Ash particle emissions from a lean burn GDI engine

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Importance of ash emissions

• Diesel engines
  • Ash builds up
  • Increases pressure drop
  • Greater DPF cleaning frequency
  • Reduces useful DPF life

• Gasoline engines
  • Deposition in 3-way catalyst leads to poisoning
  • Solid nanoparticle emissions if GPF not used, especially with metallic additives
  • Ash can be good or bad in GDI engines
    • Ash membrane increases GPF efficiency
    • May enhance soot oxidation
    • But increases pressure drop

• Relationship to engine lube oil consumption mechanisms

Ash distribution in exhaust filter channels (Heibel and Bhargava, 2007)

3-way catalyst poisoning by ash deposits (Franz, et al., 2005)
Engine ash emissions

• Non-combustible fraction of diesel aerosol
• Derived from metallic lube oil additives and engine wear metals
• Metallic particles tend to ‘decorate’ carbonaceous exhaust particles
• But form separate particles at sufficiently high metal to soot ratios

Jung, et al., 2005

Sappok and Wong, 2007

Jung and Kittelson, 2005
High temperature oxidation method (HTOM)

• Originally developed to study Diesel engine ash emissions in real time
• Allows oil consumption to be estimated – atomized but not vaporized oil – this material may contribute to sub 10 nm emissions
• Allows quick estimates of soot reactivity

• Current presentation
  • Brief review method
  • Example of application to Diesel
  • Impact of oil formulation on GDI engine soot reactivity and ash emissions
High temperature oxidation method (HTOM)

Diesel exhaust or other metallic ash containing aerosol

Oxidize soot and hydrocarbons within high temperature tube furnace

Stable metal oxides and other refractory metal compounds are formed or survive high temperature tube furnace

Cooled particles measured using real/near-real time particle instruments

Gladis, 2010
Diesel examples

- Soot oxidation
- Transient ash emissions
Deere off-road tier IV engine
1400 rpm 50 N-m
Transient ash emissions – load steps at constant engine speed, Deere engine, 1500 rpm
GDI engine tests

- N43B20, 2.0 L BMW GDI Engine – 4 cylinder naturally aspirated lean burn engine
- Constant speed and load: 2000 rpm, 6 bar BMEP, lambda = 1.2.

- Three lube oil additive packages
  - 5,000 ppm Ca
  - non-additized 100% PAO
  - 10,000 ppm ZDDP
N43B20, 2.0 L BMW GDI Engine
Oil 1 – 5,000 ppm Ca
N43B20, 2.0 L BMW GDI Engine
Oil 2 – non-additized 100% PAO
N43B20, 2.0 L BMW GDI Engine
Oil 3 – 10,000 ppm ZDDP
Soot Reactivity and Ash Fraction
Conclusions

• The high temperature oxidation method allows relatively simple assessments of soot reactivity and ash content

• Ash emissions - 5,000 ppm Ca > non-additized 100% PAO > 10,000 ppm ZDDP

• Soot reactivity - 5,000 ppm Ca > non-additized 100% PAO > 10,000 ppm ZDDP > Diesel