What Causes Low-Speed Pre-Ignition?

Results from Afton's rigorous testing shed more light on LSPI.

Afton's studies have confirmed that two mechanisms can lead to LSPI:

1. Oil or fuel droplets ejected from the piston crevice*
2. Combustion chamber deposits†

Recently, Afton published a study focusing on the deposit-induced pre-ignition process†. We set out to simulate all the processes involved in deposit-induced pre-ignition to gain deeper insight into the impact of different particle characteristics. We developed our simulation based on established parameters for the following processes:

- Particle Heat Transfer
- Particle Mass Transfer
- Bulk Fuel-Air Mixture Conditions
- Solid-Phase Oxidation Kinetics
- Gas-Phase Auto-Ignition Kinetics
- Deposit Physical and Thermal Properties

The Effects of Different Deposit Characteristics and Engine Conditions

1. Particle Survival in the Combustion Chamber
Only persistent particles heat up sufficiently and achieve high enough temperatures to induce LSPI.

Below 660 °C, 150 micron particles actually cool during the intake stroke:
No pre-ignition

Above 820 °C, 150 micron particles show little drop in temperature:
Pre-ignition

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* "Relative Impact of Chemical and Physical Properties of the Oil-Fuel Droplet on Pre-Ignition and Super-Knock in Turbocharged Gasoline Engines". No. 2016-01-2278. SAE Technical Paper, 2016.
† "Impact of Particle Characteristics and Engine Conditions on Deposit-Induced Pre-Ignition and Superknock in Turbocharged Gasoline Engines." SAE International Journal of Fuels and Lubricants 10.2017-01-2345 (2017).

2. Particle Size

The bigger the particle, the earlier the pre-ignition and the more intense the superknock. Only particles with enough mass can induce LSPI.

Particles smaller than 250 microns at 727 °C actually cool during the intake stroke:
No pre-ignition

Particles larger than 300 microns at 727 °C show little drop in temperature:
Pre-ignition

3. Boost Pressure

The higher the intake air pressure, the higher the rate of oxidation of the particles and therefore, the higher the LSPI.

10%
increase in boost pressure beyond typical levels can significantly increase propensity for LSPI

4. Engine Air-Fuel Ratio

Lean mixtures lead to a higher rate of oxidation of the particles and higher LSPI.

10%
increase in Lambda from typical stoichiometric levels can significantly increase propensity for LSPI

5. Engine Exhaust Gas Recirculation (EGR)

The higher the EGR, the higher the concentration of inert gases, the lower the rate of particle oxidation and the lower the LSPI.

5%
increase in internal residuals or EGR from typical levels can significantly reduce propensity for LSPI

Key Takeaways

- Insights from this study help identify deposit characteristics that drive LSPI performance.
- Engine operating conditions have a significant impact on LSPI.
- Differing properties of real world deposits significantly affect LSPI performance.
- Engine oil formulations can impact deposit properties and LSPI propensity.

Afton Brings a Balanced Approach to LSPI

Afton utilizes a variety of engine test platforms and a fundamental and mechanistic research approach to deliver technology solutions. Because we're not limited by ingredients or technology, we can deliver superior formulations that solve your LSPI challenges without negatively impacting other areas of performance. Afton's research-driven, market-focused approach enables us to develop holistic solutions that meet all requirements for a specific region.

Learn more at
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