Catalytic aftertreatment of PM emissions
(Katalytisk efterbehandling av partikelemissioner)

Project summary
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Catalytic aftertreatment of PM emissions

- Start: January 2013, end July 2017
- Main grants receiver: Chalmers
- Industry partners:
  - Volvo Group,
  - Volvo Cars Corporation
  - Haldor Topsoe AS
- FFI-programme: Energy and Environment
- Grant: 4.01 MSEK
Motivation

• > 6 Million deaths due to ambient air pollution [1]
• Road transportation needs lower CO₂ emissions and “zero” local emissions
  – Efficient filters needed (DPF & GPF)
  – With low pressure drop (low fuel penalty)

Project objectives

• To increase understanding of soot oxidation
  – To reduce CO$_2$ emissions
  – To enable oxidation at lower temperatures
  – Effects of upstream EATS component (DOC)

• To bridge the gap between lab scale and full scale experimentation
Project description (Outline)

1. Soot oxidation at Nano-scale
2. Method development at lab scale
3. Soot oxidation of synthetic soot and of collected particulate matter (Light duty diesel)
4. Soot oxidation of collected particulate matter (Heavy Duty Diesel) in mini DPF
Soot oxidation at nano-scale

\[ r \sim \exp\left(-\frac{E_a}{RT}\right)O_2^b \]

\( E_a \sim 113\text{kJ/mole} \)

\( b \sim 0.84 \)

O\(_2\): 2mbar

T=475°C

Ian J. Allen et. Al., “Mechanism and kinetics of oxide-catalyzed soot oxidation studied by electron microscopy”, in manuscript
Method development

- Short pulses
  - Varying O₂ conc.
  - Varying Temp.
  - @ 3 conversions

- Results
  - Apparent Ea change with conversion and with O₂ conc.
  - Tracer exp. Indicates significant surface species

M. Englund et al., “Pulse experiments for investigation of soot oxidation kinetics”, CAPoC 10 Brussels 2015
Comparison lab scale-engine PM

- Apparent on-set depends on $O_2$ and $m_C$
- $r_{CO} > r_{CO2}$
- More PM at inlet
- Catalyst lower onset temperature
- $r_{CO} < r_{CO2}$
Soot sampling in mini-DPF

- 24 mini DPFs
  - Different coatings
  - Short & Long loading
  - With & without DOC
- Soot oxidation in lab-scale reactor
  - Pulse experiments
  - O₂ & NO₂ oxidation
Kinetics analysis

- **Global reaction scheme**
  - \( r = ke^{-\frac{E_a}{RT}}m_0(1-X)^{2/3}O_2^{0.8} \)
- **Ea higher w DOC**
  - HC “stripped” in DOC

Not shown:
- **Ea lower for high PM loading**
  - Mas transfer limitations
- \( r_{\text{CO}} < r_{\text{CO}_2} \)

Soot loading analysis

• Higher loading w DOC
  – Same “driving force”
    (big DPF)
  – Stripped PM in DOC gives “narrow” PSD
    • Lower “specific pressure drop” => higher flow
      (more PM collected)

• Similar effect from catalyst
Summary

• Increased understanding of soot oxidation
  – Lower pressure drop by use of DOC & catalyst
  – Reaction rate depends on
    • Oxidant and oxidant concentration (incl. adsorbed O)
    • Degree of conversion
    • Particle size (engine operation)
    • Amount of VOC (adsorbed HC)
    • Catalyst

• Bridging the gap from small scale to full scale
  – Oxidation by O2: power of ~0.8 (ETEM & HD-PM)
  – Differences in flow through and DPF reactor
Implications for PM emissions control

- **Adsorbed species** as intermediates needed to model transient behaviour
- Different “aged” PM at all times calls for **population balance** modelling approach
- **Upstream components** and flow field aspects will influence PM capture and resulting pressure drop
- Soot cake internal **mass transfer limitation** should be considered
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