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Environmental Technologies

Advanced Particulate Filter Technologies for Direct Injection Gasoline Engine Applications

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Introduction

Drivers for Gasoline Particulate Filters

- In Europe GDI engine technology continues to gain share within the segment of spark-ignition powered vehicles
  - GDI enables better fuel economy and therefore a further reduction in CO_2 emissions compared to fuel port injection engines
  - GDI engines show significantly *higher* PM and PN emissions while compared to fuel port injection engines
- With the EU6c emissions regulation in 2017 particulate number emissions of *6×10^{11}#/km* will be introduced for all spark-ignition engines
- Besides the current NEDC drive cycle more challenging test methods are currently being discussed – *RDE*
- Particulate filter technologies have been introduced successfully as a robust means to reduce PM and PN emissions from diesel engines
  - Similar technologies can be applied as an alternative *or* to supplement improved combustion recipes for GDI powered vehicles

Gasoline Particulate Filter Applications

Potential On-Engine System Configurations

Reference systems

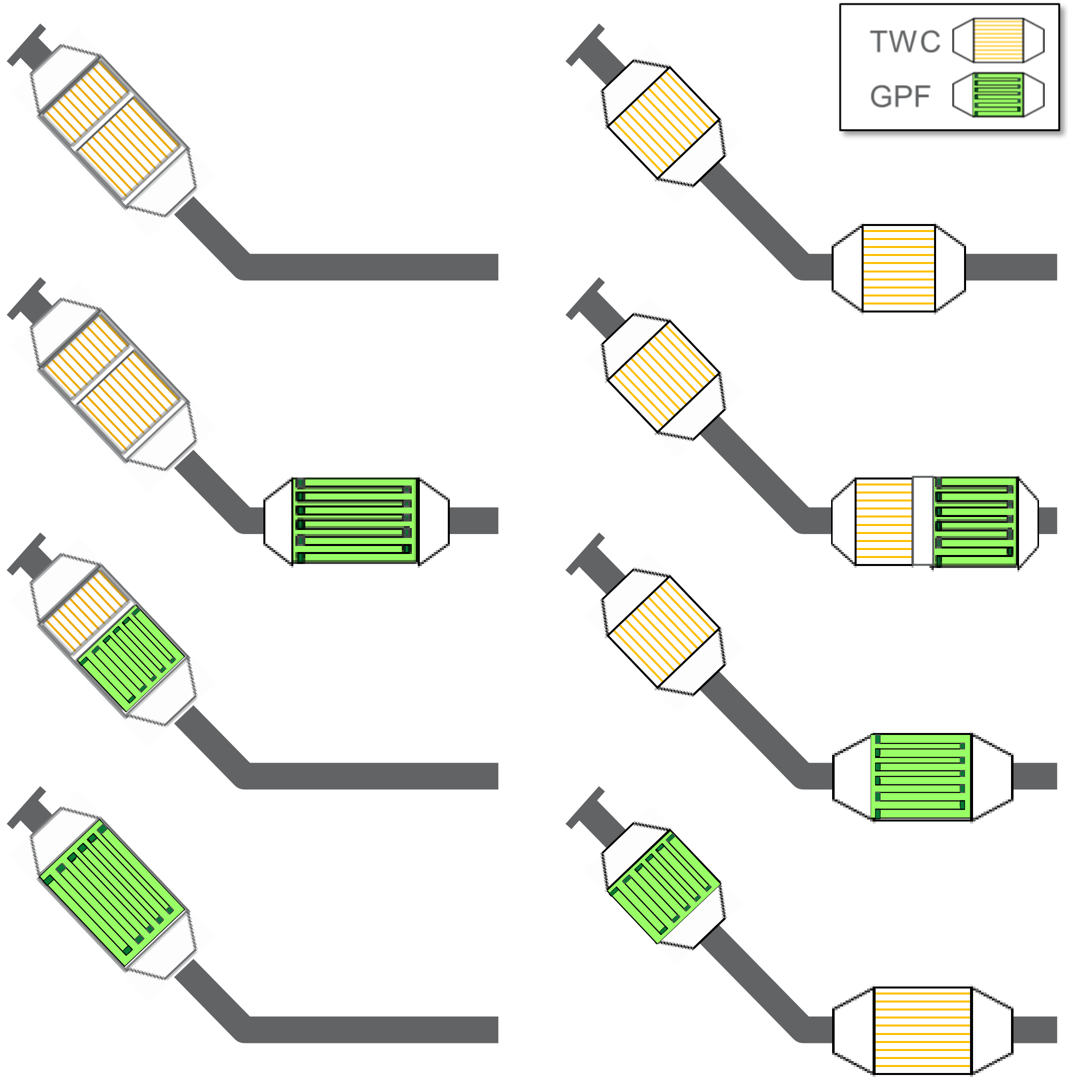
One or two three way catalyst components in close coupled and/or underbody position

