Impact of catalytic stripper (CS) on the characteristics of particle number (PN) emissions from a GDI vehicle over the world-harmonized light-duty vehicle test cycle (WLTC)

Introduction

1. GDI leads to increased particle number (PN) due to partially fuel-rich zones, incomplete combustion, and wall wetting to piston.

2. From September 2017, PN emissions of gasoline vehicles should be lower than 6.0 x 10^{13} N/km over WLTC and PN emissions have to be lower than 9.8 x 10^{13} N/km (conformity factor = 1.5) during real driving emissions (RDE) test.

3. Owing to particle losses in sampling systems and high uncertainty of measuring nucleation mode particles, Catalytic stripper (CS) emerged as a key apparatus in the PN measuring systems.

Focused on PN Emission Characteristics of a GDI vehicle over WLTC at the cold start / hot start with and without CS.

Experimental Apparatus and Condition

Test vehicle specification

- Engine Type: 2.0L 4-cylinder Engine
- Engine Capacity: 1500 cc
- Engine Displacement: 2.0 L
- Compression Ratio: 12.3:1
- Turbocharged: Yes
- Fuel Type: Gasoline
- Air/Fuel Ratio: 14.7:1
- Boost Pressure: 0.15 MPa
- Camshaft-driven high pressure pump
- Bore: 80 mm
- Stroke: 97 mm
- Cylinder: 4
- Pressure Pump: Camshaft-driven high pressure pump
- Engine Oil: SAE 5W-30
- Coolant: Coolant 50/50 Mix
- Mass Flow: 9.75 L/min
- Flow into the aerosol charger
- Outlet temperature: 160°C
- Particle size range: 0.1 to 1.0 μm
- Concentration range: 1 to 200 mg/m³
- Response time: 10 ms
- Sample flow: 0.1 L/min
- Accumulation mode particles dominated the cold start PN size distribution because GDI leads to fuel impingement on combustion chamber surfaces and pistons.
- Droplets accumulate on the surfaces to form soot particles emitted a lot compared with PN at hot start.
- PN size distribution because GDI leads to fuel impingement on combustion chamber surfaces and pistons.

Catalytic stripper

- The working principle – CS
  - Oxidation efficiency >99% of propane
  - Solid particles composed a large portion of total particles in the warm-up phase because accumulation mode particles dominated the cold start PN size distribution.
  - CS effect (%) 82.9002114 93.53086 91.71527 93.29329 91.94661

Vehicle mode - WLTC

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Results

- Cold start / hot start Catalytic stripper PN emission Phase 1 Phase 2 Phase 3 Phase 4 Total
  - Cold start
    - CS O  coldstart
    - PN emissions with CS
      - 7.9181E+12
    - PN emissions without CS
      - 6.402E+12
    - CS effect (%) 82.9002114
  - Hot start
    - CS O  hotstart
    - PN emissions with CS
      - 4.7171E+11
    - PN emissions without CS
      - 3.806E+11
    - CS effect (%) 93.53086

Conclusion

The effect of catalytic stripper

- Solid particles composed a large portion of total particles in the warm-up phase because accumulation mode particles are highly formed at the cold start.
- Volatile particles consisted of about 90 % of the total particles at the cold start condition.
- The 27 % of PN emissions at the cold start were volatile particles which were removed by the CS.

The time-resolved PN concentration at the cold start / hot start

- Most of PN emission at cold start emitted in the warm-up phase (~20s).
- There is no significant difference on PN emission between cold start after warm-up phase and hot start.
- PN emission are mainly affected by the cold/ hot start condition and TWC temperature.
- Total PN emissions at the hot start (15.4E+11) decreased up to 90 - 97 % compared to them at the cold start (15.5E+12).

The effect of cold start / hot start

- Particles were primarily formed in the warm-up phase due to fuel-rich mixture, incomplete combustion and Cylinder being cold.
- Accumulation mode particles dominated the cold start PN size distribution because GDI causes fuel impingement on combustion chamber surfaces and pistons.
- Solid particles composed a large portion of total particles in the warm-up phase because accumulation mode particles are extremely formed before TWC reached the LOT.
- Volatile particles consisted of about 90 % of the total particles at the cold start condition after warm-up phase and hot start condition.

This research will offer some insight into the characteristics of PN emissions for forthcoming emission regulation depending on start condition and usage of CS.