How the humidity affects the microwave-based soot load determination of a DPF

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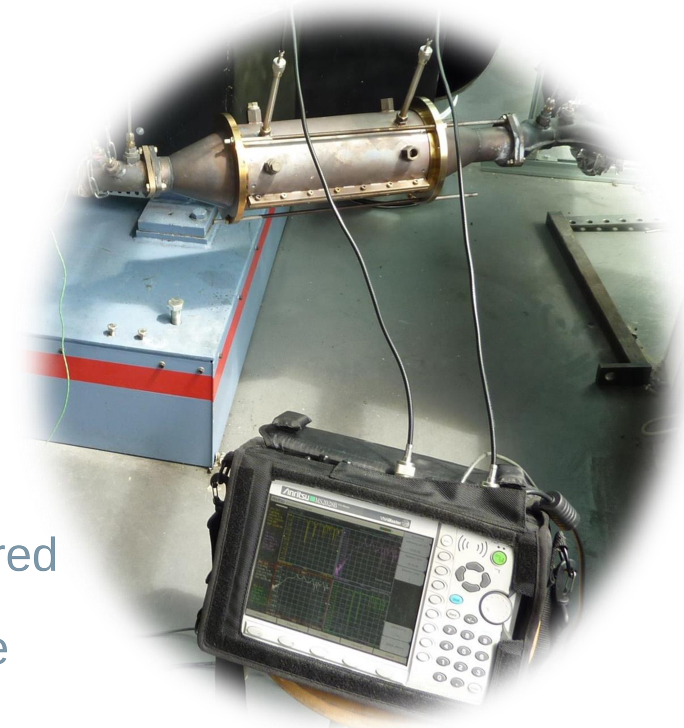
Fundamentals

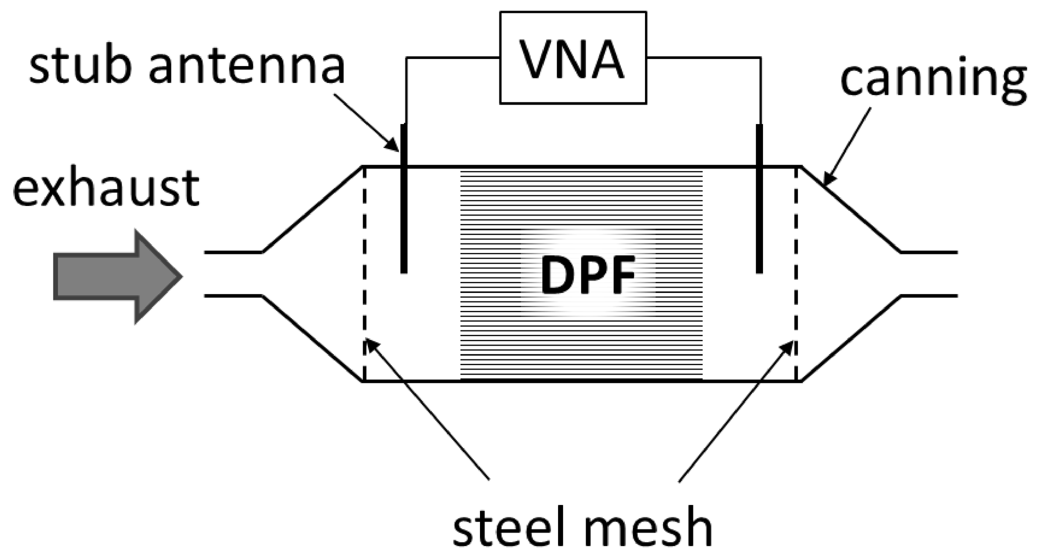
▶ Knowledge of the actual trapped soot mass of diesel particulate filters (DPF) is important for a fuel-efficient engine control and filter regeneration strategy
→ State of the art: indirect and model-based soot load evaluation, involving the pressure loss at the DPF [1]

▶ Novel approach enables direct and contactless soot load detection of a DPF using microwaves:

- Two antennas are installed in the canning up- and downstream of the filter:
  With a Vector Network Analyzer (VNA), microwaves (0.5 - 2.5 GHz) are emitted into the resonator and recorded at the same time.
  Inside the housing characteristic standing waves (resonance modes) form, as the metallic canning defines a cavity resonator.
- Measuring of reflection- (S_{11}, S_{22}) and transmission- (S_{12}, S_{21}) spectra
- Spectra vary with conductivity and hence with the soot load inside the DPF
- Various parameters possible: here resonance frequency, f_{res}, and the transmission factor, averaged between 0.8 - 2.5 GHz, are considered



▶ System found to be basically suitable for in-operation soot load detection [2-4]. Influencing parameters on the measuring system need to be examined. Here we focus on humidity and temperature in a range below 100°C.



DPF: uncoated aluminum titanate, 5.66“ x 6“, 300 cpsi
VNA: Anritsu MS2028B

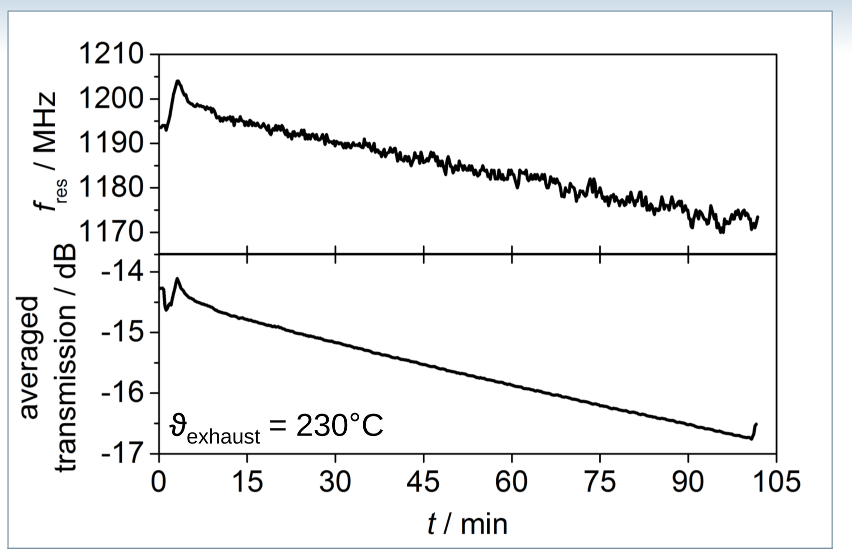
1. Soot loading

Filter was mounted in the exhaust pipe of a dynamometer test bench (3.0 l TDI engine, 6 cyl.)
Soot loading under constant speed and load (2350 min^{-1}, 20%)
→ soot mass on DPF at end of experiment: 1.5 g/l$_{DPF}$

▶ Linear decrease of resonance frequency f_{res} (TE112-Mode) and the averaged transmission parameter during soot loading

▶ Accumulating soot changes the electrical conductivity and permittivity inside the resonator

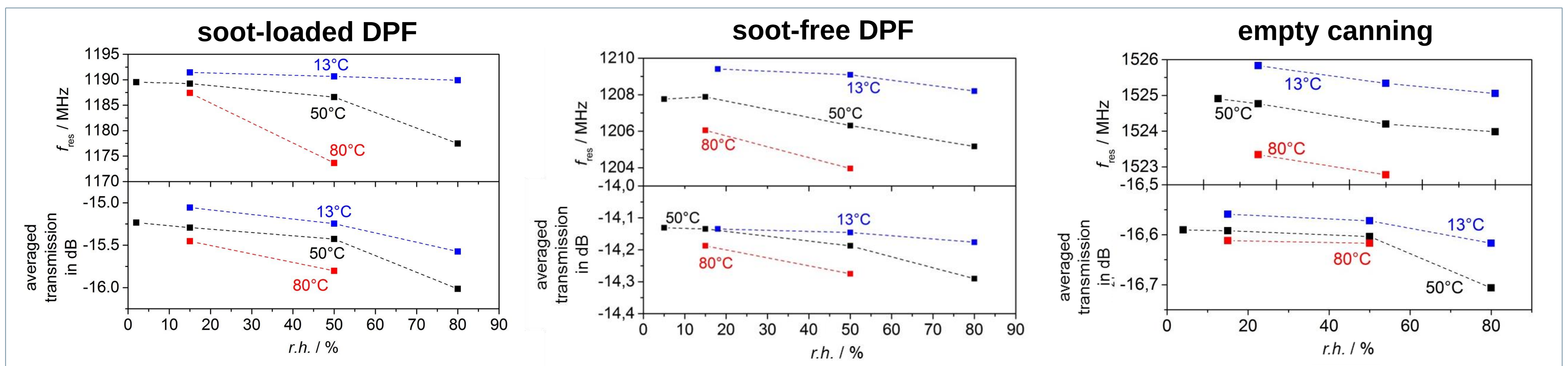
▶ Behavior is consistent to previous results and literature [2, 3, 4]