"Add on" systems

Uncoated or low washcoat containing gasoline particulate filter in downstream position

Integrated systems

Substitution of conventional coated flow-through substrates by close coupled or underbody gasoline particulate filter with integrated three way catalyst functionality

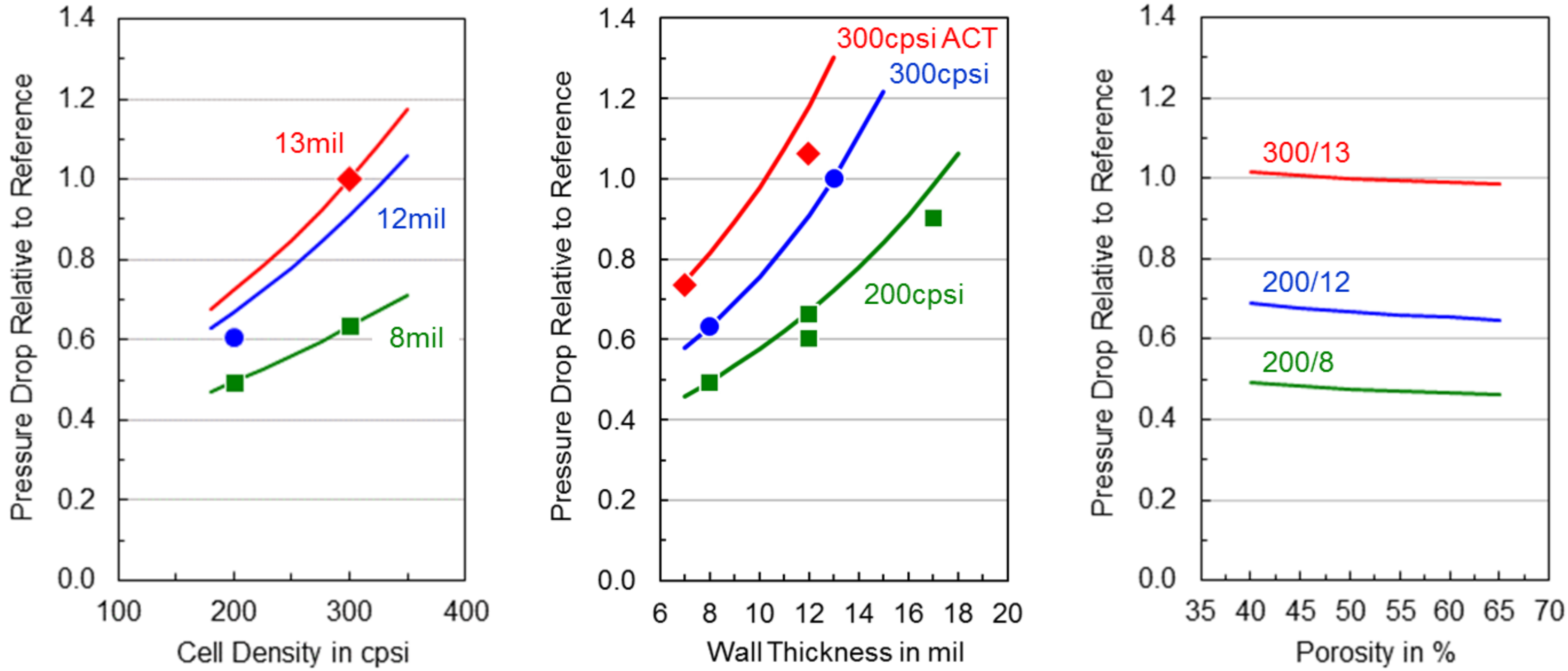


“Add On” GPF Systems

Pressure Drop – Impact of GPF Design

A range of materials, microstructures and designs have been screened to optimize the GPF for “add on” systems

- Due to low expected soot loads lower cell densities are favored for “add on” systems
- Reduction in pressure drop can be achieved by thinner wall designs
- Benefit from increasing porosity is minor due to the high intrinsic permeability of advanced particulate filter technologies



