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

Markus Feulner, Ralf Stöber, Gerhard Fischerauer, Ralf Moos

Bayreuth Engine Research Center (BERC), University of Bayreuth, 95447 Bayreuth, Germany
funktionsmaterialien@uni-bayreuth.de

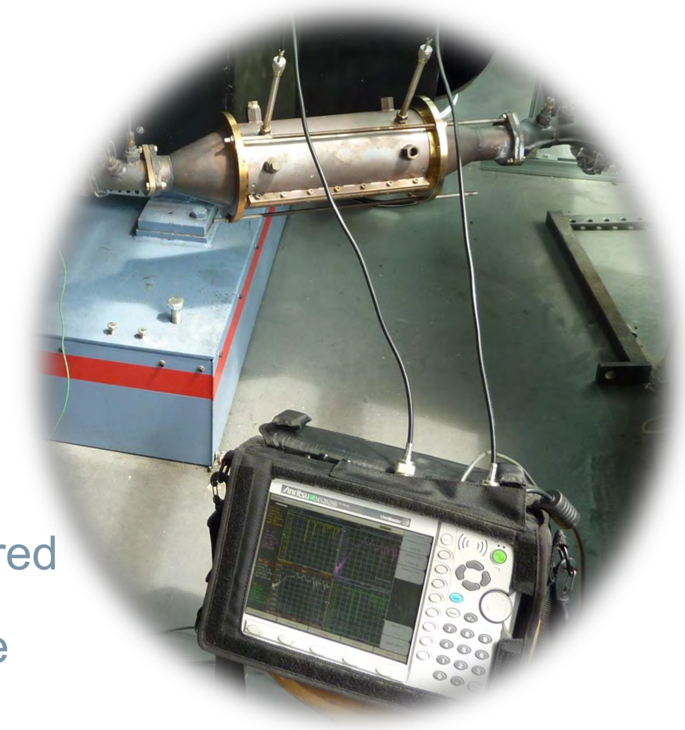
BAYREUTH ENGINE RESEARCH CENTER

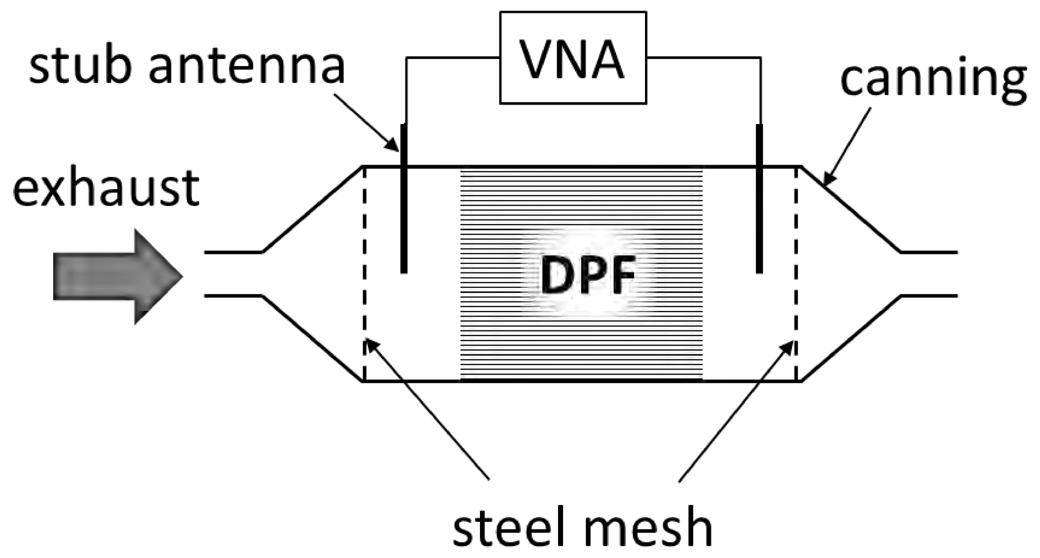
Lehrstuhl für Mess- und Regeltechnik Prof. Dr.-Ing. Gerhard Fischerauer

FM | funktionsmaterialien

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.





