Reducing Diesel Railcar CO2-Emissions by means of Electric Energy Storages

Discussion of Operating Concepts for Hybrid Diesel Multiple Units

Holger Dittus
Introduction – Diesel Multiple Units (DMUs)

• Typical regional DMUs:
  – vMax ~ 140 km/h
  – distance between stations 1 to 10 km
  – diesel engine with electric, hydraulic or hydro-mechanic drive train
  – vehicle weight 90 to 150 t
  – ~ 14 % of passenger train km in Germany

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• Basic strategy for energy efficient driving:
  – accelerate as fast as possible
  – drive with constant speed → “cruising”
  – roll out without traction power → “coasting”
  – brake to still stand with high deceleration rate
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Hybrid DMU Concept 2

- Characteristics of concept 2:
  - Strategy: provide traction support
  - Brake energy recuperation
  - Mechanically powered auxiliaries

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Hybrid DMU Concept 1

- Characteristics of concept 1:
  - Strategy: shut down diesel during station stops to avoid inefficient operating points, no traction support
  - Brake energy recuperation
  - No emissions & noise within station area
  - Electrically powered auxiliaries

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Hybrid DMU Concept 3

- Characteristics of concept 3:
  - Strategy: shut down diesel engine during station stops, provide traction support
  - brake energy recuperation
  - no emissions & noise within station area
  - electrically powered auxiliaries
Questions

– Which concept achieves lowest CO2-emissions?

– Is energy efficient driving style appropriate to hybrid DMUs? Which influence has the deceleration rate?

– How does electric drive power affect recuperated energy & CO2-reduction?

– Where do the reductions result from?
Simulation Input Parameters

- DMU mass conventional 96 t, hybrid 102 t (+ 6 t for electric drive & storage)
- diesel engine 560 kW, 3200 Nm per power pack
- electric drive, power ratings: 150, 300, 450 kW (1000, 2000, 3000 Nm)
- constant mechanic / electric auxiliary load 45 kW per power pack
- stop time in stations 60s, distance between stations 5 & 10 km, flat track
- max. velocity 100, 120 & 140 km/h
Simulation Results

- Energy efficient driving style
  - Conventional DMU

  ➔ high deceleration rate increases fuel & CO2-savings
  ➔ savings up to 9 % at high deceleration rate
Simulation Results

• Energy efficient driving style
  – Hybrid DMU Concept 2

Hybrid DMU Concept 2
- Distance: 5 km
- Max. Velocity: 140 km/h
- Mass: 102 t
- Electric drive power: $2 \times 450$ kW

### Deceleration

- 0.6 m/s²
- 0.8 m/s²
- 1.0 m/s²

### Norm. Charge Energy

<table>
<thead>
<tr>
<th>Deceleration</th>
<th>Norm. Value [%]</th>
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</thead>
<tbody>
<tr>
<td>0.6 m/s²</td>
<td>100</td>
</tr>
<tr>
<td>0.8 m/s²</td>
<td>90</td>
</tr>
<tr>
<td>1.0 m/s²</td>
<td>80</td>
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</table>

### Norm. Fuel Consumption

<table>
<thead>
<tr>
<th>Deceleration</th>
<th>Norm. Value [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 m/s²</td>
<td>70</td>
</tr>
<tr>
<td>0.8 m/s²</td>
<td>60</td>
</tr>
<tr>
<td>1.0 m/s²</td>
<td>50</td>
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Simulation Results

- Energy efficient driving style
  - Hybrid DMU Concept 2

  → 34 % less energy recuperated at 1 m/s²
  → 3 % reduction of CO2 & fuel consumption
  → smaller effect of deceleration rate variation

  → Driving Style adaptation to hybrid DMU needed!

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Simulation Results

- **Effect of electric drive power**
  - Hybrid DMU Concept 2

  ![Bar chart showing the effect of electric drive power on normalised charge energy and relative fuel consumption.]

  - More power increases amount of recuperated energy
  - CO2 & fuel savings increase with drive power

**Hybrid DMU Concept 2**
- Distance: 5 km
- Max. Velocity: 120 km/h
- Mass: 102 t
- Deceleration rate: 0.8 m/s²

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Simulation Results

- Effect of electric drive power
  - Where do the CO2 and fuel savings result from?

Additional traction power $\rightarrow$ shorter acceleration phase
$\rightarrow$ extended coasting phase
Simulation Results

- Engine stop within stations
  - diesel engine operating points

→ Engine stop avoids > 25% of idle time compared to conventional DMU

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<td>Max. Velocity:</td>
<td>120 km/h</td>
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<tr>
<td>Mass:</td>
<td>102 t</td>
</tr>
<tr>
<td>Electric drive power</td>
<td>2 x 450 kW</td>
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<tr>
<td>Deceleration rate</td>
<td>0.8 m/s²</td>
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Simulation Results

• Comparison of Concepts

- Concept 1: limited CO2-savings
- Concept 2: CO2 & fuel savings up to 12 %
- Concept 3: Combination of zero emission in stations and overall CO2-reduction up to 10 %

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Summary – Concept 1

• Pros:
  + local zero emission operation in station area
  + CO2 and fuel savings up to 4 %

• Cons:
  - maximum CO2-reduction & fuel savings predefined by stop time & auxiliary load → capped benefit
  - minimum electric drive power required to provide benefit
  - changes in system layout (electric auxiliaries)
Summary – Concept 2

• Pros:
  + best in CO2 & fuel savings (up to 12 %)
  + benefit even with small electric drive power
  + add-on system, no changes in auxiliary system
  + similar storage power when charging / discharging
  + recuperates more brake energy than other concepts

• Cons:
  - local emissions in station area
  - highest storage capacity needed
Summary – Concept 3

• Pros:
  + local zero emission operation in station area
  + CO2 & fuel savings up to 10 %
  + additional electric power provides higher benefit

• Cons:
  - minimum electric drive power required to provide benefit
  - changes in system layout (electric auxiliaries)
Conclusions

• Traction support provides best CO2-reduction & least complex system layout

• Engine stop functionality requires sufficient electric drive power & changes in system layout

• Combined hybrid system provides good CO2-reduction and local zero emission

• Adaptation of energy efficient driving style to characteristics of hybrid DMUs recommended
Conclusions

Thank you for your attention!

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