Proposal for the test mode

2019.1. 9

Based on VIAQ-07-08,
VIAQ-08-08,
VIAQ-14-15

Korea Transportation Safety Authority
Korea Automobile Testing & Research Institute
Background

- Consumer complaints “Exhaust gas entering into vehicle cabin”
  - Exhaust smell can disturb driving and raises safety concerns
- Ministry of Land, Infrastructure and Transport had launched an investigation into this issue
  - Possible leakage of exhaust fumes and exposure to carbon monoxide inside the vehicle
    - Defect Investigation in 2011 (49 vehicles) and in 2016 (1 vehicle)
    - Free repair service 3 vehicle models in 2012 and 1 model in 2016

<KBS news regarding “exhaust gas entering into vehicle cabin”>
<Official Press Release by MOLIT>
How could the exhaust gas enter into vehicle cabins?

- When cars highly accelerate with the condition on internal circulation mode, exhaust gases could enter the passenger compartment due to pressure difference in cabin and vortex flow in back part of the car.

Warning in vehicle owner’s manual: The boot lid must always be completely closed when the vehicle is moving, otherwise exhaust fumes can be drawn into the interior.

<table>
<thead>
<tr>
<th>Display messages</th>
<th>Possible causes/consequences and Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>🛒</td>
<td>Sedan: the trunk lid is open.</td>
</tr>
<tr>
<td></td>
<td>► Close the trunk lid.</td>
</tr>
<tr>
<td>🛣</td>
<td>Wagon: the tailgate is open.</td>
</tr>
<tr>
<td></td>
<td>► WARNING</td>
</tr>
<tr>
<td></td>
<td>When the engine is running, exhaust gases can enter the vehicle interior if the tailgate is open.</td>
</tr>
<tr>
<td></td>
<td>There is a risk of poisoning.</td>
</tr>
<tr>
<td></td>
<td>► Close the tailgate.</td>
</tr>
</tbody>
</table>

- Pull down the boot lid by the handle on the inside and let it drop into the latch = ![Image]
Computational Fluid Dynamics (CFD)

- Simulation for exhaust gases entering into cabin using the CFD method

- The vortex flow occurs in the back part of sedan vehicles depending on vehicle speed

* Source: Fundamentals of Vehicle Dynamics, Thomas D. Gillespie
Computational Fluid Dynamics (CFD)

- Simulation for exhaust gases entering into cabin using the CFD method
Test mode for exhaust gases entering into cabin

- Idling mode, (basic conditions)
  - Engine idling in normal condition

- Constant speed driving mode, (normal conditions)
  - 80 ± 5 km/h, 100 ± 5 km/h, 120 ± 5 km/h, 140 ± 5 km/h

- Acceleration mode, (worst-case conditions)
  - Accelerate vehicles from 65 km/h to 130 km/h right after that coast-down (deceleration) to 65 km/h, repeat mode

- Real-road driving mode
  - Real-road driving mode with/without acceleration
Proving Ground Test

- Proving ground driving test
  - Idling condition, cruising speed condition, acceleration condition
- Test vehicle: Gasoline vehicle, 3,000 cc, sedan
- Measurement devices setting position
  - Nose position of front seat, back seat
  - Center position of truck
  - Rear of vehicle
Gas and Speed Measuring Devices

- Test Device: Vbox mini
  - Speed Range: 0.1 ~ 1,609 km/h
  - Resolution: 0.1 km/h
  - Accuracy: 0.2 km/h

- Test Device: Testo 330 LL
  - CO Range: 0~500 ppm
  - Resolution: 0.1 ppm
  - Accuracy: ±2 ppm (0.0~39.9 ppm), Other range ± 5%

- Test Device: Testo 350K
  - NO Range: 0~300 ppm
  - Resolution: 0.1 ppm
  - Accuracy: ±2 ppm (0.0~39.9 ppm), Other range ± 5%
  - NO2 Range: 0~500 ppm
  - Resolution: 0.1 ppm
  - Accuracy: ±5 ppm (0.0~39.9 ppm), Other range ± 5%
Idling mode test

