Real driving emissions from a diesel-hydraulic rail vehicle

Michal Vojtisek-Lom1, Janůš Jirků2, Martin Pechout3
1 Institute for Automobile, Combustion Engine and Railway Engineering, Czech Technical University in Prague
2 Faculty of Transportation Sciences, Czech Technical University in Prague
3 Department of Vehicles and Engines, Faculty of Mechanical Engineering, Technical University of Liberec

Contact: michal.vojtisek@fs.cvut.cz, tel. (+420) 774 262 854

**Background:** Real driving emissions are often higher than those during laboratory certification tests, as they include conditions for which some engines are not optimized. They are monitored on heavy on-road vehicles in the EU and U.S., with better extension to non-road mobile machinery (NRMM). Testing of non-road engines over 560 kW is difficult—there are few laboratories, and measuring and transporting engines is expensive. Diesel-electric locomotives can be tested at standstill using a load bank, but diesels-hydraulic locomotives need to be moving in order to maintain load on the engine. Portable on-board emissions monitoring systems (PEMS) can be used, but surprisingly, given safety and operational constraints, there is not much available space on many types of machinery including rail vehicles.

**Goal:** Evaluation of real driving emissions of a diesel-hydraulic motorized rail vehicle during its regular service on passenger train routes.

**Approach:**
- Czech Railways model 854 motorized railcar with a 2004 12-cylinder, 29-liter, 808 kW (only 588 kW used) Caterpillar 3412 engine (US EPA 0.29 g/kWh PM), with about 1 million km in service, was fitted with a miniature PEMS mounted entirely at the end of the dead-end isle of the engine compartment (no place elsewhere).
- The car was running alone or with up to three non-motorized cars on local and express train routes on the Praha-Turnov route.

**Severe environment:** 0-55°C; vibrations, "rail dust" (a mixture of soot, oil, grease, iron oxide brake dust); lack of access during most of the train run.

**Lack of space:** Confinement into "dead-end isle" of engine compartment (nothing can be put outside of the train, no opening to conductor cabin; one aisle to remain free for train engineer to walk through during turnarounds).

**Home-made mini PEMS design**
- CO, CO2, NDIR - NO, NO2: electrochemical cells
- PM mass: proportional sampling gravimetric
- Indicative online PM mass: light scattering
- Particle length: measuring ionization chamber
- Position & speed: GPS
- Intake air flow: calculated using speed-density method from measured engine rpm and measured intake air pressure and temperature

**Summary data**

<table>
<thead>
<tr>
<th>All measured segments</th>
<th>303.9</th>
<th>107</th>
<th>0.14</th>
<th>2835</th>
<th>8.2</th>
<th>43</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start &amp; switching</td>
<td>1.7</td>
<td>212</td>
<td>0.33</td>
<td>5625</td>
<td>22.4</td>
<td>77</td>
<td>3.2</td>
</tr>
<tr>
<td>Praha - Mladá Boleslav (Os 9504) 1+1</td>
<td>71.6</td>
<td>94</td>
<td>0.15</td>
<td>2483</td>
<td>8.9</td>
<td>31</td>
<td>0.8</td>
</tr>
<tr>
<td>Mladá Boleslav - Turnov</td>
<td>85</td>
<td>0.11</td>
<td>2248</td>
<td>9.7</td>
<td>33</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Turnov - Praha (express R 1145) 1+3</td>
<td>103.6</td>
<td>125</td>
<td>0.14</td>
<td>3321</td>
<td>5.9</td>
<td>55</td>
<td>2.5</td>
</tr>
<tr>
<td>Mladá Boleslav - (Os 9514) 1+2</td>
<td>74.9</td>
<td>107</td>
<td>0.14</td>
<td>2836</td>
<td>9.5</td>
<td>42</td>
<td>2.4</td>
</tr>
</tbody>
</table>

**Emissions per passenger-km**

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Fuel liters per 100 km</th>
<th>PM [g/km]</th>
<th>CO2 [g/km]</th>
<th>CO [g/km]</th>
<th>NO [g/km]</th>
<th>HC [g/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Praha-Mladá Boleslav (Os 9504)</td>
<td>221</td>
<td>1.70</td>
<td>0.0027</td>
<td>45</td>
<td>0.16</td>
<td>0.57</td>
</tr>
<tr>
<td>Turnov - Praha (express R 1145)</td>
<td>467</td>
<td>1.07</td>
<td>0.0012</td>
<td>28</td>
<td>0.05</td>
<td>0.47</td>
</tr>
<tr>
<td>Praha - Mladá Boleslav (Os 9514)</td>
<td>344</td>
<td>1.24</td>
<td>0.0017</td>
<td>33</td>
<td>0.11</td>
<td>0.49</td>
</tr>
</tbody>
</table>

**Conclusions:**
- Measurement challenging but feasible
- Moderate excess PM at cold start, long idle, transients—otherwise steady-state
- PM exhaust emissions relatively low

**Acknowledgments:**
The authors thank to the Czech Railways Praha-Vršovice locomotive depot for allowing the test to be carried on during routine on-board emissions for technical support.

The work at TU Liberec was funded by the EU LIFE+ program, project MEDETOX – Innovative Methods of Monitoring of Diesel Engine Exhaust Toxicity in Real Urban Traffic (LIFE10 ENV/CZ/651). The work at Czech Technical University was funded by the The Ministry of Education, Youth and Sports program NRU I (LO), project I.01.1.03/10/00241. Support of inter-university mobility and quality enhancement of research teams at Czech Technical University in Prague.