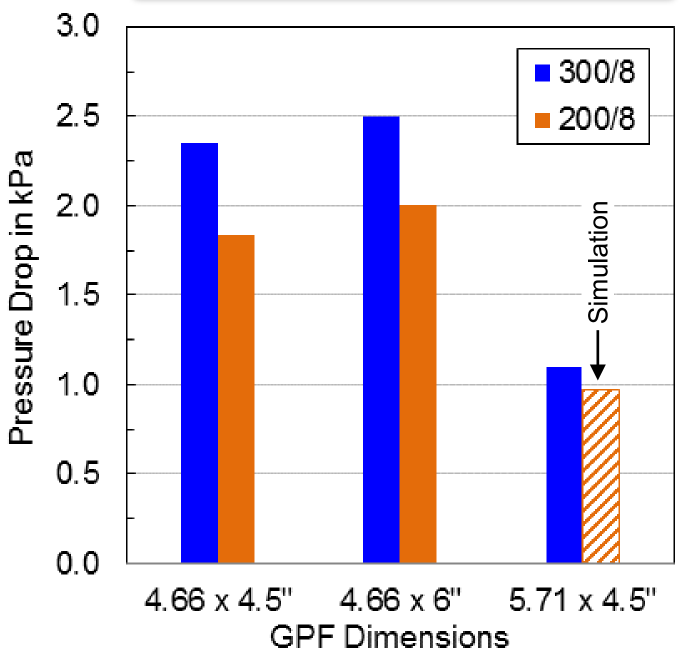
Symbols: Vehicle test data at 1000m³/h, V_{GPF} = 1.25l; **Lines:** Modeling results; **Reference:** GPF 300/13 with 50% porosity

“Add On” GPF Systems

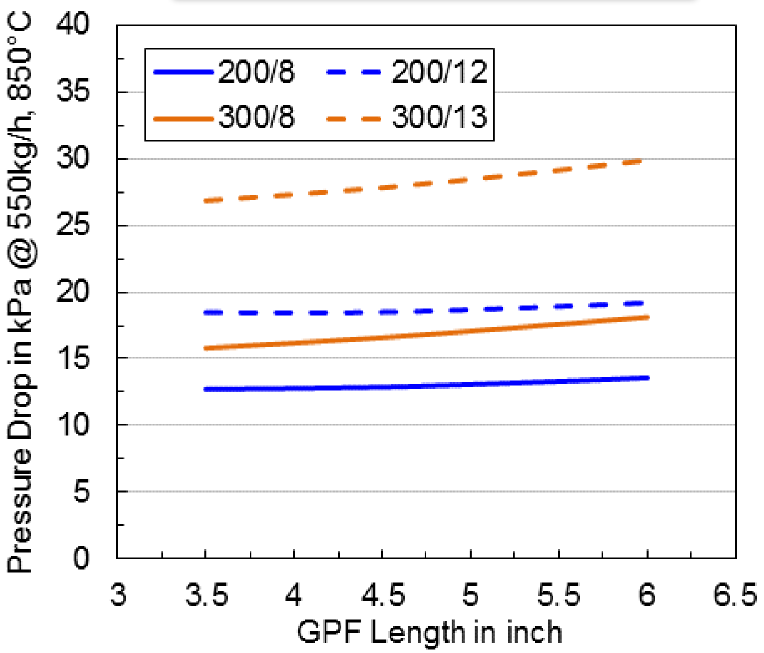
Pressure Drop – Impact of GPF Diameter and Length

- GPF pressure drop strongly impacted by component size and dimensions
  - Larger diameter enables significantly lower pressure drop for similar GPF volume
- Besides lowest pressure drop values the 200/8 design also offers lowest back pressure sensitivity to filter length
  - Volume can be adjusted by GPF length to consider ash storage requirements