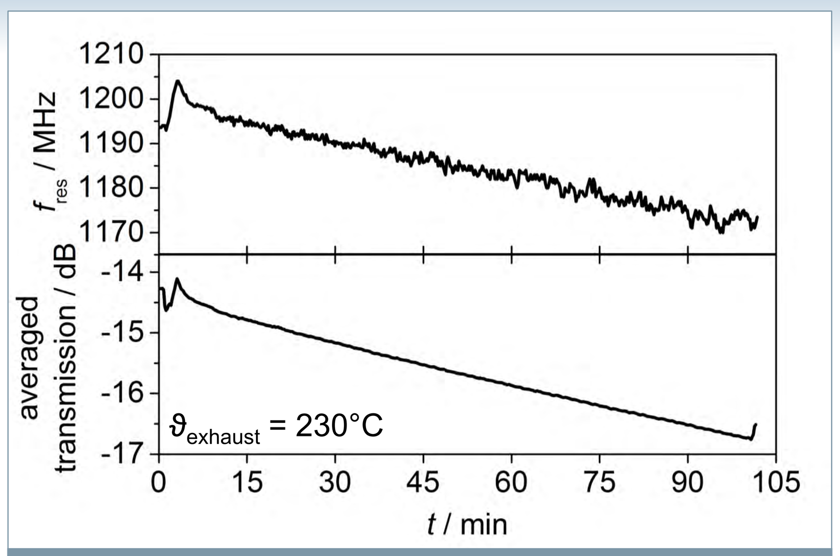
DPF: uncoated aluminum titanate, 5.66" x 6", 300 cpsi
VNA: Anritsu MS2028B

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$_{DPF}$

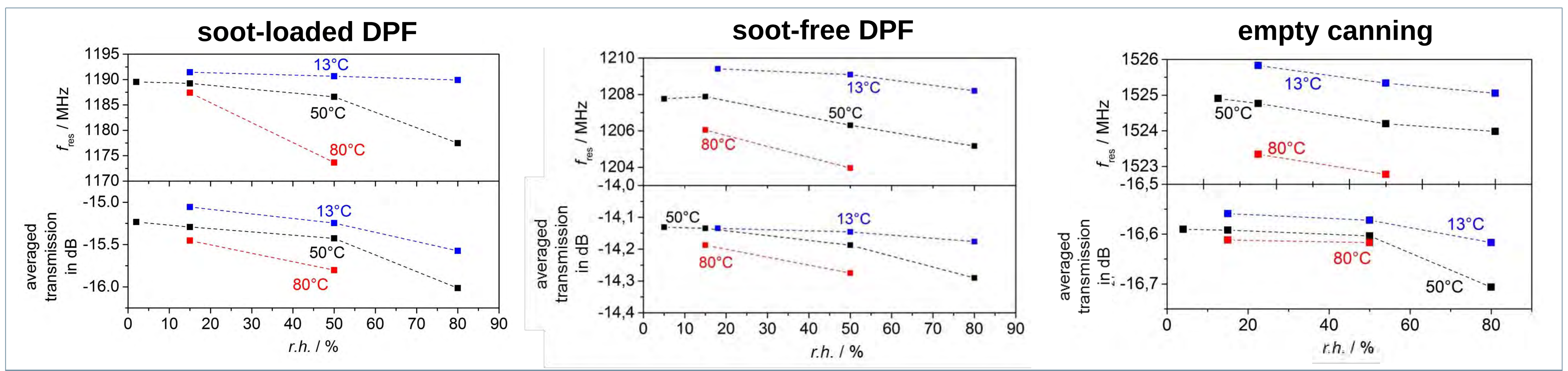
- ▶ Linear decrease of resonance frequency f_{res} (TE112-Mode) and the averaged transmission parameter during soot loading
- ▶ Accumulating soot changes the electrical conductivity and permittivity inside the resonator
- ▶ Behavior is consistent to previous results and literature [2, 3, 4]



