In-flame soot particles in an automotive-size diesel engine

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We know about exhaust soot particles but have a limited understanding on in-flame soot.

Cambustion DMS500 for “mobility diameter”

Morphology of exhaust soot particles (Zhu et al, 2005)

How would soot particles here look like?
“Hot soot” luminosity movies suggest successful sampling of soot particles.

The sampler design, cyclic variations, soot exposure time, soot overloading, image processing details are found:
Soot images exhibit similar shapes and structures of those collected in the exhaust.

Exhaust soot particles  

In-flame soot particles inside the engine cylinder  
(Present study)
Post-processing of soot particle images...
What is the practical value of this in-flame soot sampling technique?

A good case study is here: injection pressure variation.

Distinct global phenomena

Sampled soot particles appear to be very different.

Detailed discussions are found in:
Aggregates are smaller and the primary diameter is lower for higher injection pressure.

High injection pressure results in not only less number/amount of soot particles but also smaller soot aggregates and primary particles.

Detailed discussions are found in:
Further application for the soot particles evolution during wall-interacting diesel flame development

1. Prior to the wall impingement
2. After the wall impingement
3. During the late-cycle burn-out
4. Engine-out soot

Stage 1: In-flame soot particles prior to the wall impingement
Stage 2: In-flame soot particles after the wall impingement
Stage 3: Soot particles at the late-cycle burn-out (soot oxidation) stage
Stage 4: Engine-out soot particles
Breakdown of soot aggregates due to the flame-wall interaction (Stage 1-2)
- Decreased $R_g$ due to the increased number of small aggregates and decreased number of large aggregates.
- No change in $d_p$ and overall fractal dimension.

Soot oxidation between the main combustion and late-cycle burn-out (Stage 2-3)
- Decreased $d_p$
- Increased $R_g$ due to the disappearance of small aggregates.
- Increased fractal dimension (more compact aggregate shape)

Similarity between the late-cycle soot and engine-out soot (Stage 3-4)
- The decrease of $R_g$ and $d_p$ suggests further oxidation but it is very minor and the fractal dimension does not change.
Summary

- Soot particles are sampled directly from a diesel flame in a working diesel engine.
- Soot aggregates with various sizes and structures form within the diesel flame, which breakdown and become smaller during the flame-wall interaction.
- The large aggregates further breakdown, small aggregates disappear completely, and the primary particles become smaller due to the continued oxidation throughout the late-cycle burn-out.
- The remaining aggregates are very concentrated, agglomerated, and compact, which are emitted to the exhaust.