Back pressure measurements for various clean filters



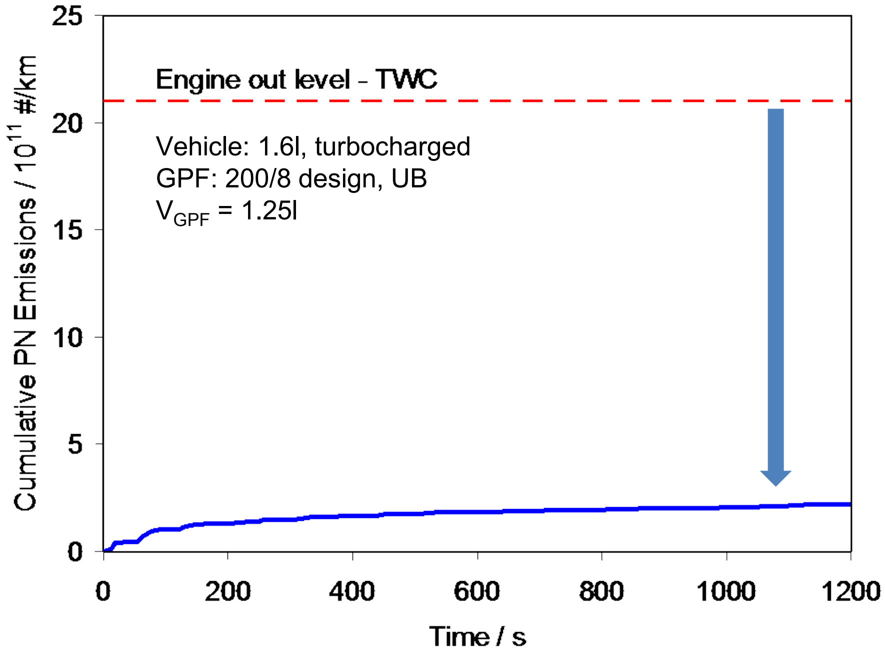
Back pressure simulation for GPF with 4.662” diameter

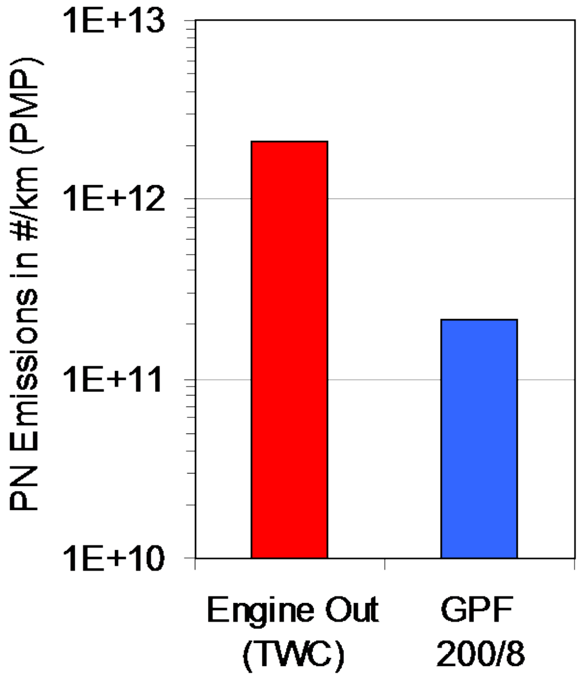


“Add On” GPF Systems

Filtration Efficiency for 200/8 GPF Design

- Filtration efficiency requirements expected to be in the range of 50 to 90%
  - Assuming engine out emissions of 8 to 20 x 10^{11}#/km and targeted tailpipe emissions below 6 x 10^{11}#/km
- 200/8 design with an optimized microstructure having a porosity in the medium range offers filtration efficiencies in the required target range



