Flow-Reactor Studies to Support Modeling of the Soot Filters Regeneration Process

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Initial Reactor Study of Soot Combustion

Outline:

- Introduction:
  - Soot combustion studies: On-Engine vs. Micro- and Pilot-Reactors
- Experimental
  - Reaction set-up and procedures
- Results
  - Qualitative:
    - Soot combustion by O_2 at different H_2O concentrations
    - Soot vs. carbon black
  - Quantitative:
    - Kinetic processing of the data
- Conclusions

Introduction:
Soot Filters Regeneration Studies

Limitations of the On-Engine Studies

- Soot loading:
  - Uncertainty of soot generation rate and continuous soot combustion rate (especially for CRT and catalyzed traps).
- Soot regeneration:
  - Impossible to vary one parameter at a time (e.g., only temperature)
  - Amount of incoming soot during regen? Other uncertainties (e.g., $T_{exhaust}$ vs. T_{filter})
  - Criteria of success: ΔP=f(soot amount & distribution, T, flow rate, transients)

Micro-Reactor Studies

- Fundamental study of the soot oxidation process=f(T, O_2, NO, NO_2, H_2O, etc)

Pilot-Reactor Studies

- Oxidation of soot loaded on the soot filter cores:
  - Study of ΔP=f(soot loading, degree of regen) at different T and flow rates
  - How the "engineering"factors (heat & mass transfer) affect the soot combustion?
  - Effect of various catalysts

Experimental Setup

<u>Sample</u>

- **Soot**: Real diesel soot sample "A"
- **Carbon black**: Provided by Cabot

<u>Reactor Loading</u>

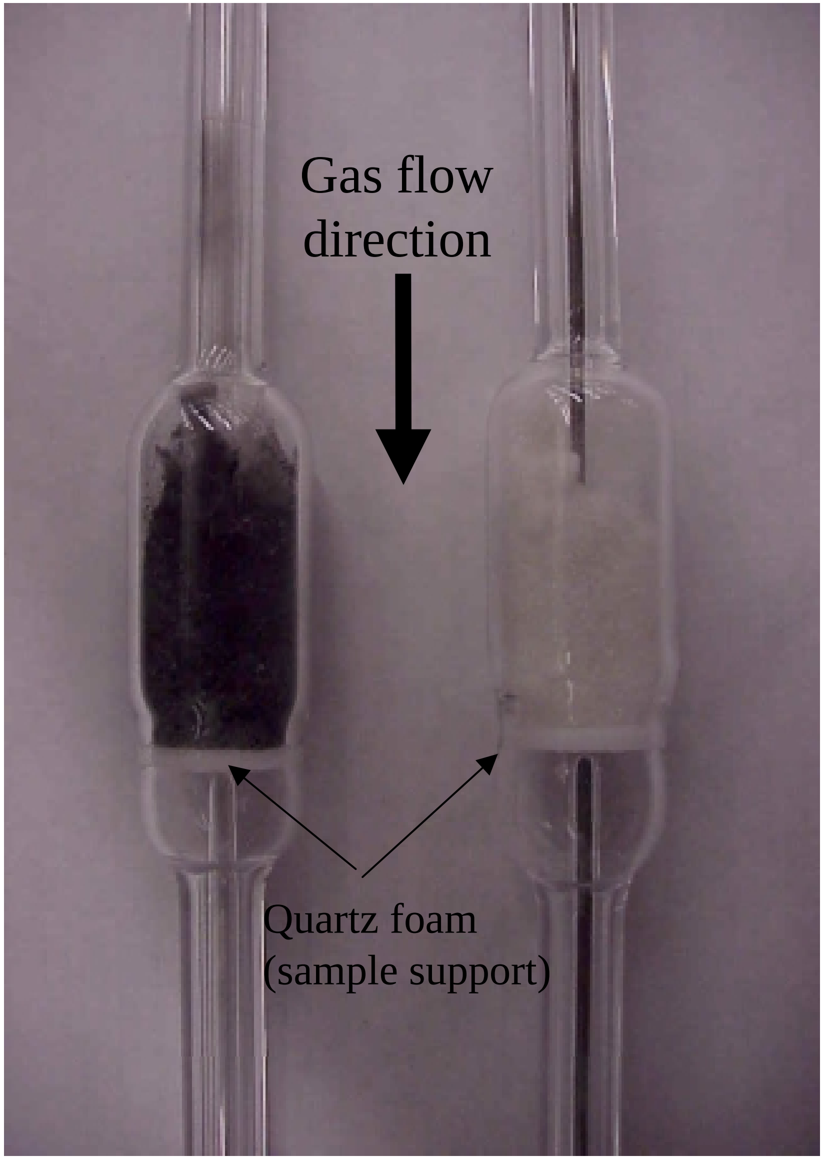
- Soot powder mixed with quartz chips for better heat dissipation

