Absicherung des thermischen Verhaltens im Fahrzeugbau

Jörg Meinlschmidt & Helge Tielbörger | 10:00-11:00 Uhr

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Conference Code: 861 802 1958#
Herzlich Willkommen

Jörg Meinlschmidt
Portfolio Development
Siemens PLM Software
▪ Studium Maschinenbau TU München
▪ 5 Jahre Forschung im Bereich „Einsatz von CAE-Methoden in der Produktentwicklung“
▪ Seit 2006 bei Siemens PLM Portfolio Development Engineering Services

Dr. Helge Tielbörger
Portfolio Development
Siemens PLM Software
▪ Studium der Luft- und Raumfahrt
▪ Promotion im Bereich Mehrphasenströmung
▪ Seit 2011 bei Siemens PLM Portfolio Development Systemsimulation
VEM / VTM Through the Vehicle Program

Contents

Introduction
Vehicle Thermal Management Solution through the Development Cycle

- Testing solution
- 1D System level modelling
- 3D CFD approaches
- Combined 1D-3D strategies
Working in the boundaries of a stringent legal & financial environment

Stricter Regulations
Europe driving emissions control

Digital technology enabling reduced costs, and time to market.

Increased Complexity
Hybrids to full EV

Electric vehicles (HEVs & EVs) share could range from 10-50% of new vehicle sold in 2030.

Reduce Cost & Time
Maintain brand value

Adoption of right technology and finding the best balance differentiates those that thrive from those that fail

Source: Bloomberg New Energy Finance
Thermal Management Challenges

Define flow requirements and pre-sizing of heat exchanger and cooling pumps

Easily assess and validate heat exchangers packaging & design and controls strategies

Balance aerodynamic drag and efficient thermal management
Siemens Offering and Expertise

Engineering Services

Testing Solutions

Scalable 1D-3D Simulation Solutions
Introduction

Vehicle Energy Management Solution

- Testing solution
- 1D System level modelling
- 3D CFD approaches
- Combined 1D-3D strategies
Simcenter™ Portfolio for Predictive Engineering Analytics

Energy management and Performance Attributes Balancing – Digital Twin

- Requirements
  - Program Planning
    - Requirements Capturing
    - Target setting
  
- Concept & Architecture
  - Initial Design
    - Architecture Selection
    - and Evaluation
  
- Virtual Design, Verification & Validation
  - Detailed Design
    - Subsystem Design
    - Validation & Testing
  
- Physical Design, Verification & Validation
  - Perf. Attributes
    - Vehicle Integration Design
    - Validation & Testing
  
- Launch
  - Program Verification
    - Prototype Validation
    - Certification

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Program / Advanced Planning
Testing and modeling services

Integrated test and simulation process

 ✓ Define the right test for the simulation needs
 ✓ Build and validate the rights models
 ✓ Merge test and simulation results for deep analysis
 ✓ Testing competing technology
 ✓ Benchmarking
Vehicle Energy / Thermal Management
Target Cascading and Performance

- Model scalability and associated test requirements
- Specify required data and data acquisition methodology
- Interface contract between subsystems but also stakeholders
- Engineering performance evaluation (post processing and metrics)
Vehicle Energy / Thermal Management
Target Cascading and Performance

- Model scalability and associated test requirements
- Specify required data and data acquisition methodology
- Interface contract between subsystems but also stakeholders
- Engineering performance evaluation (post processing and metrics)
Customer Use Case:
Multi-attribute virtual trade-off investigation

Passenger comfort vs Fuel economy

case 1: baseline, no PTC, no Heat Storage

<table>
<thead>
<tr>
<th>Cabin comfort</th>
<th>Fuel consumption [g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to reach 15°C [s]</td>
<td>diff vs baseline</td>
</tr>
<tr>
<td>case 1</td>
<td>595</td>
</tr>
<tr>
<td>case 2</td>
<td>548</td>
</tr>
<tr>
<td>case 3</td>
<td>563</td>
</tr>
<tr>
<td>case 4</td>
<td>530</td>
</tr>
</tbody>
</table>

case 2: baseline + Heat Storage, no PTC

case 3: baseline + PTC, no Heat Storage

case 4: baseline + PTC + Heat Storage
Vehicle Energy / Thermal Management
1D-3D Simulation Scalability through the V-cycle

Detailed 3D Geometry not available

- Functional description
- Limitations of the 1D approach for the airflow
- Need for a more detailed analysis

Detailed 3D Geometry

- Weak coupling
- Co-simulation
- Imposed Boundary Conditions
- Detailed Geometry

Concept & pre-design
Subsystems pre-sizing
Subsystems sizing / System performance
Steady-State detailed cooling performance & validation