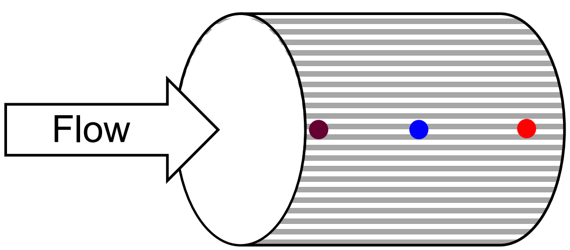


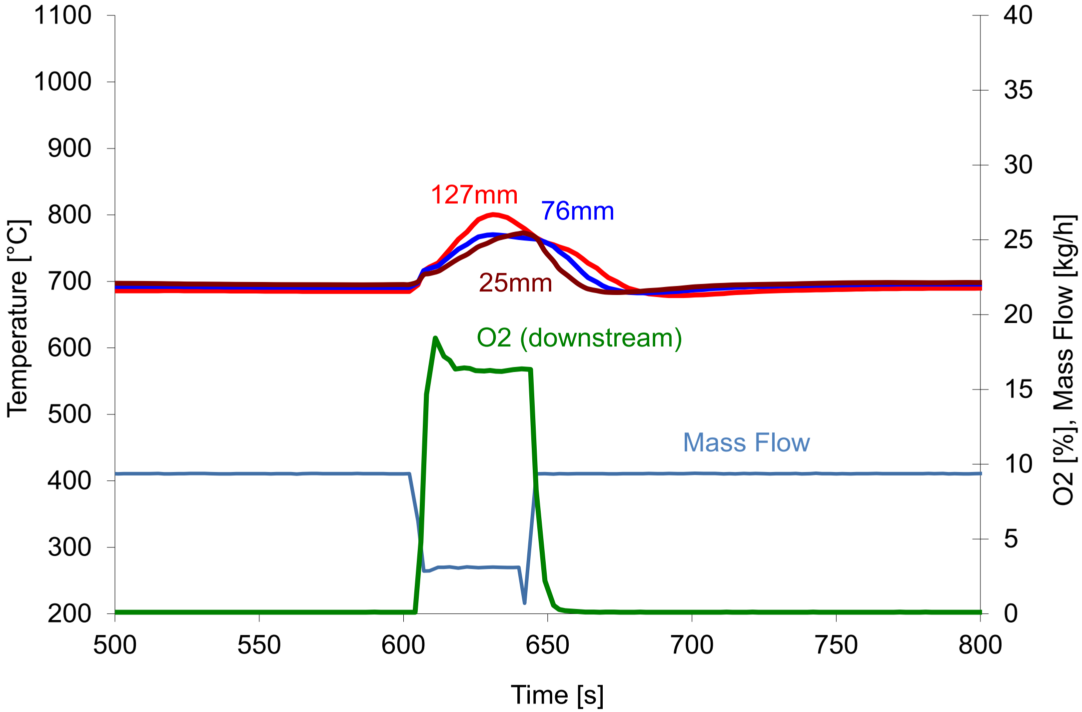
“Add On” GPF Systems – Thermal Robustness

Lab Reactor Fuel Cut Experiments

- Similar to diesel applications, the accumulation and uncontrolled oxidation of soot is expected to lead to high GPF temperatures and therefore high thermal stress
  - Typical soot load expectations for GPF around 2 to 3g/l
- Lab reactor study on thermal response for GPF during simulated fuel cut engine operation – simulation of oxygen supply during gasoline engine operation

<u>Lab scale fuel cut experiment</u>
Uncoated GPF in 200/8 design with 50% porosity
Inlet temperature 700°C
Oxygen pulse 40s