Resonance frequency (upper graph) and averaged transmission factor (lower graph) during soot loading.

2. Humidity and temperature variation

Stepwise variation of ambient temperature (13 – 80°C) and relative humidity (2 – 80 %) in a climate cabinet. Thereby, no direct gas flow through the DPF was enforced!
Climatic exposure test was conducted several times: with empty resonator/housing, with a soot-free DPF, with the soot-loaded DPF (1.5 g/l$_{DPF}$).

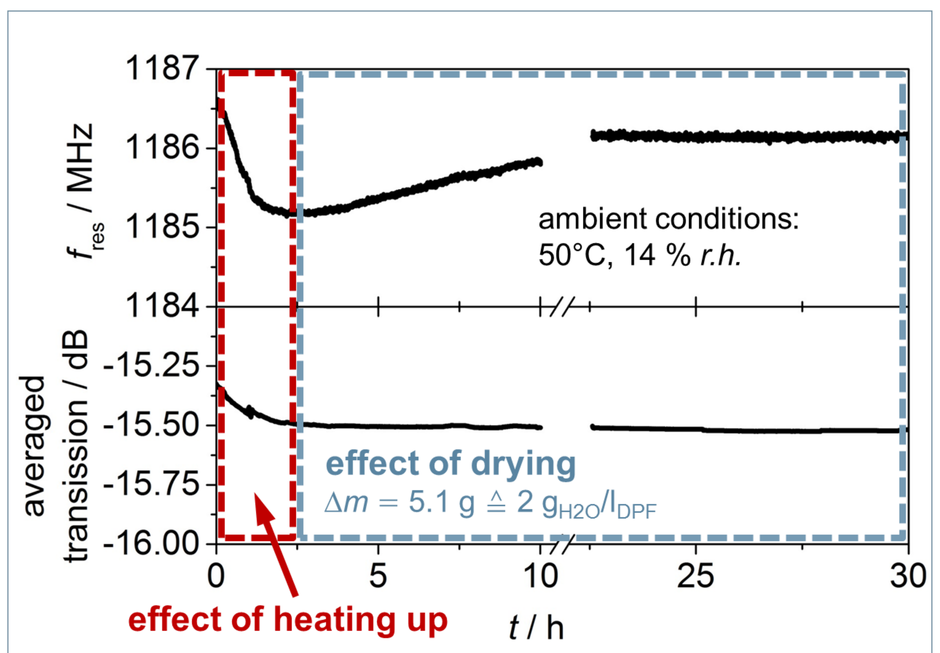


f_{res} (upper graphs) and averaged transmission factor (lower graphs) over relative humidity at different temperatures. Each step was set for 2hrs before measuring the rf-parameters.

▶ Increase of temperature or humidity lead to decrease of f_{res} and the averaged transmission factor → change in conductivity and permittivity with ϑ and *r.h.*

▶ Sensitivity on humidity increases with higher temperature (especially for f_{res})

▶ Values of f_{res} and the transmissions parameter are higher than at the end of soot loading → lower temperature ($\vartheta_{exh.}$: 230°C)



Resonance freq. (upper graph) and averaged transmission (lower graph) during long-term-drying of a soot-loaded DPF at 50°C.