+3D airflow maps
Weak coupling Detailed Geometry
Vehicle Energy / Thermal Management
1D-3D Simulation Scalability through the V-cycle

1D internal flows added value: transient analysis, system simulation & when no CAD available
3D external flow added value: detailed steady-state analysis
Vehicle Energy / Thermal Management
Bridging the 1D / 3D Divide

Geometry Parameters
Components Performance data

Heat release from each Heat exchanger, car velocity, …

Air velocity and temperature maps for each Heat exchanger
Vehicle Energy / Thermal Management
Architecture selection and design refinement

Thermal management modelling – The Digital Twin development

When necessary, integrate impact of thermal management on subsystem performance and so define thermal management targets
- Subsystem cooling systems (ICE / Battery / EM / Fuel Cell)
- Heat exchanger stacking
- HVAC system with cabin volume
Vehicle Energy / Thermal Management
Architecture selection and design refinement
Vehicle Energy / Thermal Management
Architecture selection and design refinement
Vehicle Energy / Thermal Management
Architecture selection and design refinement

Coefficient Of Performance (COP)
Vehicle Energy / Thermal Management
Architecture selection and design refinement

Thermal management modelling – The Digital Twin development

When necessary, integrate impact of thermal management on subsystem performance and so define thermal management targets
- Subsystem cooling systems (ICE / Battery / EM / Fuel Cell)
- Heat exchanger stacking
- HVAC system with cabin volume

Outcome:
- Compute Thermal Management component heat exchanges / load requirements to complete target
- Analyze impact of such Thermal Management on system global performances
Vehicle Energy / Thermal Management
Architecture selection and design refinement

凉却液温度

Hot start

Cold start

T Water - Measurement - NEDC Cold [degCl]
T Water - Simulation - NEDC Cold [degCl]
T Water - Measurement - NEDC Hot [degCl]
T Water - Simulation - NEDC Hot [degCl]
Vehicle Energy / Thermal Management
Architecture selection and design refinement

Digital Twin outcome - Energy distribution flow chart

- Energy decomposition available thanks to model and test results
- Track the different energies: transferred, stored, losses
- In different physical domain: electrical, mechanical, thermal
- Battery status, energy recovery, …
Vehicle Energy / Thermal Management
Architecture selection and design refinement

Digital Twin outcomes:
- Energy decomposition available thanks to model and test results
- Track the different energies: transferred, stored, losses
- In different physical domains: electrical, mechanical, thermal
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Vehicle Energy / Thermal Management
Detailed Design

Capturing 3D physics to explore performance improvements

Performance evaluation
- For each subsystem
- Prepare integration
- Provide transparent link between 1D and 3D simulation

Optimize component performance
- Retrieves CAD and non-geometric data
- Automate workflow
- Run Design Exploration
- Optimize component design for critical operating points
Vehicle Energy / Thermal Management
Detailed Design

Working Towards the Virtual Prototype

Front End / External Air Flow

Complex Sub-system Modeling

Detailed Sub-Models

VTM Modelling – Over 5k+ Parts

Greater Model Complexity
Vehicle Energy / Thermal Management
Optimizing the Aerodynamics

Challenge:
• Increased legislation / demand to drive up efficiency and fuel economy
• Decrease emissions
• Increased importance of noise with EVs

Steady State:
• Efficient method to study design changes and narrow down selection

Transient:
• Used to provide accurate drag and lift coefficients on selected designs

Design Space Exploration:
• Multiple objective optimization: Reduce drag, heat shield temperature, weight, cost…. But maximize cooling, efficiency,…
• Find Sensitivities in your design space: Random sampling technology lets you see “what happens if”
Mercedes-Benz
Using design exploration to achieve record drag value

- Reduced time for generation new concept by nearly 50%
- Over 300 design variations were compared
- Digitalizing entire value chain – from development, through production to marketing & sales

Concept IAA (Intelligent Aerodynamic Automobile)

- Aerodynamics was developed with numerical flow simulation
- Vehicle changes shape over 80 km/h to reduce drag at highway speeds

- Over one million CPU hours was used to simulate air flow of the new prototype
- Drag coefficient reduced to 0.19 through design exploration

“What previously took up to one and a half years, we managed in less than 10 months thanks to digitalization”

Dr. Dieter Zetsche, Head of Mercedes-Benz Cars
Case Study: Thermal Cracking

Challenge:
• Assess temperature distribution in block and associated potential cracking

Services Solution:
• Close collaboration with Engineering Services team helped develop validated CHT methodology
• Analysis shifted from reactive to predictive
• Provides ability and confidence to run the analysis months ahead of the tests, highlighting any concerns
Detailed Subsystem Modelling: Heat Release Through Cooling Circuit