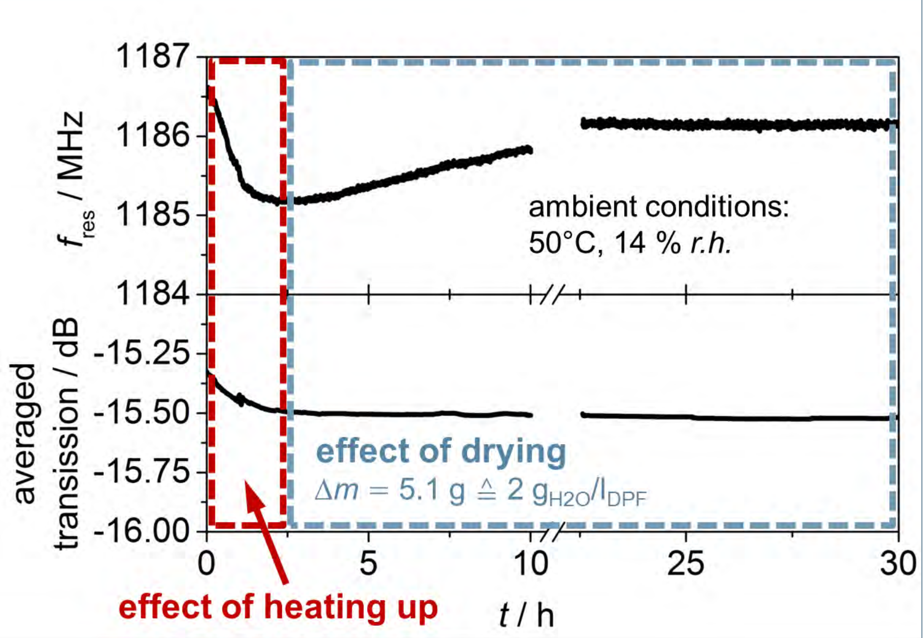
Resonance frequency (upper graph) and averaged transmission factor (lower graph) during soot loading.

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.



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

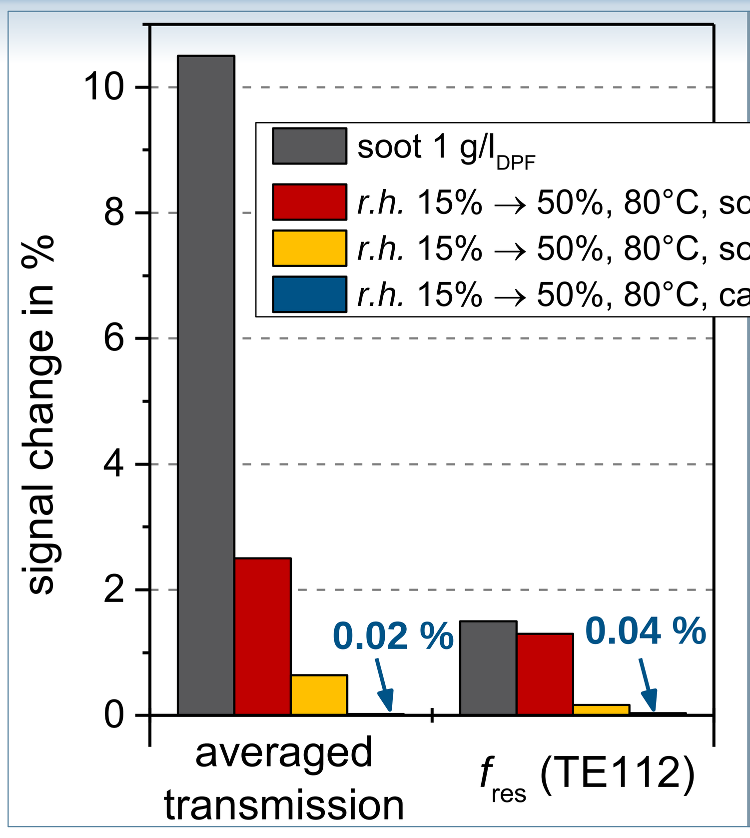
- ▶ Increase of temperature or humidity lead to decrease of f_{res} and the averaged transmission factor → change in conductivity and permittivity with ϑ and *r.h.*
- ▶ Sensitivity on humidity increases with higher temperature (especially for f_{res})
- ▶ Values of f_{res} and the transmissions parameter are higher than at the end of soot loading → lower temperature ($\vartheta_{exh.}$: 230°C)
- ▶ 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.

ACKNOWLEDGMENT
This work was supported by the German Research Foundation (DFG) under MO 1060/6-2 and FI 956/3-2.

DFG Deutsche Forschungsgemeinschaft

REFERENCES
[1] D. Rose, T. Boger, SAE Paper 2009-01-1262, 2009. [2] G. Fischerauer, M. Förster, R. Moos, Meas. Sci. Tech. 21 (2010) 035108. [3] M. Feulner, G. Hagen, A. Müller, A. Piontkowski, G. Fischerauer, D. Brüggemann, R. Moos, Topics in Catalysis 56 (2013), 483-488. [4] A. Sappok, L. Bromberg, J Parks, V. Prikhodko, SAE Paper 2010-01-2126, 2010.

www.berc.uni-bayreuth.de

AUTOMOTIVE COMPONENTS ENGINEERING

UNIVERSITÄT BAYREUTH