LABORATORY OF APPLIED THERMODYNAMICS

Dipl.-Ing.
Thomas Bollerhoff
VECOM Early Stage Researcher

ARISTOTLE UNIVERSITY THESSALONIKI
SCHOOL OF ENGINEERING
DEPT. OF MECHANICAL ENGINEERING

Validation of a DPF model based on engine experiments

Overview

- Motivation
- Simulation software Axisuite
- DPF with inhomogeneous wall structure
- Validation of the inhomogeneous wall structure model
- Conclusion and outlook

Motivation

- Targets in development of DPF:
  - Minimize fuel penalty caused by DPF
  - Maximize filtration efficiency of empty filters
  - [...]
- Important tool: Simulation, e.g.:
  - Parameter optimization => pressure drop, filtration efficiency
  - Estimation of soot loading => regeneration intervals
- Necessity: Validated good models

3

Axisuite

- Modular software for the simulation of exhaust aftertreatment devices and systems

axisuite						
module	principle	TWC	DOC	LNT	SCR	DPF
axicat	flow-through	✓	✓	✓	✓	–
axitrap	wall-flow	✓	✓	✓	✓	✓
axifoam	deep-bed	✓	✓	✓	✓	✓
axiheat	exhaust pipe	single-wall / double-wall / insulating material / reacting flow				

Exothermia
modeling efficiency

4

Axitrap

- Axisuite module for simulation of wall-flow filters

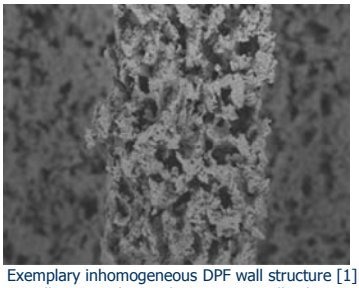
- Features of filtration model
  - spherical or aggregate particles
  - diffusion and interception mechanism
  - PM mass and number based
  - filtration according to microstructure of wall and cake
  - independently changeable properties in top and bottom layers for inhomogeneous wall structures and membrane technologies

5

DPF with inhomogeneous wall structure

- Goals:
  - increase filtration efficiency
  - decrease soot accumulation inside the wall
    => decreased pressure drop
    => decreased fuel penalty caused by the DPF

- Drawback:
  - inhibited passive regeneration due to less contact of soot and catalytic coating

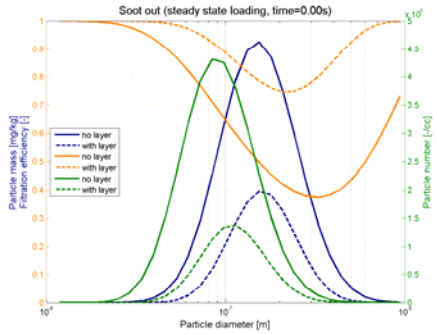


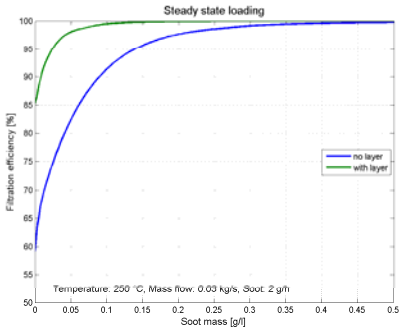
Exemplary inhomogeneous DPF wall structure [1]: small pores in layers, big pores in wall substrate

6

[1] S. Hajireza: "XP-SiC: An Innovative Substrate for Future Applications with Low Weight and High Porosity", DEER 2009 Conference

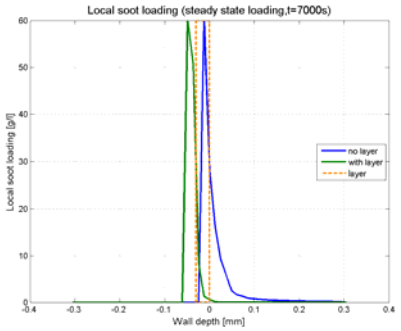
DPF with inhomogeneous wall structure: Filtration

