Particle Emissions From Vehicle Exhaust During Engine Start-up

Pilot Study

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• Develop a sampling system to measure:
  – Real time solid particle number concentration (#/cm³)
  – Solid particle Size distributions
  – Metallic ash particle number

• Compare results from different engine types during engine start-up:
  – Gasoline Port Fuel Injection (PFI)
  – Gasoline Direct Injection (GDI)
  – Diesel with Diesel Particulate Filters

• Develop a method of ranking vehicles according to a particle number (PN) emissions index
• Frequency of engine ignition (startup) is common in:
  – Household garages
  – Parking lots
  – Hybrid vehicles alternating between engine and battery power
  – Vehicles with frequent engine stops or shutdown
    ▪ This is a common future trend for fuel economy saving

• Human exposure to engine startup particle emissions can be significant in:
  – Shopping centers parking lots
  – Traffic jams
  – Etc..

• Engine start-up requires substantial fuel enrichment in gasoline vehicles, which can lead to a rise in particle formation
Dilution System-Solid Exhaust
Particle Measurement Only

[Diagram of the dilution system with labels for each component: Inlet, 1st Dilution, P1, DP1, T1, Catalyst, T2, P2, DP2, 2nd Dilution, Cooling Coil, EEPS Sample, CPC Sample, Overflow/Exhaust, Dilution Air.]
Particle Penetration as a Function of Size

- Highest losses in Primary section – largely thermophoretic losses.
Testing Method

• Vehicle approaches measuring station
  – Turn off engine
  – Sample probe inserted in the tailpipe
• As the vehicle was turned on, the “start-up” phase began
  – ~ 20 to 30 seconds
• Vehicle left to idle
  – ~ 30 seconds
• Probe removed from tailpipe
• Start-up test completed!
• Total time (~2 minutes)
• Diesel vehicles are common in large engines and trucks in the USA but not for passenger type vehicles.
• GDI vehicle’s market penetration is increasing (50% to 60% in 2016)
• Vehicles were tested in the parking lots of:
  • University of Texas-San Antonio Campus and Southwest Research Institute
  • Ambient temperature was ~35°C

Verification that the older the car is, the more mileage it has.
Automated algorithms can be used for identification of vehicle start-up region and data computation.

Allows for processing of data from an array of vehicles at once.
• Particle concentration increases as engine size increases for PFI vehicles
• GDI engines as highest particle emitters and Diesel with DPF’s the cleanest
• Geometric Mean Diameter shows GDI engines high in accumulation mode particles (> 25nm)
• Current PMP method does not detect PFI particles
Particle Number Indexing Concept

• Diesel with high efficiency DPF as the baseline/reference
  – **Best Available Technology**
• PN indexed each vehicle as compared to the Diesel Vehicle
• Average Concentration and Engine Size (L) obtained per group
  – Served as a basis for comparison for other vehicles in the group

\[
PM \text{ Index}_i = \frac{\text{Concentration}_i}{\text{Concentration}_{\text{Diesel}}} \times \frac{\text{Engine Size (L)}_i}{\text{Engine Size (L)}_{\text{Diesel}}}
\]

• Vehicles indexed for nuclei and accumulation mode
  – Rank from 1-900 (900 = worst) for Nuclei Mode
  – Rank from 1-9000 (9000 = worst) for Accumulation Mode
• GDI engines have high Particle Number and Ash Concentration
• Soot particles may act as a carrier of ash
• Low soot content may result in ash deposits on exhaust walls
• Engine startup can be a significant source of solid particle number
• Gasoline PFI and GDI vehicles can be a significant source, compared to diesel with DPF
• Compared to best available technology (diesel with DPF), the PN index can be as high as 9000. This is a factor of 9000 higher than best available technology
• This work was done at hot ambient temperature of 35°C. It will be of interest to expand this work to low temperature environment
• The PN emissions index is a concept that can be fine tuned and refined to reflect differentiating vehicles beyond the required emissions standard:
  – e.g. GDI vehicles meeting the same standard:
    ▪ One with exhaust filter and one without an exhaust filter. The PN emissions index defined here will show a huge difference between the two
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