▶ Influence of temperature overbalances that of drying

▶ f_{res} depends more on humidity of the DPF than the averaged transmission factor (almost no effect)

Summary and conclusions

▶ In total, signal shifts caused by humidity are very small compared to shifts during soot loading

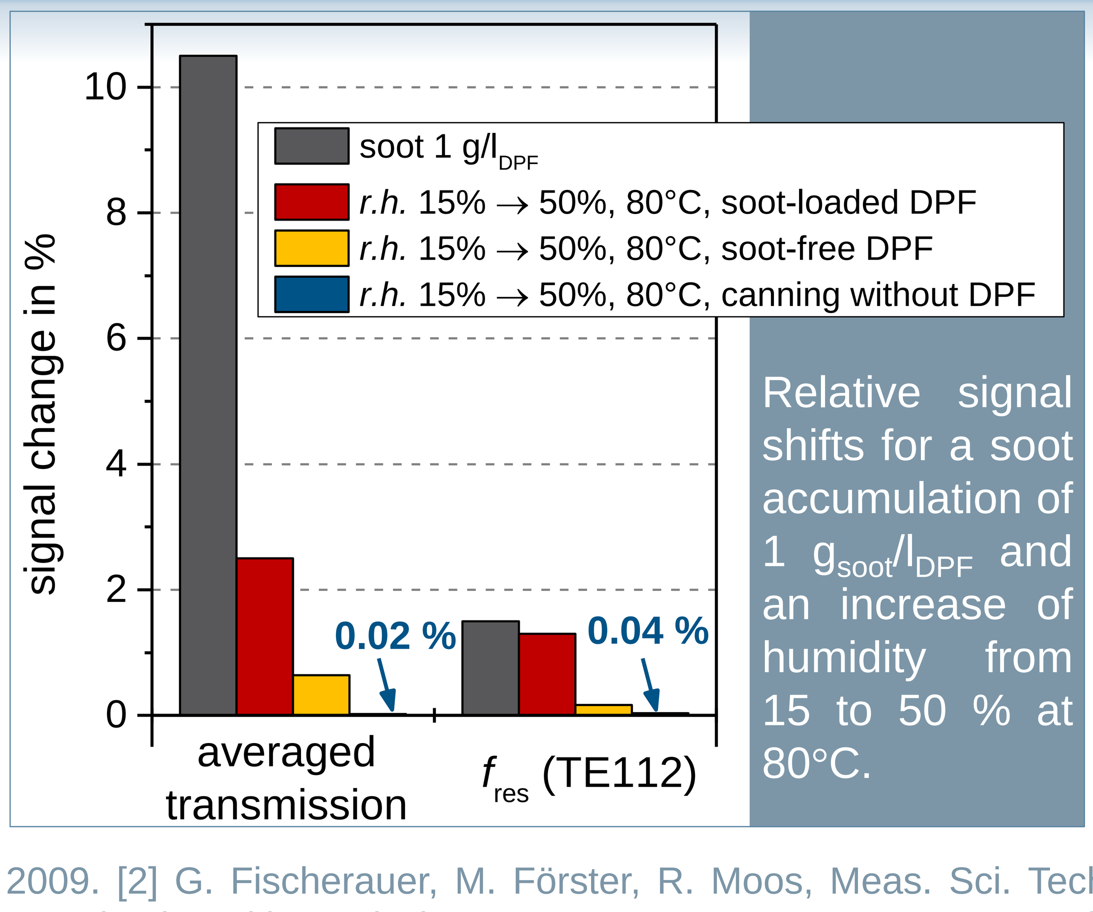
▶ Soot-free DPF or empty canning: almost no influence of humidity occurs

▶ Soot loaded DPF: ambient conditions need to be considered in real-world applications

▶ Especially f_{res} is affected by humidity; only minimal influence on averaged transmission parameter (for ϑ < 100°C !)

➔ Behavior above 100°C needs to be examined

➔ The averaged transmission seems more suitable for application



Relative signal shifts for a soot accumulation of 1 g$_{soot}$/l$_{DPF}$ and an increase of humidity from 15 to 50 % at 80°C.

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