- Engine idling in normal condition, not moving
- Total test time: 10 min
  - Stabilizing time: 5 min, Measuring time: 5 min
- CO was detected in the rear hatch, but not detected in cabins
Cruising speed driving mode

Cruising speed driving mode, (normal conditions)

- 80 ± 5 km/h, 100 ± 5 km/h, 120 ± 5 km/h, 140 ± 5 km/h
- Each test time in stated speed : 5 min
- If CO is detected in test speed, test again that speed in 20 min
- CO was detected in 140 km/h,
Cruising speed driving mode

- 140 ± 5 km/h
- Total test time: 20 min (stabilizing time 10 min, measuring time 10 min)
- CO was detected in cabin with 140 km/h (8 ~ 9 ppm)
✓ **Acceleration mode**

**Acceleration mode, (worst-case conditions)**

- Test cycle: accelerate vehicles from 65 km/h to 130 km/h (WOT), right after that coast-down (deceleration) to 65 km/h, cruise drive 500 meter, and then repeat mode.

- Total 8 cycle (4 stabilizing cycle, 4 measuring cycle)
Acceleration mode

- Acceleration mode, (worst-case conditions)
  - When accelerating, high concentration of CO was detected in rear area (max 3,000 ppm)
  - When accelerating, CO enter into the trunk zone through the rear of hatch (max 100 ppm)
  - CO concentration was increased gradually from 40 ppm to 80 ppm
Real-road Driving Test

- Real-road Driving test
  - Real-road driving mode
    - Real-road driving test in same course with/without acceleration (2 mode)
    - Driving course: 45 km (most of highway road)
    - Average vehicle speed: approx. 80 km/h
    - Driving time: approx. 40 min
Real-road Driving Test

- Real-road Driving test
  - Real-road driving mode
    - Real-road driving test in same course without acceleration
    - Smoothing driving, Throttle open not more than 50%
    - CO was not detected in cabin
- **Real-road Driving test**
  - **Real-road driving mode**
    - Real-road driving test in same course with acceleration (near WOT)
    - Overtaking driving depending on road traffic
    - CO was detected in cabin 20 ~ 35 ppm
Test results

- CO gas could enter into cabin with acceleration or high speed driving, especially for overtaking driving in highway, with the condition of the recirculation mode.
- After repair, CO gas was not detected in most test mode.
- Rear hatch door sealing problems, air extractor design, sunroof tilt open, tail pipe position might affect exhaust leak into cabin.

<table>
<thead>
<tr>
<th>Test results for CO gas incursion</th>
<th>Before repair</th>
<th>After repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunroof</td>
<td>closed</td>
<td>tilt open</td>
</tr>
<tr>
<td>Idle mode</td>
<td>N.D.</td>
<td>-</td>
</tr>
<tr>
<td>Cruising mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>N.D.</td>
<td>N.D.</td>
</tr>
<tr>
<td>100</td>
<td>N.D.</td>
<td>N.D.</td>
</tr>
<tr>
<td>120</td>
<td>N.D.</td>
<td>N.D.</td>
</tr>
<tr>
<td>140</td>
<td>8~9 ppm</td>
<td>0~3 ppm</td>
</tr>
<tr>
<td>Acceleration mode</td>
<td>40~80 ppm</td>
<td>30~35 ppm</td>
</tr>
<tr>
<td>Real-road driving mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal driving</td>
<td>N.D.</td>
<td>-</td>
</tr>
<tr>
<td>Overtaking driving</td>
<td>20~35 ppm</td>
<td>-</td>
</tr>
</tbody>
</table>
### Proposal for Test mode

Test mode, if exhaust gases, which are generated from their own engine, could enter into cabin

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idling mode</td>
<td>- Russian Proposal</td>
</tr>
<tr>
<td>Constant speed mode</td>
<td>- Driving vehicles at constant speed (e.g. 130 ±5 km/h)</td>
</tr>
</tbody>
</table>
| Acceleration mode   | - Test mode: Accelerate vehicles from 65 km/h to 130 km/h after that coast-down (deceleration) to 65 km/h, repeat 8 cycle,  
                      |   - Target: SI Engine, CO should be measured                                 |
Thank you

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