Contribution of Gasoline Particulate Filter (GPF) and Lubricant to the TGDi System Solution

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Outline

△ GPFs: The need for change

△ What is a GPF?

△ Engine Oil: Part of the solution

△ Lubricant impact on GPF function

△ Summary
Gasoline Particulate Filters: The Need and the Challenge
Emission Targets Driving Fundamental Shift in Gasoline Vehicle Technology

Timeline – Toxic Emissions Standards Passenger Cars

1970/90s
Control of priority pollutants
• Adoption of catalysts and engine control
• Reduce HC, CO, NOx

Mid 2010s
Fuel Efficiency
• Improve FE/CO2 emissions
• Engine downsizing and power enhancement

Late 2010s
More stringent emission regulations
• Particulates
• RDE

What is a Gasoline Particulate Filter?

Exhaust gas, including PM10 and PM 2.5

Alternatively Open or Plugged Passages

Particle Filtration (and Catalyst Reaction if coated)

Tailpipe Emissions
What is a Gasoline Particulate Filter? continued

- Gasoline engines generate particulate emission (soot)
- GPFs are filters, or ‘traps’, fitted within the exhaust system of vehicles to catch particulate matter
- GPFs are not DPFs!
Successful deployment of GPF technology needs system optimization for various performance requirements

...Including the engine lubricant
Effect of Ash on Backpressure

How Soot and Ash accumulate and are managed can have a marked impact on GPF performance and ultimately vehicle fuel economy.

- Backpressure increases with soot and ash accumulation amount
- Low mileage and dyno aged filters contained far less fully oxidized ash mass than the full useful life (FUL) filter
- Approximately 50 wt% of the collected ash was not directly related to the oil consumption

Ref.: SAE 2012-01-1241 (Shimoda et al)
Ref.: SAE 2017-01-0930 (Lambert et al)

XRF Analysis of Ash in GPFs

AftonChemical.com
Initial Insights

- Global emission legislation is driving towards more TGDi engines fitted with GPFs
  - Physical removal and oxidation of carbonaceous particulates
- Ash (and soot) loading rates / levels are one of several critical factors in GPF efficiency
- Lubricant formulation characteristics impact GPF filtration efficiency
  - Additive ash contribution
Lubricants: Part of the System Solution
Roles of a Lubricant & Lubricant Additives

- Lubricate
- Cool
- Pressurize
- Prevent Wear
- Reduce Friction
- Remove Contaminants
- Protect the oil
- Enhance Performance
- Modify Oil Properties
Key Lubricant Additives Adding Ash

ZDDP
(zinc dialkyldithiophosphate)
Primary, and most effective anti-wear agent (durability)
Used for over 80 years
Also most cost-effective anti-oxidant

Metal Detergents
(sulfonate, phenate, salicylate)
Keeps engines clean, and neutralises combustion-acids.
Most chemically efficient way to add base to the lube
Range of surface impacts

MoDTC
(molybdenum dithiocarbamate)
Inorganic friction modifier
Increased use since mid-'90s
Particularly effective in motored-friction tests (fuel economy)
Zero ash lubes are theoretically possible, but practically prohibitive. Thankfully, our research evaluations show we don’t need to be so drastic.

We must maintain a holistic approach to lubricant formulating.
Initial Insights

- Certain lubricant additives do add ash to the system
- These additives perform several roles that are critical to the effective operation of the engine
- The overall vehicle performance and protection is a complex system
  - Lubricant impacts both the engine and GPF operations
  - We need to consider the best overall solution
Lubricant Impact on GPF: Afton Testing
No significant difference in PM/PN emission, backpressure and fuel consumption between two lube ash levels in end-of-life performance

Poorer particulate filtration rate for unconditioned GPF

Clear impact of ash-loading on GPF backpressure

Note: Full Scale Engine/Vehicle Ash Loading/System Durability Studies

Source: Afton data 2017
Green filtration efficiency needs improvement to meet legislation requirements.

Filtration efficiency improves greatly from bed filtration to cake filtration.

Ensuring the vehicular emissions for new vehicles with “green” particulate filters may be a significant challenge.
PM (soot) oxidation is affected by its composition, temperature, catalyst etc.

Increased soot burn-off rate can equate to fuel economy savings

Lubricant oil formulation can change oxidation rate

Lubricant oil formulation can impact GPF regeneration rate and hence benefit fuel economy
Driving condition (cold start vs. hot start) has significant impact on both PN and FE

Test Protocol: Cold Start US06-soak (1h)-US06-soak (1h)-US06-soak (1h)-US06-soak (1h)-US06

Source: Afton data 2017
Summary
Summary

- Global emission legislation is driving towards more TGD\text{i} engines fitted with GPFs
- Lubricant formulation characteristics impact GPF filtration efficiency
- The overall vehicle performance and protection is a complex system
  - Lubricant impacts both the engine and GPF operations
- Generally the industry is gravitating to 0.8\% Ash lubricants
  - Balancing engine durability and GPF efficiency requirements
- Green filtration sees a potential challenge in attaining low PN targets
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