<u>Gas:</u>

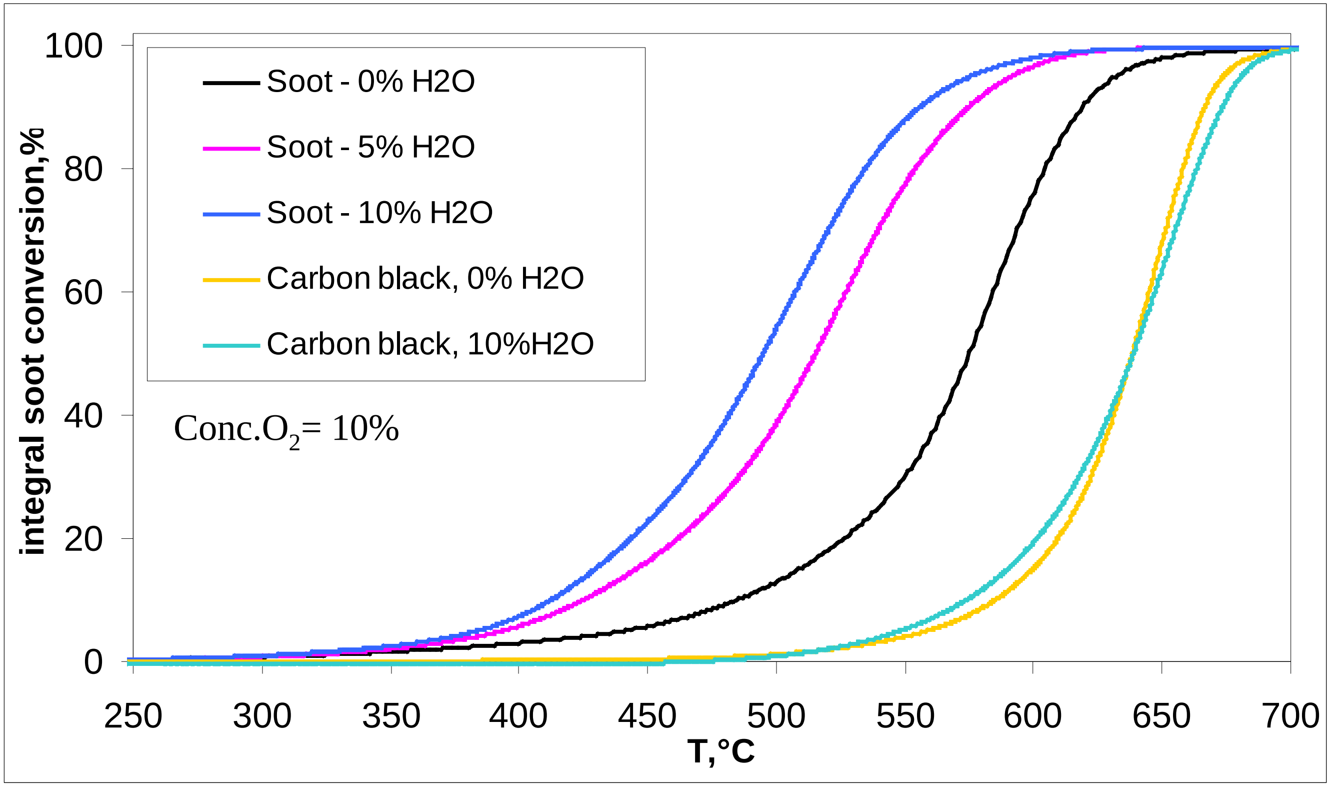
- O_2 -10.0% (vol.), H_2O 0-10% (vol.) / He

<u>Analysis:</u>

- "DOC" catalyst downstream (oxidizes CO to CO_2 - to simplify material balancing)
- Mass-spec analyses (broad dynamic range)
- This configuration allowed to perform studies in a broad range of temperatures (conversions)