3D velocity maps extracted from CFD

Amesim stack model with HEAT library

Amesim System Model

OR
Vehicle Energy / Thermal Management
Detailed Design

Case Study: Full Vehicle Heat Protection

Challenge:
• Predict temperature and HTC distribution

Services Solution:
• Developed Co-simulation methodology (Fluid and Solid)
• Steady or Transient solution
Vehicle Energy / Thermal Management
Drive Cycle Analysis

Challenge:
• Complete fluid / solid model (5000+ parts)
• Flexible de-coupled solution to allow easy set-up of different cycles
• Accurate prediction of component temperatures
• Using the full vehicle model enables prediction of transient component temperatures under different driving scenarios:
  • Vmax, Idle (Hot countries), Thermal Soak, Drive Cycles
Vehicle Energy / Thermal Management
Vehicle Integration, balancing attributes

- Feeding back the knowledge gained from the detailed 3D analyses into the system model to further increase the accuracy

- Predict cell temperature variation, and optimize battery pack using full system simulation including battery, electric systems, thermal systems, coupled with detailed 3D cell model

- Use the model to balance battery performance to HVAC, defining the control systems
Vehicle Energy / Thermal Management
Vehicle Validation for Digital Sign Off

Controls
- Final validation and calibration of control software (SiL / HiL)
- Simulate millions of miles and perform up to 80% controls software validation
- Pre-calibrate controls software parameters
- Model-based testing
- Prototype testing and verification

Final digital and product sign-off
Vehicle Energy / Thermal Management
Vehicle Validation for Digital Sign Off

Plant model

Control model

Export

RT integration

HIL
Test bench

Intake Pressure
+-5%

Torque
+-5%

AirFlow
+-5%

Injected fuel
+-5%

Test automation

Remote access to HIL systems

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Vehicle Energy / Thermal Management  
Vehicle Validation for Digital Sign Off
Customer Usecase – Continental
Optimizing electric vehicles driving range with Simcenter Amesim

- Shortened early stages of design
- Optimized electric vehicle and increased driving range
- Enhanced reputation for expertise and knowledge in the marketplace

Accelerating strategic decisions and prototype development

- Evaluate the impact of thermal management strategies on vehicle performance
- Compare different battery heating and cooling methods

“We were able to rapidly select the right architecture with the best performance and focus on the next steps of the project.”

Sebastian Brixner, System Engineer
Samsung SDI
STAR-CCM+ improves battery pack cooling

- Designed novel liquid coolant based thermal system
- Predicted sensitivity of thermal performance to contact resistance
- Reduced thermal variation inside battery pack

Examining tradeoff between pressure loss on coolant system to temperature uniformity

- Thermal systems is critical for high performance and long battery back life.
- Simulation helps maintain batteries in narrow temperature range

Volumetric Heat Rejection and Jelly Roll Temperatures are generated inside the pack.

“Using the CFD-based TMS functional model with STAR-CCM+ and Battery Design Studio, a close agreement between simulations and experimental measurements was achieved, validating the model against experiment with greater than 90% accuracy”

Dr. Suman Basu – Senior Chief Engineer at SAIT
Vehicle Thermal Management study using 1D & 3D CFD

Mitsubishi
STAR-CCM+ enables thermal management for PHEV SUV

- Ensured SUV has extended range while balancing thermal challenges in the design.
- Enabled cutting edge innovation for Plug-in Hybrid Electric Vehicles
- Conducted loosely coupled 1D/3D simulation to enable different drive conditions.

HVAC System with Simplified 1D Network

Using 1D Simulation Coupled to 3D for Improved Idle Performance

- Used 1D and 3D CFD to define all internal thermal ventilation for optimal performance.
- 3D CFD applications include cabin comfort, windshield defrosting, air ventilation duct design, radiator and underhood thermal design.

“Currently, our 1D and 3D co-operative analysis approach is leading our accuracy improvements. We use it to evaluate equipment parts and it is ideal to have the performance of each single, required AC part, simulated to satisfy the targeted cooling system performance level.”
Conclusions

Simcenter provides a single source of products and consulting that encompasses complete vehicle testing, measurement and simulation for Vehicle Thermal Management applications.

Capabilities include:

- Appropriate use of Testing, 1D and 3D simulations that can help addressing the Full Vehicle Thermal Management challenges throughout the entire vehicle design program
- Thermal Analysis from component to system level
- Dedicated Testing facilities and Engineering Services expertise for Vehicle Thermal applications
Vehicle Energy / Thermal Management
Where to go next…

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Kontakt

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