Performance of HORIBA-SPCS in the PMP LDD ILCE

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Acknowledgement

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Joint Research Center
Motivation of Development

Conventional PM Measurement
- Mass Measurement is approaching to limit
- Variation of Measurement is very high

PMP Background
- Alternative/Improvement of Mass Measurement
- Considering danger of Nano-Particles

ECE Draft Regulation from PMP
- Number Counting of Particles
- (Keeping Mass Measurement Active)
PMP Recommended System

Dilution Air

PND_2: Cold Dilution
PND_1: Hot Dilution

CPC

PNC

Pre-classifier

Pump

Evaporation

Stable

Unstable

CVS Tunnel

@25C

@320C

@150C

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SPCS Flow Schematic

Sample

@150°C

Dil Air

FM-1

PND1

FM-2

EU

@320°C

PND2

CPC

@Room Temp

MFC

Dil

Air

Dil

Air

MFC

MFC

MFC

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ETH 2005

SAE Paper 2006-01-0864

SAE Paper 2006-01-0865

JSAE Paper 20065044
Basic Performances
In Brief
Penetration of Solid Particles

Penetration = \frac{\text{Concentration after SPCS} \times \text{DR}}{\text{Raw Concentration Before SPCS}} \times 100

- **PMP >90%**
- **Particle Loss <3%**
- **Penetration >97%**
Dilution Ratio Check with $C_3H_8$

Actual DF = \frac{\text{Raw Concentration (C}_3\text{H}_8)}{\text{Diluted Conc. - Background}}

Error in DF = \frac{\text{Ref. DF} - \text{Act. DF}}{\text{Ref. DF}} \times 100

PMP Recommendation:
- Ref. DF
- Act. DF

< 2% DF Error <6%

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Removal of 50nm C40 Particles

Evaporator

99% Removal

EU: OFF

Removal > 99%

EU: ON

25 °C

320 °C

Particle Number

Time sec
### Linearity of Counter

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Particle Only</th>
<th>Reference</th>
<th>HORIBA-SPCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>7200</td>
<td>7200</td>
<td>7200</td>
</tr>
<tr>
<td>80%</td>
<td>5760</td>
<td>5757</td>
<td>5775</td>
</tr>
<tr>
<td>60%</td>
<td>4320</td>
<td>4317</td>
<td>4300</td>
</tr>
<tr>
<td>50%</td>
<td>3600</td>
<td>3598</td>
<td>3580</td>
</tr>
<tr>
<td>40%</td>
<td>2880</td>
<td>2877</td>
<td>2860</td>
</tr>
<tr>
<td>30%</td>
<td>2160</td>
<td>2164</td>
<td>2155</td>
</tr>
<tr>
<td>20%</td>
<td>1440</td>
<td>1445</td>
<td>1435</td>
</tr>
<tr>
<td>10%</td>
<td>720</td>
<td>728</td>
<td>720</td>
</tr>
<tr>
<td>0%</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

**Formula:**

\[ y = 0.994x - 33.463 \]

\[ R^2 = 0.9997 \]

**Graph:**

- **Good linearity**
- **Reference Concentration**
- **CPC Concentration**

**Legend:**
- **Calculated**
- **Actual**
## Test Vehicles

<table>
<thead>
<tr>
<th>Engine</th>
<th>Swept Vol.</th>
<th>After Treatment system</th>
<th>Mileage</th>
<th>Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>GV TC-DI Diesel</td>
<td>2.0 L</td>
<td>SiC + FBC</td>
<td>2898 km</td>
<td>Manual 6</td>
</tr>
<tr>
<td>AV-1 TC-DI Diesel</td>
<td>2.0 L</td>
<td>DPF + DOC</td>
<td>2140 km</td>
<td>Manual 5</td>
</tr>
<tr>
<td>AV-2 NA-DI Gasoline</td>
<td>3.0 L</td>
<td>TWC + NRC</td>
<td>9317 km</td>
<td>Automatic</td>
</tr>
</tbody>
</table>
Real Time Emission from GC

Golden Vehicle
NEDC Mode

Measured by SPCS

Highly Repeatable

Golden Vehicle
NEDC Mode

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Particle Emission Rate = 100 \times \sum_{0}^{T=t} N / \sum_{0}^{T=1200} N

Golden Vehicle
NEDC Mode

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Test under JC08 Driving Mode

Golden Vehicle

Highly Repeatable

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Particle Emission Rate

GDI Vehicle
NEDC Mode

![Graph showing particle emission rate over time for a GDI vehicle in NEDC mode.](image)
Repeatability of PM Mass

Test No.

PM gm/km

GV

AV-1

AV-2

PM gm/km

GV

AV-1

AV-2

COV (%)

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Golden vehicle driven under NEDC mode
Co-Efficient of Variation

![Bar Chart]

<table>
<thead>
<tr>
<th></th>
<th>GPMS</th>
<th>SPCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GV</td>
<td>11.8%</td>
<td>21.2%</td>
</tr>
<tr>
<td>AV-2</td>
<td>6.8%</td>
<td></td>
</tr>
<tr>
<td>AV-1</td>
<td>3.6%</td>
<td></td>
</tr>
<tr>
<td>Coefficient of Variance</td>
<td>32.9%</td>
<td>7.1%</td>
</tr>
</tbody>
</table>
Conclusions

A solid particle counting system has been developed according to PMP recommendation.

The SPCS shows excellent sensitivity and repeatability for vehicle test.

The SPCS exhibits over 97% penetration for solid particles and error in dilution ratios less than ± 6%.

The system participated to the LDD_ILCE@NTSEL successfully.

Number counting of solid particles shows better repeatability than the conventional gravimetric mass measurement if the car is conditioned appropriately.
Thanking you

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