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CONVERSION AND PRESSURE DROP IN CATALYTIC PARTICULATE FILTERS

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Introduction

- Combustion engines produce harmful **particulate matter** (PM, „soot“)
  - size: 10^{-3} – 10^{1} µm,
  - composition: carbon, ash, sulfates, soluble organic fraction, adsorbed hydrocarbons, …
- PM is captured in **particulate filters** (DPF for Diesel, GPF for gasoline fuelled engines)
  - exhaust gas flows through honeycomb substrate with alternately plugged channels – gas passes through porous substrate walls (Figure 1)
- The filters need to be combined with catalysts that control emissions of gaseous pollutants (CO, NO_x and unburnt hydrocarbons)
  - catalytically active coating can be applied directly inside and/or onto porous filter walls
  - **catalytic particulate filters** reduce aftertreatment system's size and cost
- **Key parameters** of catalysed particulate filters **depend on**:
  - filtration efficiency
  - pressure drop
  - catalytic activity
  - substrate morphology
  - washcoat morphology
  - washcoat distribution

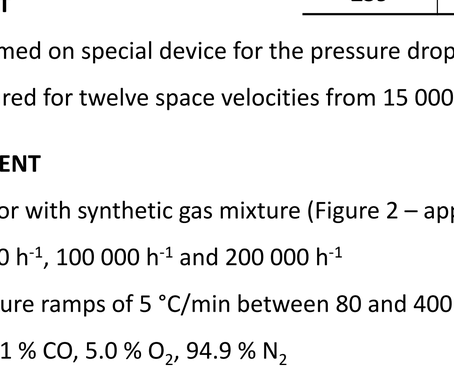

Figure 1: Particulate filter function

Experimental setup

STUDIED SAMPLES

- Catalytic particulate filters
  - Pt/Al_2O_3 on cordierite
  - **Catalyst particle sizes d_{90}:** 0.3 µm, 4 µm
- **Filter size:** diameter 2.5 cm, length 6 cm (lab sample)

Table 1: Samples specification

Sample ID	Coating location	Catalyst particle size [µm]
Z7	Inside wall	4
Z8	Inside wall	0.3
Z16	On wall	0.3
Z39	On wall	4

PRESSURE DROP MEASUREMENT

- The experiments were performed on special device for the pressure drop measurement
- The pressure drop was measured for twelve space velocities from 15 000 h^{-1} to 240 000 h^{-1}

CATALYTIC ACTIVITY MEASUREMENT

- Laboratory tubular flow reactor with synthetic gas mixture (Figure 2 – apparatus scheme)
  - **GHSV:** 50 000 h^{-1}, 100 000 h^{-1} and 200 000 h^{-1}
- **Experiments:** linear temperature ramps of 5 °C/min between 80 and 400 °C
- **Inlet mixture composition:** 0.1 % CO, 5.0 % O_2, 94.9 % N_2
- **Outlet gas analysis:** FTIR gas analyzer, MS Hiden QGA

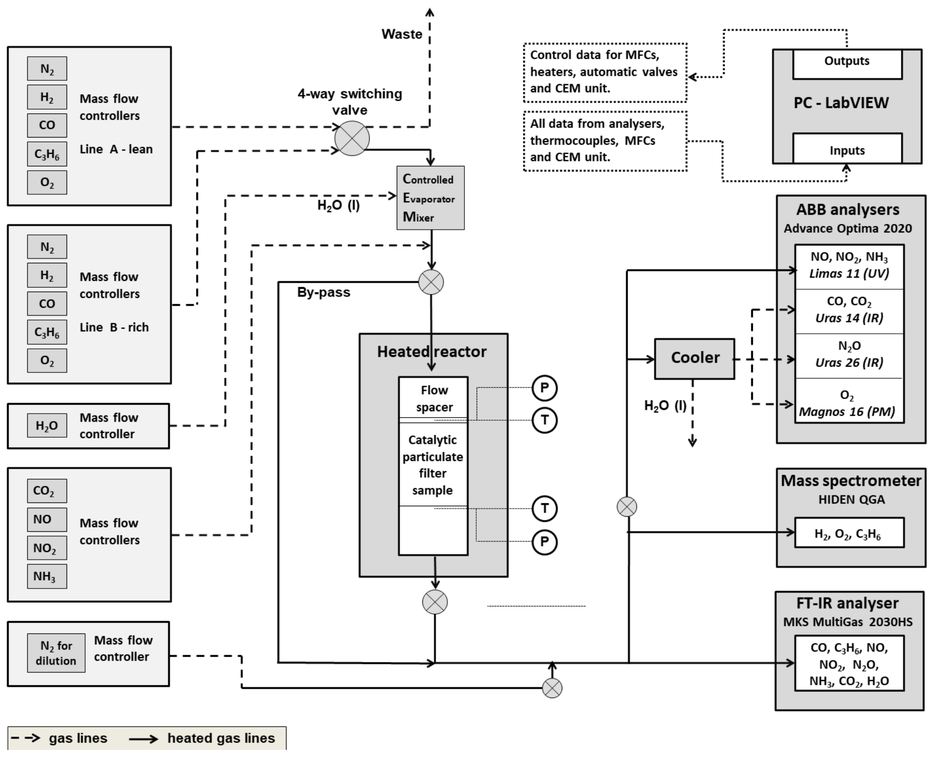

Figure 2: Laboratory apparatus scheme

Results

PRESSURE DROP

- Highest pressure drop: Z39 (d_{90} = 4 µm, on wall)
- Lowest pressure drop: Z8 (d_{90} = 0.3 µm, in wall)
- For in-wall coating, the pressure drop does not depend much on catalyst particle size
- For on-wall coating, the pressure drop is determined by cracks and uncoated parts
  - more cracks and less uniform on-wall layer: Z16 (d_{90} = 0.3 µm)

