Tasks of complete vehicle simulation to ensure future CO2 regulations

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Complete Vehicle / Energy Management
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Dynamic Simulation in Vehicle Engineering
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Problem of Energy Management Simulation

Aerodynamic CFD Simulation

Simulation Fuel Consumption and Driving Performance

Results:
Interesting pictures with colors
Looks very complex

Results:
Some black numbers
Looks very simple

<table>
<thead>
<tr>
<th>NEDC</th>
<th>7,6 l/100 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acc 0...100 km/h</td>
<td>8,9 sec.</td>
</tr>
</tbody>
</table>
Content

• Introduction Energy Management
• CO2 emission regulation
• Complexity of simulation model variants
• Level of detail of the simulation models
• Universal model for hybrid vehicles
• Automated simulation
• Optimization of vehicle fleet
• Conclusion
Responsibility of Energy Management

ENERGY MANAGEMENT

- Fuel Economy
- CO₂ Emission
- Driving Range
- Performance
- Driving Quality

Life Cycle Assessment LCA

Vehicle/propulsion architecture

Operating strategy

Simulation

Validation Verification (Testing)

Costs
CO2 emission regulation in Europe

Example vehicle fleet distribution

- Improve Gasoline vehicles
- Improve Diesel vehicles
- Improve Hybrid vehicles
- Increase number of hybrid and electric vehicles

Source data: www.mercedes-benz.de
Walk Chart for reducing CO2 emissions

**2015 Fleet Target 130gCO2/km**
- Base Vehicle
- ECO Tire
- Aerodynamic
- LightWeight
- Thermal Management
- Automated Gearbox
- Engine Optimize Setp 1
- Engine Optimize Step 2
- Engine Start Stop
- Regulated Voltage Control
- MicroHybrid 48V

**2020 Fleet Target 95gCO2/km**
- Updated Vehicle

**Target 2015 for 1280 kg**
- Target 2015 for 1180 kg

**Target 2020 for 1180 kg**

**Complete Vehicle**
- Powertrain
- Hybrid Systems

**Exemplary vehicle**: C-Segment Sedan, 1280 kg, 1,6 l gasoline ICE, Manual Transmission, 155 gCO2/km
Simulation model

- Engine dynamic
- Tire characteristic
- Heat up
- Dynamic demand of auxiliaries
- Shifting procedure

Effort Complexity Accuracy
Detailing engine heat up

- Option 1: Detailed thermal simulation tool

- Option 2: simplified modelling
**Detailing engine heat up**

- **Comparison heat up in NEDC**

![Graph showing the comparison between measurement, detailed simulation, and simplified simulation of coolant temperature over time.](image)

- **Y-axis:** Coolant temperature [°C]
- **X-axis:** Time [s]
- **Legend:**
  - **Black line:** Measurement
  - **Blue dashed line:** Detailed simulation
  - **Green dashed line:** Simplified simulation
  - **Light green dotted line:** Deviation temperature
  - **Purple dotted line:** Deviation cumulated fuel consumption

**Note:** Disclosure or duplication without consent is prohibited.
Comparison heat up in NEDC with startstop

- Detailing engine heat up

![Graph showing coolant temperature vs. time for a base vehicle with startstop, with measurements compared to simplified simulation and deviation analysis.](image-url)
How to analyze hybrid vehicles in feasibility phase

- Additional degree of freedoms for hybrid vehicles
  - Battery size
  - Electric motor size
  - Location of electric motor(s)

- Operating strategy
  - Power limitations
  - SOC balance
  - Electric driving
  - ICE driving
  - Recuperation
  - Load point shifting / charging
Example: universal mild hybrid model

- 12 V system
- HV system
- Variable Battery Dimension
- Variable Electric Motor Dimension
- Variable Operating Modes
- ICE
- CLUTCH
- GEARBOX
- Vehicle
- 12V STARTER
- 48V STARTER/GENERATOR
- BELT DRIVE
Example: universal mild hybrid model

- Vary motor power and location

![Graph showing acceleration time improvement vs. fuel consumption improvement for different motor power and location settings. The graph includes data points for various power levels, such as 6 kW and 12 kW, and highlights the improvement in acceleration time and fuel consumption improvement for each setting.]
Example: universal mild hybrid model

Regenerative Energy on Battery [Wh]
Mechanic Peak Power of ISG [kW]

- Kinetic potential at 1360 kg
- Mechanic potential
- Electric potential
- Including operating strategy limits

Efficiency E-Motor
Operating strategy and Operating points
Engine drag torque

Drag and loss due to Aerodynamic, tire, powertrain

Average demand electric auxiliaries

*diagram based on Das 48V Bordnetz, R. Friedrich, 2013
Relevance for fleet calculation

Example vehicle fleet distribution

CO2 Emissions [gCO2/km]
Curbweight [kg]

Status simulation runs for whole vehicle matrix

Improve fuel consumption for new vehicles in feasibility phase

Body
Transmission
Engine
Vehicle matrix
Cycles
Measures for improvements
Using scripting for automated simulation

- **Global parameters**
- **Simulation model**
- **Parameterization**
- **Run Simulation**
- **Extract results**
- **Scripting**
Process from feasibility to serial development

Define vehicle matrix

Select data for components

Select simulation model

Set of basis models

Detailed model

Analyze cycles

Evaluate influence of measures for improvement

Verify with measurements

Current Status
- Eco Tires
- Aerodynamic Improvement
- Thermo-management
- Start Stop
- Regulated Voltage Control
- Optimize Engine

Step 1: Optimize Engine

Step 2: Status with Potentials

CO₂ Emissions [g/km]

Europe

Select simulation model

Verify with measurements

Analyze cycles

Evaluate influence of measures for improvement

Set of basis models

Detailed model

Select data for components

Define vehicle matrix
Influence due to different markets

Question: Global Optimal Vehicle Configuration?
Cost optimization of vehicle fleet

Vehicle Matrix
- Engine
- Transmission
- Tire
- Body
- Equipment

Legal Regulation
- Europe
- US
- ...

Simulation Environment

Analysis Methodology

Improvements for fuel economy
- Aerodynamic
- StartStop
- Water Pump
- ...

Results
- Cost of vehicle x
- Cost of vehicle y
- ...

*project founded by Austrian BMVIF in thematic “Talente”
Summary

• CO2 regulations require improvement of every vehicle of the fleet

• Flexible simulation model is needed

• Due to high simulation number find best compromise between simulation time and accuracy

• Degrees of freedom of hybrid vehicles requires flexible simulation model to handle all possible configurations

• Stricter regulation increase the impact of additional cost

• For observance of the CO2 targets the whole fleet on global level have to be optimized
Thank You
For Your
ATTENTION!

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