2. Model Description and Results
3. Summary and Outlook
Summary and Outlook

Checklist

- Steady-State Validation with Test Rig Data ✓
- Comparison of different Engine Concepts ✓

- Next steps „short term“:
  Transient Full Vehicle Model in GT-Suite

- Next step „medium term“:
  Implementation of more detailed vehicle components via FMU
Summary and Outlook
Mean Value Engine with Full Vehicle Model

- Boundary Conditions
- Route Profile
- Longitudinal Dynamics
- Gear Shift Calibration
Summary and Outlook
Mean Value Engine with full Vehicle Model and FMUs

- Boundary Conditions
- Route Profile
- Longitudinal Dynamics
- Gear Shift Calibration
Thank you for your attention