Evaluation of Volatile Particle Remover Devices for Exhaust Particle Quantification

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Motivation

- Diesel exhaust is an important source of harmful particles with diameters below 100 nm.\(^1\)
- In 2011, a new legislation was introduced in the EU to limit the emission of fine diesel particles on the basis of the particle number (N\(_p\)).\(^2\)
- Before determination of N\(_p\), with a condensation particle counter (CPC\(_{23nm}\), 50% counting efficiency for 23 nm particles), volatile particles have to be removed from the exhaust gas with a volatile particle remover (VPR).
- Evaporation tube (ET) and catalytic stripper (CS) are two possible VPR types with different functional principles.

VPR Set-Up

**Evaporation Tube:** Application of thermal treatment and subsequent dilution to separate volatile exhaust components from the particle phase.

**Catalytic Stripper:** Application of catalytic oxidation (diesel oxidation catalyst) and chemical binding (sulfur trap) to remove volatile particle forming components from exhaust gas.

- Diesel oxidation catalyst: HC + x O \(\rightarrow\) y CO + z H\(_2\)O
- Sulfur trap: x H\(_2\)SO\(_4\) + y BaO \(\rightarrow\) y BaSO\(_4\) + x H\(_2\)O

VPR Removal Efficiency

- Application of polydisperse sulfuric acid and tetracotane (C\(_{40}\)) aerosols in mass concentrations higher than in real exhaust gas (< 200 \(\mu\)g/m\(^3\)).\(^3\,^4\)
- Comparison of ET (green) and CS (red) efficiency in removing volatile particles.

Reduction of particle number concentration less than 1% with ET and CS possible!

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Dilution Ratio Reduction

Insufficient dilution in ET leads to formation of nucleation mode (NM) particles (D\(_p\) < 23 nm).

Reduction of Sulfur Storage Capacity

Comparison of CS devices with and without sulfur storage capacity applying polydisperse H\(_2\)SO\(_4\) aerosol.

Missing storage capacity leads to reduced removal efficiency and formation of NM particles (D\(_p\) < 23 nm) is possible.

Particle Composition

Ratio of detected nucleation mode particles (D\(_p\) < 23 nm) depends on CPC\(_{23nm}\) counting efficiency (CE) and consequently also on particle chemical surface composition.\(^5\)

Average CE for NM particles (10 nm > D\(_p\) < 23 nm): 49 % (sulfuric acid) and 29 % (soot).\(^6\)

Summary

- Successful removal of C\(_{40}\) and H\(_2\)SO\(_4\) aerosol particles (more than 99%) in concentrations higher than in real exhaust!
- Reduction of dilution ratio (ET) and storage capacity (CS) may lead to formation of nucleation mode particles (D\(_p\) < 23 nm).
- Chemical composition of nucleation mode particles is the crucial factor considering the ratio of NM particles detected with a CPC\(_{23nm}\)!

References:


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