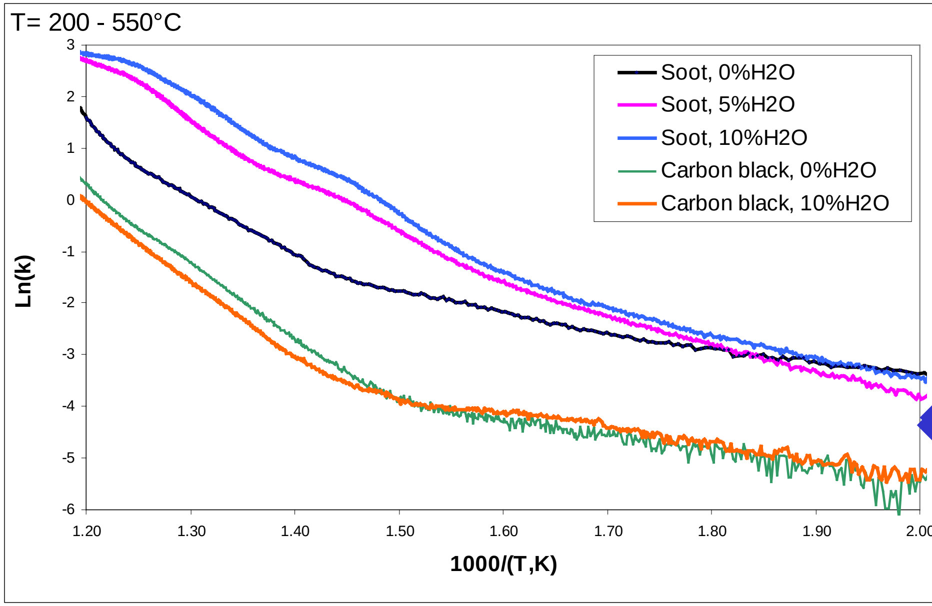


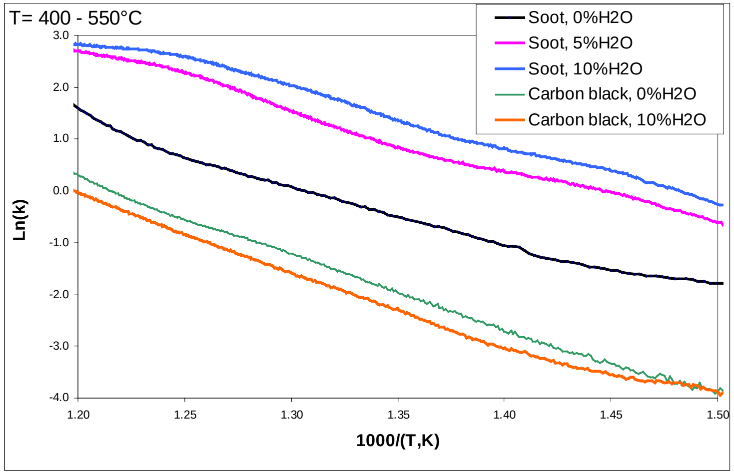
Effect of H_2O on soot oxidation by O_2

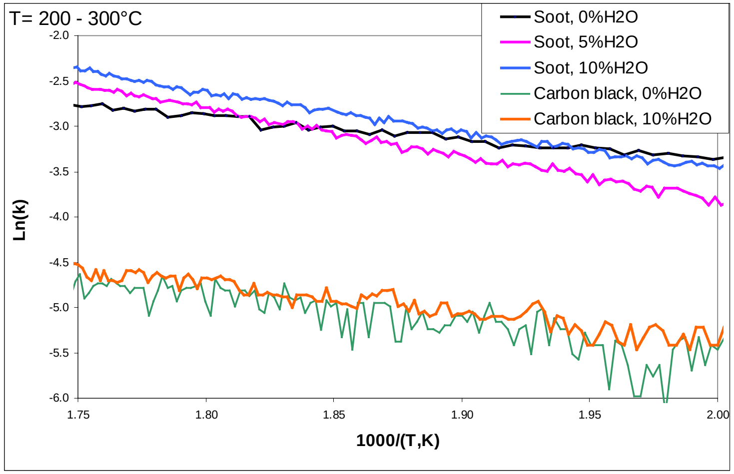


- Soot combustion by O_2 was enhanced by the presence of H_2O up to ~10%.
- Combustion of carbon black was not affected by the presence of 10% H_2O.
- Origin of soot significantly affects both qualitative and quantitative results (possibly one of the reasons of controversy of the literature data)
- Consistent material recovery was achieved, allowing us to apply quantitative kinetic processing to the data