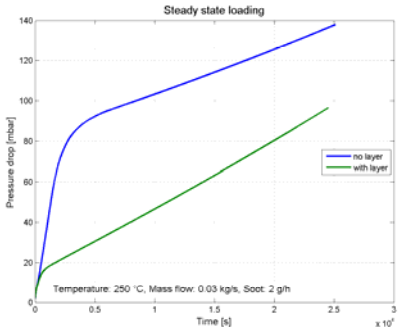




Significantly increased filtration efficiency with layer at empty DPF

DPF with inhomogeneous wall structure: Pressure Drop



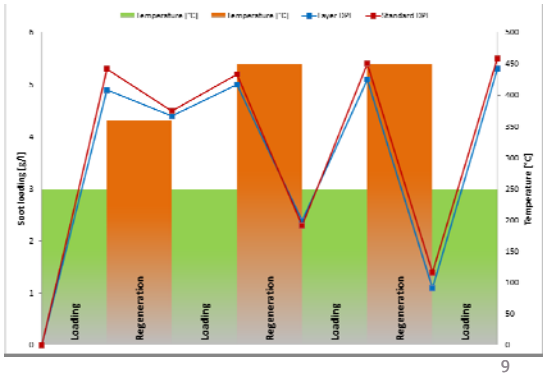


Less pressure drop due to less soot accumulation inside the wall

Validation

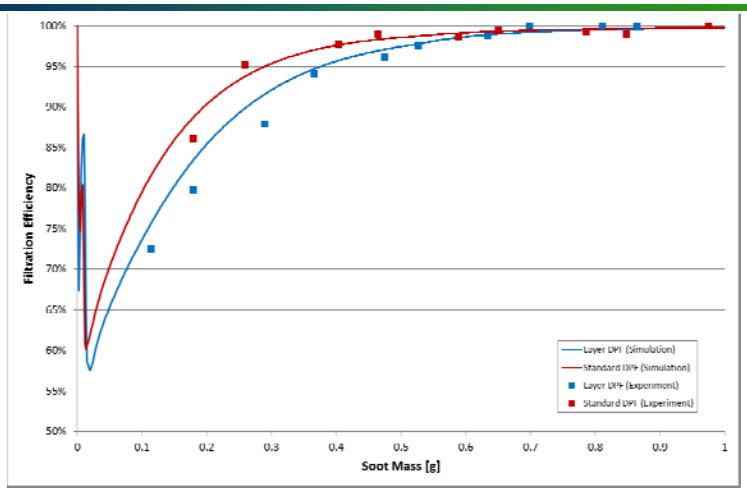
- Validation against experimental data comparing a standard cordierite DPF and a SiC DPF with inhomogeneous wall structure
  - Steady state loading/partial regeneration cycles
  - Steady state loading at balance point

- Main tasks
  - filtration efficiency
  - pressure drop
  - catalytic reactions (soot mass)



9

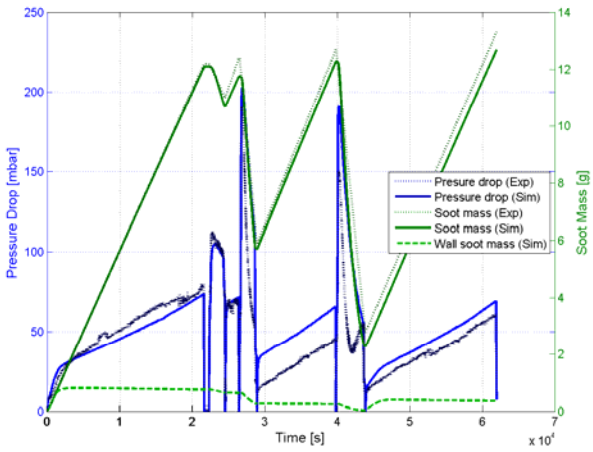
Filtration



Slightly better filtration at very low soot loadings with Standard DPF
Good correlation of simulation and experimental data

10

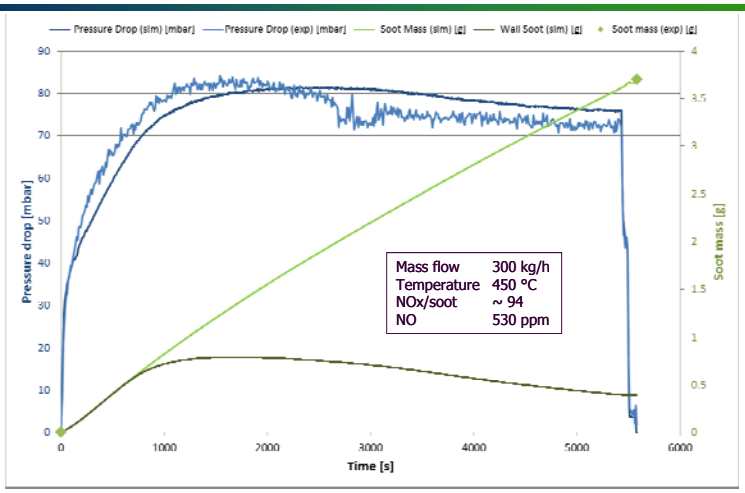
Soot mass and pressure drop (cycle)



Acceptable correlation of simulation and experiment

11

Soot mass and pressure drop (balance point)



Acceptable correlation of simulation and experiment

12

Conclusion

- Simulations of a loading/partial regeneration cycle and a loading at a balance point for a DPF with inhomogeneous wall structures were compared with experimental data
- Good correlation for filtration efficiency between simulation and experiment
- Acceptable correlations for pressure drop and soot mass
- Model for DPF with inhomogeneous wall structures successfully validated

13

Outlook

- Upcoming related presentations/papers:
  - "Filtration and regeneration modeling for particulate filters with inhomogeneous wall structure" (MODEGAT II, Catalysis Today)
  - "Modeling the interactions of soot and SCR reactions in advanced DPF technologies with non-homogeneous wall structure" (SAE proposal)

14

Thank you for your attention!
Any questions?

