Propulsion System Trends

Evolution of the TMM
A Closer Look at Electrification
System Integration Approach
Outlook

Powertrain Technology Roadmap
Megatrend: $\text{CO}_2$ Reduction

- Variety of propulsion → Modular architecture + advanced system integration
- Electrification → Responsible charging + waste-energy recovery, use, storage
- Stop/Start and Hybrids → Increased complexity + multiple cooling circuits
- Integrated Turbochargers → Increased + accelerated energy transfer to cooling circuit
- ICE Downsizing → Reduced heat capacity + increased specific load

Current situation → Future challenges
The Case for Enhanced Control

- Reduced heat capacity with higher nominal operating temperatures (ICE)
- Precisely reach and hold target temperatures
- Temperature as control factor is too slow
- Fast, load-based system control via ECU logic
- Allows for proactive heat rejection
- Larger sandbox for combustion strategy/innovation

Schaeffler TMM enables CO₂ savings up to 3% (NEDC)

- Faster warm-up
- Precise temperature level
- Wide temperature flexibility

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Gen I TMM - Overview

- Fail-safe thermostat
- DC-motor
- Main actuator – double-worm gear train
- Sensor cover with inductive position feedback
- Rotary valve #1 to control flow rate and routing

Engine mounting + block & cylinder head flows
Outlet flow to radiator
Outlet flow from oil HEX
Inlet flow to radiator
Inlet flow from turbo
Inlet flow from radiator outlet

Gen II TMM - Overview

- H-bridge integrated into PCB
- Smart actuator for split cooling
- Sensor cover with inductive position feedback
- Main actuator – high-efficiency spur gear train

Outlet flow to bypass
Outlet flow to heater core
Outlet flow to heater core
Inlet from block
Inlet from cylinder head
DC-motor double worm gear drive
Rotary valve #1 (Radiator/bypass/heater core)
**Gen III – Smart Single Valve (SSV) & Integrated Coolant Valve (ICV)**

- **Controller**
  - Voltage supply
  - Watchdog/wake
- **Motor driver/H-bridge**
- **Sensor**
- **EMC**
- **LIN**
- **Diagnostics**
- **PWM/analogue/SENT**
- **Interface to DC-motor**
- **Positioning sensor**
- **Ready for 48V**

- BUS interface
- Integrated motor driver & controller
- Power consumption: 0.2–0.4 A depending on hydraulic load
- Operating temperature: -40°C – 140°C

**Complexity of product**
- **Gen I TMM**
  - Zero-Flow Warm-Up
  - Active Cooling
  - Fail-Safe Thermostat

**Complexity of system**
- **Gen II TMM**
  - Split Cooling
  - Active Oil/Trans Heating
  - Smart Actuator
- **Gen III TMM**
  - Connect Independent Cooling Circuits
  - Support Electrification Systems
  - Modular Integration Options

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2018 Schaeffler Symposium
Pete Brazas – Thermal Management Synergy Through Integration
9/6/2018
Gen II – SMART Block Rotary Valve (BRV) Actuator

Gen II – Rotary Valve and Sealing Elements
Gen II – Cutaway View

Hydraulic Simulation Support – TMM Level

- CFD analysis of pressure losses
- Temperature mixing behavior
- Hydraulic forces on rotary valve
- Measurement of pressure losses
- Validation with experimental results
- Automated calculation of effective flow area
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Hybrid system generates much less waste heat energy than ICE
Must condition battery & cabin during transient ambient conditions
Energy emission from ICE is 30 kW + CAC 5-10 kW
How to optimize the system to maximize electric range & reliability?
Is plug-in conditioning responsible & what if no plug available?
Hybrid Case – Warm-Up Optimization

Why run the ICE early & often?
- Utilize the ICE as a heat energy source!
- Integrate TMM to enable fast warm-up of ICE
- Add SSV/ICV integration to distribute ICE heat energy to cabin & battery
- Further optimization through active heating/cooling engine oil and drivetrain

Hybrid Case - Optimization Effect on Battery SOC

Optimization Result
- Significantly lower power is applied to the PTCs
- Battery power consumption is reduced by more than 10% of battery capacity
- Electric range is enhanced without additional fuel consumption
- Further optimization possible with integration of TMM + SSV/ICV
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Optimize Your Energy Source (ICE)
Consider Case for Conditioning Battery & Cabin in Transients

Include Drivetrain in System-Level Integration
Simulation Model – Look for Synergy

Partner with Us for Simulation Support

Coolant system

Module

Physical behavior (3D CFD)

Flow branches flow rate

Component model

System model

CFG Software: OpenFOAM Autodesk Simulation CFD

1D mapping
Integrate Modular Solutions

Why ICV?
- System control at point-of-use
- No hoses = packaging benefit and mass reduction
- Fast system response due to less thermal mass
- Mounting concept eliminates external housing
- Centralized ECU control or independent SMART control

- Engine optimization – split cooling, flow control
- Drivetrain elements – transmission, differential, transaxle
- Electrification – battery conditioning, hybrid synergy, energy recovery/storage

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Propulsion Variety vs. Energy Balance

Start-up in transient conditions becomes more challenging with a higher degree of electrification.

Look for System-Level Synergy
Seek Integrated Solutions from an Expert Partner

Thermal Management
Synergy Through Integration

Opportunities for further optimization of ICE & drivetrain
Electrification challenges & optimization require a system approach
Consider PHEV transient conditions & responsible charging
Focus on synergy & integration for maximum efficiency and e-range
Schaeffler is ready to support with advanced component & system
Know-how, simulation tools, testing capacity, and innovative solutions