Arrhenius plot: 200-550°C

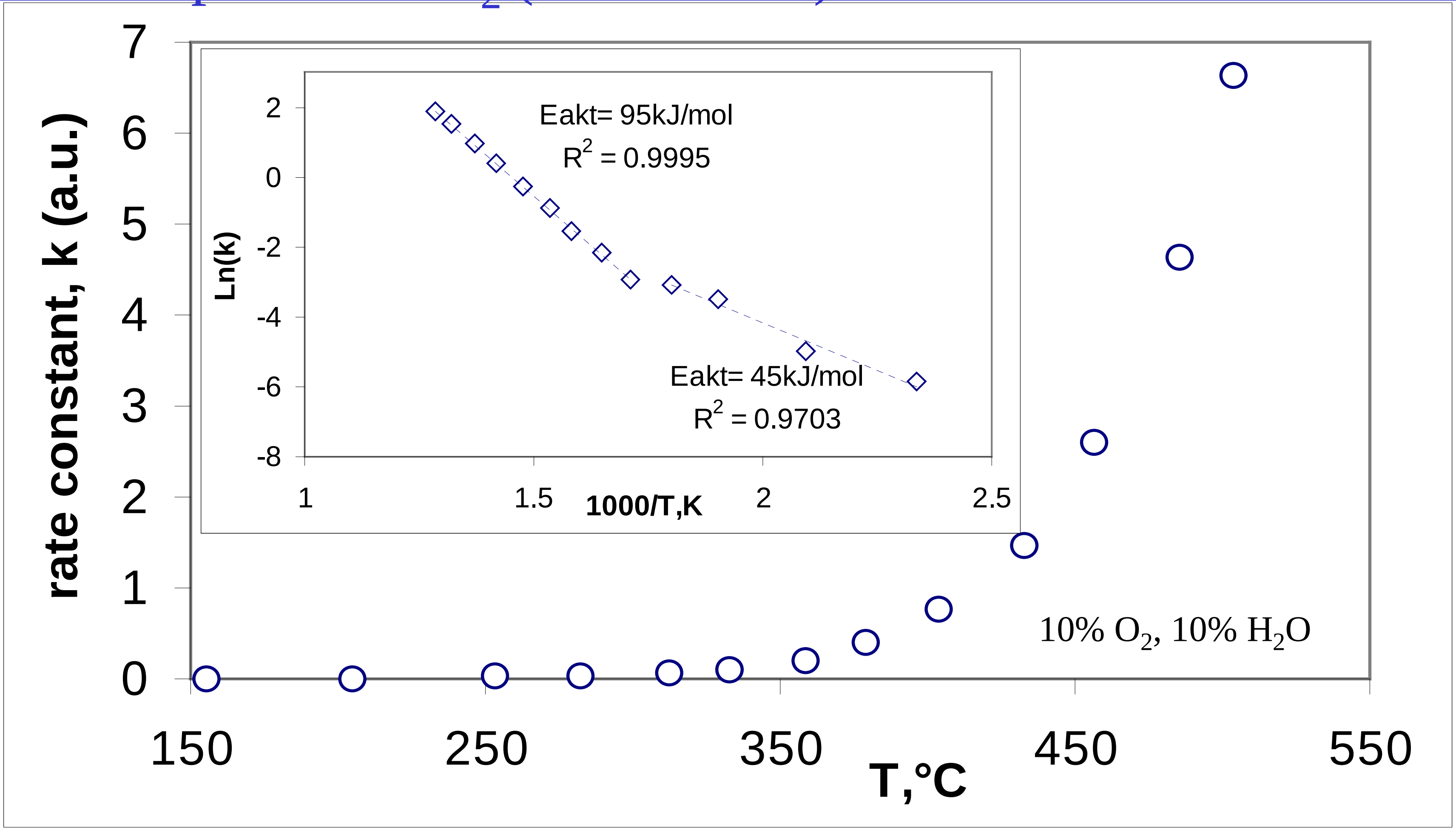






H_2O % vol.	200-300°C		400-550°C	
	E_a,kJ/mol	R^2	E_a,kJ/mol	R^2
Carbon black				
0	**32**	0.788	**117**	0.999
10	**24**	0.914	**114**	0.993
Soot				
0	**21**	0.986	**92**	0.994
5	**39**	0.986	**97**	0.986
10	**34**	0.990	**92**	0.994

Advanced experimental technique:
- pulses of O_2 (150-500°C)



Obtained results are **independent** of the experimental technique:

- qualitatively - similar transition from lower to higher Ea
- quantitatively (e.g., for 300-500°C: E_a = 92 vs. 95 kJ/mol)

Conclusions:

- Equipment and methodology for quantitative fundamental studies of soot oxidation were demonstrated.
- Cummins' reactor systems provide unique capabilities for studying soot combustion (sensitivity, time resolution)
- Presence of H_2O has a different effect on the oxidation of diesel and synthetic soot samples. This emphasizes the dependence of the results on the origin and properties of the soot.
- Unexpected change in the kinetic behavior (reproduced by different techniques) needs to be understood:
  - Does soot undergo some changes during the experiment ("aging")?
  - Is there initial inhomogeneity of soot samples ("easy"- and "hard"-burning moieties)? Is it related to the soot "age"?