Nanoparticle characteristics of exhaust and soot-in-oil from gasoline direct injection automotive engines

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Introduction

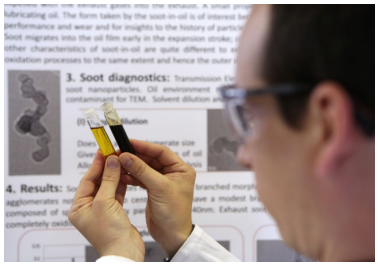
What are **exhaust soot and soot-in-oil**?

- Carbon nanoparticles formed in the combustion chamber
- Emitted in part with the exhaust gases
- Transfer to the engine oil and contribute to its degradation
- Common problem in direct injection engines

Exhaust soot generated in Gasoline Direct Injection (GDI) internal combustion engines has been widely investigated; soot-in-oil less so. Although soot is typically only a fraction of a comparable diesel engine, this is certainly a new challenge for the modern GDI engine as soot-in-oil raises concerns on wear and engine durability.

The Problem

Over one billion of soot-in-oil nanoparticles can be found in a single 1ml drop of used engine oil. They are invisible to the naked eye and can only be seen by the most powerful electron microscope.



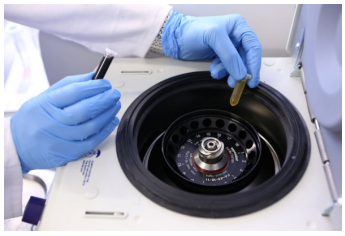
There is a considerable interest within the automotive industry to better understand the complex interactions between soot morphology and properties of lubricating oil.

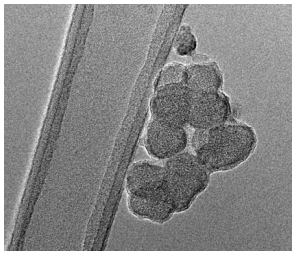
The morphology, agglomeration and other characteristics of soot-in-oil are likely to be quite different to exhaust soot.

A clearer understanding of soot structure-property relationships could lead to extending oil changing intervals avoiding engine failure and poor performance.

Methodology

The soot samples used in the study were collected from a modern wall-guided GDI engine.

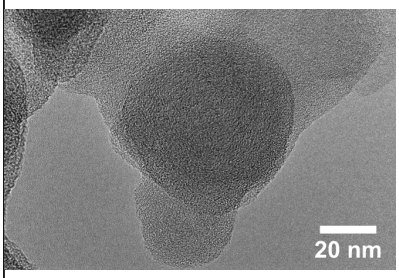




Solvent extraction and centrifugation have been used to prepare suitable samples for TEM analysis onto graphene oxide TEM support films.

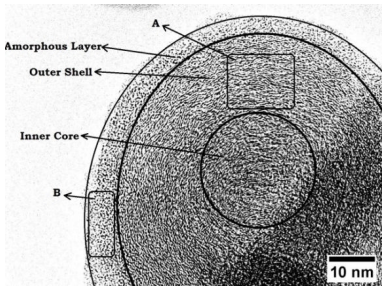
Results

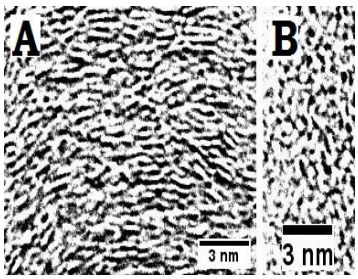
Soot primary particles appeared mostly as spheroids with distortions and irregularities assembled into chainlike and small cluster aggregates.



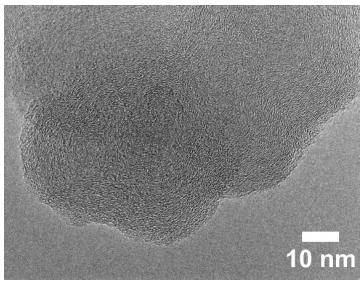
Exhaust primary particles were found in the range 20-70nm, with a mean diameter of 38.6nm. Only 1.2% were smaller than 30nm. Exhaust soot exhibits a nearly amorphous nanostructure.

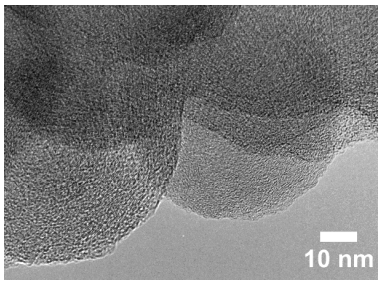
Soot-in-oil possesses a radial variation. Typically, a core comprised of short, disorganized segments (nuclei) followed by a layer of fringes viewed edge-on on TEM projections (2-6nm) and in some cases a thin amorphous layer of 2-3nm.



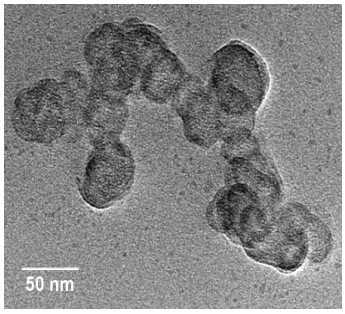


Differences in nanostructure may reflect a combination of different operating conditions, combustion temperatures and chemical species contributing to particle growth at various stages.





GDI soot agglomerate size was found to be comparable to diesel engine soot-in-oil.



Soot agglomerates have a modest branched morphology, and exist in clusters and chainlike structures in a range from 40 to 400nm. Agglomerates show an average length of 150nm and are composed of spherical primary particles of 18-60nm.

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