Exhaust particles formed during engine braking: contribution on total particle emissions of GDI vehicles

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INTRODUCTION
Particle formation mechanisms

- Engine-out particles
- After dilution & cooling
- Engine braking

Steady, transient

Transient, Engine brake (negative torque)
Our first observation (Rönkkö et al. 2014): Diesel truck
What is needed for the detection of particles during engine braking?

1. Careful choice of exhaust sampling location
2. Sampling without typical exhaust tracers such as CO₂
3. Real-time (~1 Hz) particle instruments capable to detect sub-10 nm particles
4. Possible ways to separate different particles from each other and
5. Data related to exhaust flow rate and temporal differences in it
6. Time delay correction from exhaust manifold to the particle instrument
EXPERIMENTAL
Methods
Laboratory studies

Real-time instruments & Sampling mimics real-world particle formation

On-road chase studies

Mobile laboratory "Sniffer" (Pirjola et al. 2004)

Real-world driving and dilution
# Gasoline vehicles

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2011</td>
<td>2011</td>
<td>2012</td>
</tr>
<tr>
<td>Displacement (l)</td>
<td>2.0</td>
<td>1.8</td>
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<tr>
<td>Turbocharged</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Injection</td>
<td>GDI (Stratified)</td>
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<td>GDI (Stratified) + PFI</td>
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<td>Tested in</td>
<td>Chassis dyno</td>
<td>Chassis dyno</td>
<td>On-road</td>
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<tr>
<td>Test routine</td>
<td>NEDC</td>
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<td>Acc./Dec. patterns</td>
</tr>
</tbody>
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RESULTS
Vehicle 1. Size distributions

1st engine braking

2nd engine braking

3rd engine braking

4th engine braking
Vehicle 2. Particles collected over the NEDC

Spheres contain oxygen, zink, phosphorus and calcium that are components of lubricant.

Particles absent during steadys.

We propose these were emitted during decelerations.
Vehicle 3. Particle emissions during engine braking under on-road conditions
### Engine braking particle emissions of vehicles (table revisited)

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<tr>
<td>Fraction of total particle concentrations</td>
<td>–</td>
<td>~35%</td>
<td>–</td>
</tr>
<tr>
<td>Fraction of total particle emissions</td>
<td>23–29%</td>
<td>~10%</td>
<td>3–18%</td>
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Future work

- Time delay from exhaust manifold to particle instrument varies depending on the driving conditions
  - Longer delay during engine braking (low exhaust flow)
- When plotting NEDC time series, the time axis for particle concentrations is not linear
- Requires modeling to stretch and compress to compare vehicle parameters and exact particle concentrations on the same axis
To conclude about particles during engine braking

- Depend largely on e.g. vehicle type, driving routine…
- Potentially harmful because contain metals (zink, phosphorus, calcium)
- Exact formation mechanism not yet known
- Can be removed by particle filtration
- Can also be affected by choice of lubricant?
- Topic needs further research
References


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