Challenges in Thermal Management

Simulation Tools as Enablers for Complexity Management

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Worldwide CO₂ Targets – A Major Automotive Challenge

Regulative Constraints

- 2015 target will be achieved using efficient powertrain concepts and energy management technologies
  → all “quick wins” implemented, eDrive market share negligible
- 2020 target only achievable using significantly more ZEV vehicles
  → making electrified passenger cars more efficient entails thermal challenges

Thermal Management

- Safety: guarantee safe operation limits
- Design: intelligent air flow management
- Comfort: develop efficient HVAC systems
- Performance: high performing cooling systems
Worldwide CO$_2$ Targets – A Major Automotive Challenge

WLTP (World Harmonized Light Vehicles Test Procedure)

- **Target:** more realistic (higher) fuel consumption values

- **New Driving Cycle „WLTC“**
  - higher average speed
  - higher dynamic, no plateaus
  - longer distance and duration

- **New Test Procedure „WLTP“**
  - influence weight, aerodynamic
  - boundary conditions
  - additional tests e.g. 14°, AC

**Effect on thermal management:**

- Higher dynamic requires improved cooling of electrified drive trains
- Longer distance reduces influence of heat management
- New 14° cold test pushes on heat storage concepts
## Challenges and Chances for Thermal Management

### Vehicle Technology Focus

<table>
<thead>
<tr>
<th>Category</th>
<th>Challenges</th>
</tr>
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<tbody>
<tr>
<td>Aerodynamic Optimization</td>
<td>- reduced cooling mass flow due to smaller openings and closed underbody &lt;br&gt; - requires active air flow management and intelligent heat protection</td>
</tr>
<tr>
<td>Heat Storage and Recovery</td>
<td>- high efficiency only at high exhaust and working fluid temperatures &lt;br&gt; - requires temperature resistant materials and efficient re-cooling systems</td>
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<tr>
<td>Hybrids and Electric Vehicles</td>
<td>- narrow temperature band of HV systems even at low ambient temperatures &lt;br&gt; - requires new vehicle system architectures and new materials</td>
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<tr>
<td>New markets and Emission Cycles</td>
<td>- driving cycles including use of HVAC systems and real driving emissions &lt;br&gt; - requires new warm up control strategies and efficient HVAC solutions</td>
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4 Key Note 20th GT Conference - Stapf, Weinrich, Weller, Siegert, Daimler AG
Challenges and Chances for Thermal Management
Powertrain Technology Focus

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<th>Category</th>
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<tbody>
<tr>
<td>Cooling System</td>
<td>∗ optimization: Trade-off between heating and cooling of components</td>
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<td></td>
<td>→ new efficient cooling concepts to avoid additional costs and weight</td>
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<tr>
<td>Oil Circuit</td>
<td>∗ appropriate use of lubricants (bearing friction, piston cooling)</td>
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<td></td>
<td>→ new approaches for oil flow control strategy</td>
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<tr>
<td>Combustion</td>
<td>∗ challenge to meet low fuel consumption, emissions and high performance</td>
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<td></td>
<td>→ application of advanced combustion strategies</td>
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<tr>
<td>Crank Train</td>
<td>∗ extreme load due to high specific power density</td>
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<td>→ global strategy: Downsizing and reduction of friction losses</td>
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Cross-linked Thinking – Thermal Encapsulation
ECO Thermo Cover in the new S-Class

Thermography

Without ECO Thermo Cover

With ECO Thermo Cover

The CO₂ emissions in case of starting a cold engine are significantly reduced by storing heat in the underhood.
Cross-linked Thinking – Thermal Encapsulation
ECO Thermo Cover in the new S-Class

The cool-down is delayed over 24 hours with a maximum effect after 5 hours. The CO\textsubscript{2} benefit is depending on the operational profile up to 0,15 l/100km (annual average).
Cross-linked Thinking – Thermal Management
Transmission Oil Thermal Management

Different technical approaches

A) Heating of oil using coolant
+ Minimal change of hardware
- Priority to engine heating up
- Energy needed for engine heat up

B) Heating of oil using exhaust gas
+ Early availability of high exhaust temperatures
+ Engine heat balance remains unaffected
- Parasitic heat in bypass mode
- Exhaust gas back pressure
- Oil stability and oil aging
Cross-linked Thinking – Thermal Management
Active Adjustable Components – Smart Cooling

Thermostat: cooling temperature level

Smart-cooling
• Realization of customer benefits by efficient control strategies of components in different circuits
• Reduction of Friction (Bearings, Piston, Liner) and power request of the main water pump

 Interaction of Vehicle, Engine and Control Strategy in a unified model

Water pump: “no flow strategy“

Driving Cycles
Ways to Handle Complexity
Modern Development Tools - Simulation as Key to Success

Use of modern development tools

Computational Process & Tools

a) Implementation
Simulation thermal protection full vehicle

Year
2004
2008
2013
2020

Road - Vehicle Days
Computer - Simulation jobs
Test bench - Test day climate tunnel
Test bench - external tests

2020

GT-Suite

GT-Cool3D

GT-Power

GT-GEM3D

CFD

Vehicle model

lead

digital platform evaluation
digital loop 1
digital loop 2
hardware loop 1
hardware loop 2

Testing

Simulation

2020

2013

2008

2004

Vehicle heat rejection

front module
Ways to Handle Complexity
Use of modern Development Tools – Focus on Unified Model

Past
• Use of different models for different subsystems and load cases
• Most models build by different teams, interaction via look-up tables or co-sim

→ input data and models exchanged between different teams

Present
• Modular design of complex model
• Adapted interfaces enable exchangeability, models provided and also used by other departments
• Use of common unified models for different load cases

→ Homologation with new cycles and new boundary conditions for testing
→ Goal: realistic prediction of customer’s fuel consumption

Regulations & Requirements

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Ways to Handle Complexity
Use of modern Development Tools – Focus on Unified Model

High vehicle dynamic
Realistic Temperatures
  – Coolant
  – Transmission oil
  – Charge Air

Low ambient Temperatures
  – Thermal Comfort
  – Fast heat-up

High load cycle
Realistic temperatures
  – Heat protection
  – Control strategies

Homologation Cycle
  – Fuel consumption
  – Control strategies
Conclusion

• Thermal management plays a key role in the worldwide CO$_2$ target achievement
• Vehicle and engine optimization are both increasing the cooling requirements
• Cross-linked thinking gives a push on new technological innovations
• Advanced development tools require close cooperation with suppliers
• Interdisciplinary unified models open a new way to handle complexity
Conclusion

Coming together is a beginning; keeping together is progress; working together is success.

Henry Ford

Source: http://mikolasek.net/ch/jedertrage/index.php