15

16

MODEGAT II

2nd International Symposium on Modeling of Exhaust-Gas After-Treatment

- Date: 19./20.9.11
- Location: Bad Herrenalb/Karlsruhe, Germany
- Info: http://www.modegat.org

17

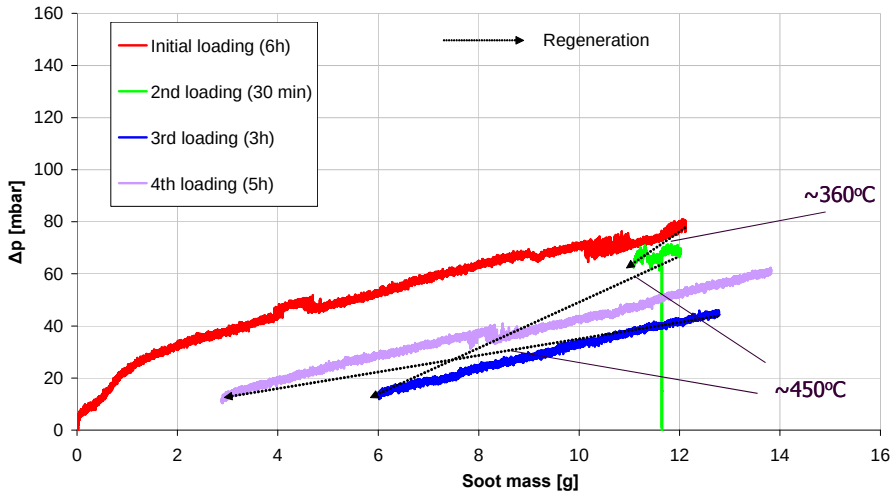
Test Summary Cycles

DOC upstream, EGR on

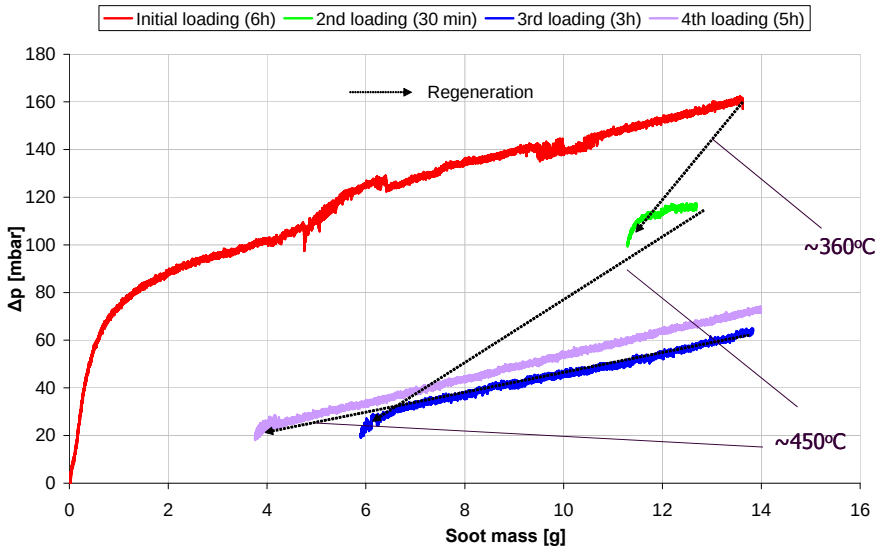
	V [kg/h]	NO_x [ppm]	Operating points	cXP200-1	COM200-1
Initial loading for 6h	130		2300 rpm/30 Nm	0 -> 12.2 g (4.9 g/l) Δm= +12.2 g	0 -> 13.2 g (5.3 g/l) Δm= +13.2 g
Reg.@~360°C for ~30 min	150	~190	2500 rpm/75 Nm	12.2 g -> 11.0 g (4.4 g/l) Δm= -1.2 g	13.2 g -> 11.2 g (4.5 g/l) Δm= -2.0 g
2nd loading for ~30 min	130		2300 rpm/30 Nm	11.0 g -> 12.4 g (5 g/l) Δm= +1.4 g	11.2 g-> 13.0 g (5.2 g/l) Δm= +1.8 g
2nd Reg.@~450°C for ~30 min	280	~510	3500 rpm/110 Nm	12.4 g -> 5.9 g (2.4 g/l) Δm= -6.5 g	13.0 g-> 5.8 g (2.3 g/l) Δm= -7.2 g
3rd loading for ~3h	130		2300 rpm/30 Nm	5.9 g -> 12.7 g (5.1 g/l) Δm= +6.8 g	5.8 g -> 13.5 g (5.4 g/l) Δm= +7.7 g
3rd Reg.@~450°C for ~60 min	280	~510	3500 rpm/110 Nm	12.7 g -> 2.8 g (1.1 g/l) Δm= -9.9 g	13.5 g -> 3.6 g (1.4 g/l) Δm= -9.9 g
4th loading for 5h	130		2300 rpm/30 Nm	2.8 g -> 13.3 g (5.3 g/l) Δm= +10.5 g	3.6 g -> 13.8 g (5.5 g/l) Δm= +10.2 g

18

Partial regeneration effect
DPF with inhomogeneous wall structure



Partial regeneration effect
Standard DPF



Δp comparison