Particle formation in homogeneously charged SI-engines

1 Background

Gasoline Direct Injection (GDI) is key technology today especially in combination with turbocharging. This gives many advantages, eg. reduction of CO_2 emissions as well as torque and power increase. However, GDI emits high amounts of particulate number (PN) emissions. Few or no automakers will be able to meet future legislations on PN without the use of Gasoline Particulate Filter (GPF). In addition to usage of GPFs it is important to also minimize the formation of particulates from the engine so that eg. GPFs can be minimized in size and have the lowest possible system back-pressure to avoid fuel consumption penalty. The highest PN formation occurs in three regions of a driving cycle namely a) high loads, b) transients and c) cold-starts/warm-up. The project aims at giving a better understanding of the underlying mechanisms that cause particulate formation. Once these mechanisms are better understood, engine operating strategies/optimization that minimize PN formation can be applied.

2 Method

This project is an experimental project and focuses on:

- PN measurements in a dual injector setup
- PN measurements with renewable fuel blends
- Particulate formation during load transients
- Visualization of soot formation using endoscope
- Particulate measurements in Miller cycle

3 Results

So far, most of the work has focused on reducing PN at high loads. In the first experiments a GDI engine with an upstream fuel source was studied. This allowed for a quick yet, better understanding of effect of mixing and spray-wall interaction on PN. Using an upstream fuel source, the homogeneity of fuel-air mixture has been increased to cause lesser PN. For this study, a thermodenuder was also enabled while sampling the exhaust to consider the solid PN, which are indeed legislated. An example of effects of mass splits between DI and upstream fuel source on solid PN are shown in. Fig 1.

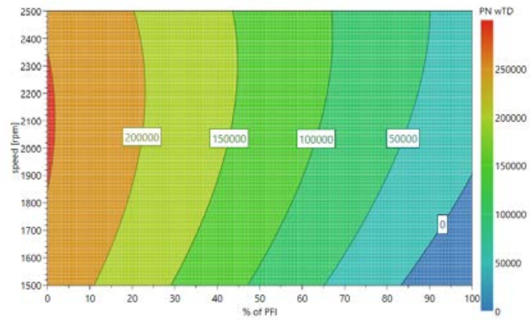

Figure 1. Solid PN measured with thermodenuder. Engine load of 7 bar IMEP, engine speeds ranging from 1500 to 2500 rpm and fuel injection mode changing from 0 to 100% PFI, R2 = 0.79

The second tests used gasoline with renewable fuel blends from NESTE, which allowed to further investigate the PN at high loads but from the fuel perspective. This investigation was carried out in a GDI with extensive after-treatment to measure both PN in raw exhaust and through a thermodenuder and catalytic stripper, all simultaneously. This enabled separate data on total PN (including VOC) and solid PN.

4 Conclusions and outlook

The investigation on dual injector setup showed how dramatic effect the mass split between DI and upstream source has on PN and solid PN. In the second investigation it was found oxygenated fuel blends tend to emit higher PN at higher loads. Using oxygenated fuels, solid PN (legislated PN) was found to be reduced with roughly 50% at lower loads.

Future investigations will include the use of an endoscope into the combustion chamber together with high-speed camera. This will allow for optical access of crucial in-cylinder soot formation. A custom made engine controller has been built which allows studies of particulate formation in load transients.