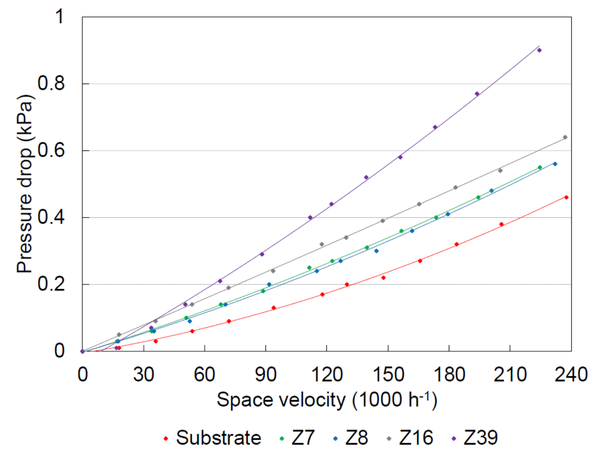

Figure 3: Dependence of pressure drop on space velocity for all samples

CATALYTIC ACTIVITY

- Figure 4 shows CO light-off curves
  - Outlet CO concentration as a function of increasing temperature
- The light-off temperature and CO slip due to transport limitation were studied (see Table 2 and 3)

Table 2: Light-off temperatures

T_{50} (°C)	Z7	Z8	Z16	Z39
50 000 h^{-1}	159.7	150.6	154.2	165.1
100 000 h^{-1}	163.0	155.6	159.3	167.5
200 000 h^{-1}	169.3	162.3	166.7	171.4

Table 3: Transport limitation of CO conversion

CO slip (ppm)	Z7	Z8	Z16	Z39
50 000 h^{-1}	0	0	0	0
100 000 h^{-1}	5	0	3	2
200 000 h^{-1}	20	2	4	8

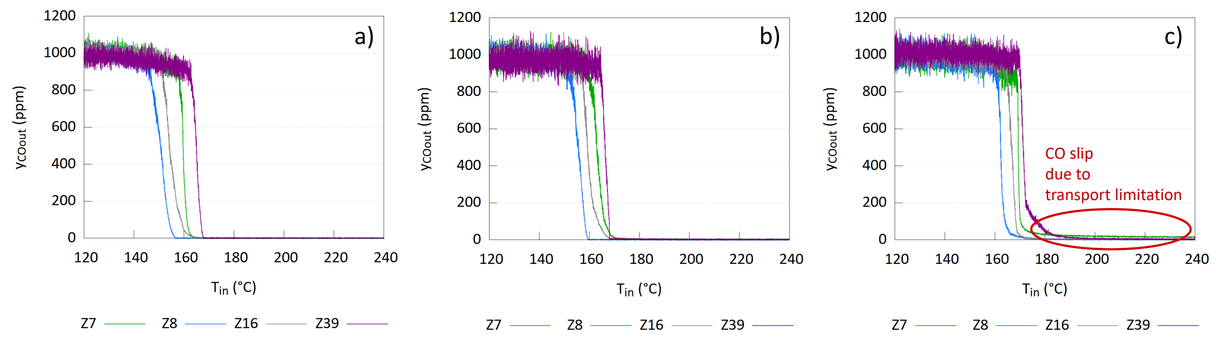

Figure 4: Dependence of the output CO concentration on the reactor inlet temperature for all samples. GHSV: a) 50 000 h^{-1}, b) 100 000 h^{-1}, c) 200 000 h^{-1}

Conclusions

PRESSURE DROP

- In-wall coating retaining free porosity of the wall → low pressure drop
  - however, low clean filtration efficiency can be expected
- On-wall layer → higher pressure drop
  - cracks prevent excessive pressure drop

CATALYTIC ACTIVITY

- Only minor effect of coating location on the conversion at low flow rates
- Transport limitation of CO conversion observed at higher flow rates (sensitive to the coating distribution)

SAMPLE Z8 (d_{90} = 0.3 um, in-wall) APPEARS TO BE THE BEST FROM THE STUDIED SAMPLES

- The lowest pressure drop and light-off temperature, no observable transport limitation

References

[1] Blažek M., Žalud M., Kočí P., York A., Schlepütz C.M., Stampanoni M., Novák V. Washcoating of catalytic particulate filters studied by time-resolved X-ray tomography. Chemical Engineering Journal 409 (2021), 128057. DOI:10.1016/j.cej.2020.128057

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