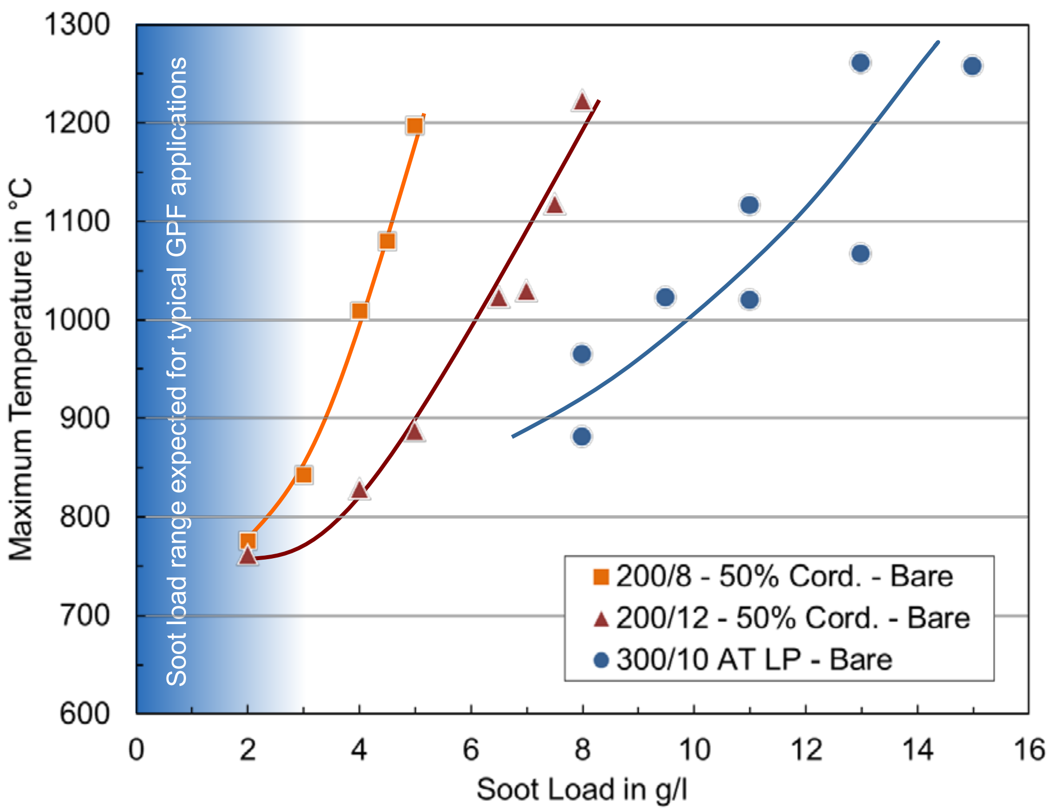




“Add On” GPF Systems – Thermal Robustness

Maximum GPF Temperatures During Simulated Fuel Cut Experiments

- Besides the experimental conditions the maximum filter temperatures observed in GPFs in this lab reactor study are dependent on:
  - Thermal mass of the filter material
  - Soot loading before fuel cut experiment

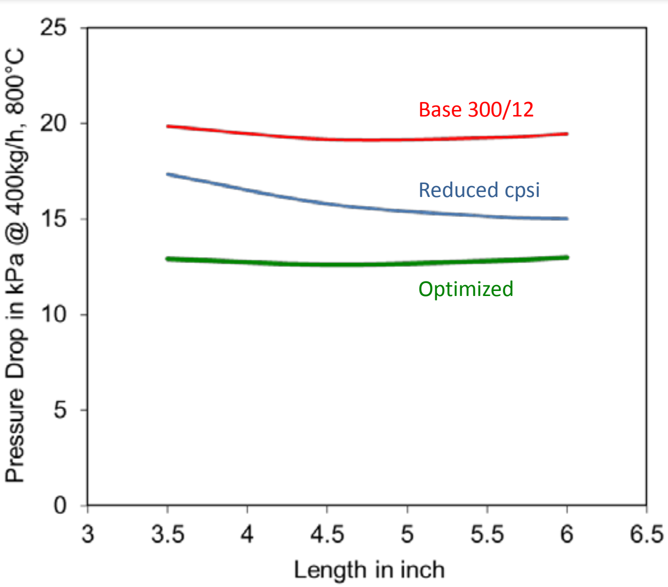


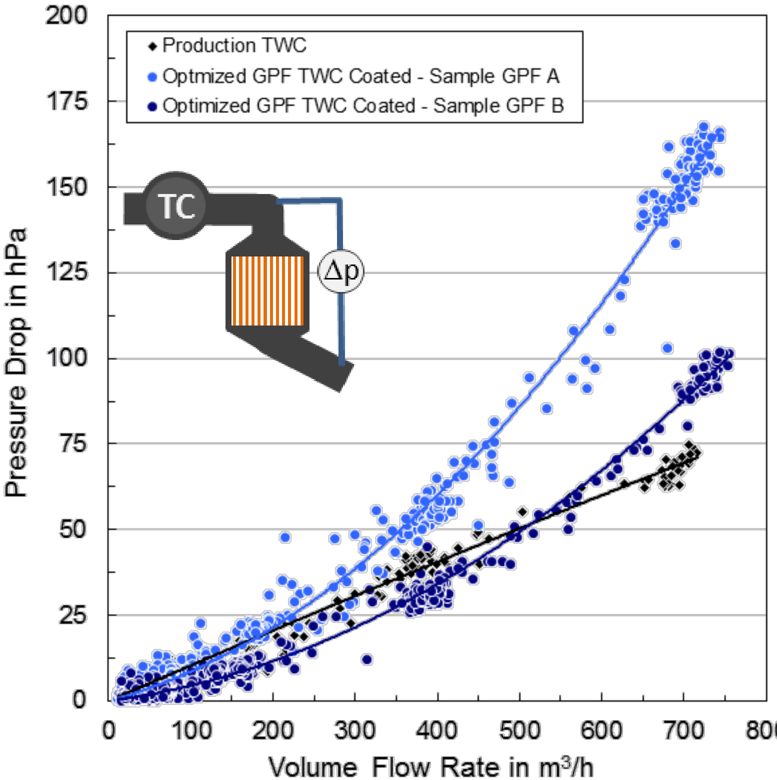
GPF With Integrated Three Way Catalyst Functionality

Pressure Drop

- Coating level has significant impact on the back pressure of the integrated GPF component
- Preferred to have the TWC coating located in the porous filter walls
  - Filter material has to provide sufficient porosity to meet challenging back pressure targets

Back pressure simulation for GPF with 4.662" diameter and 50 to 60% TWC integration

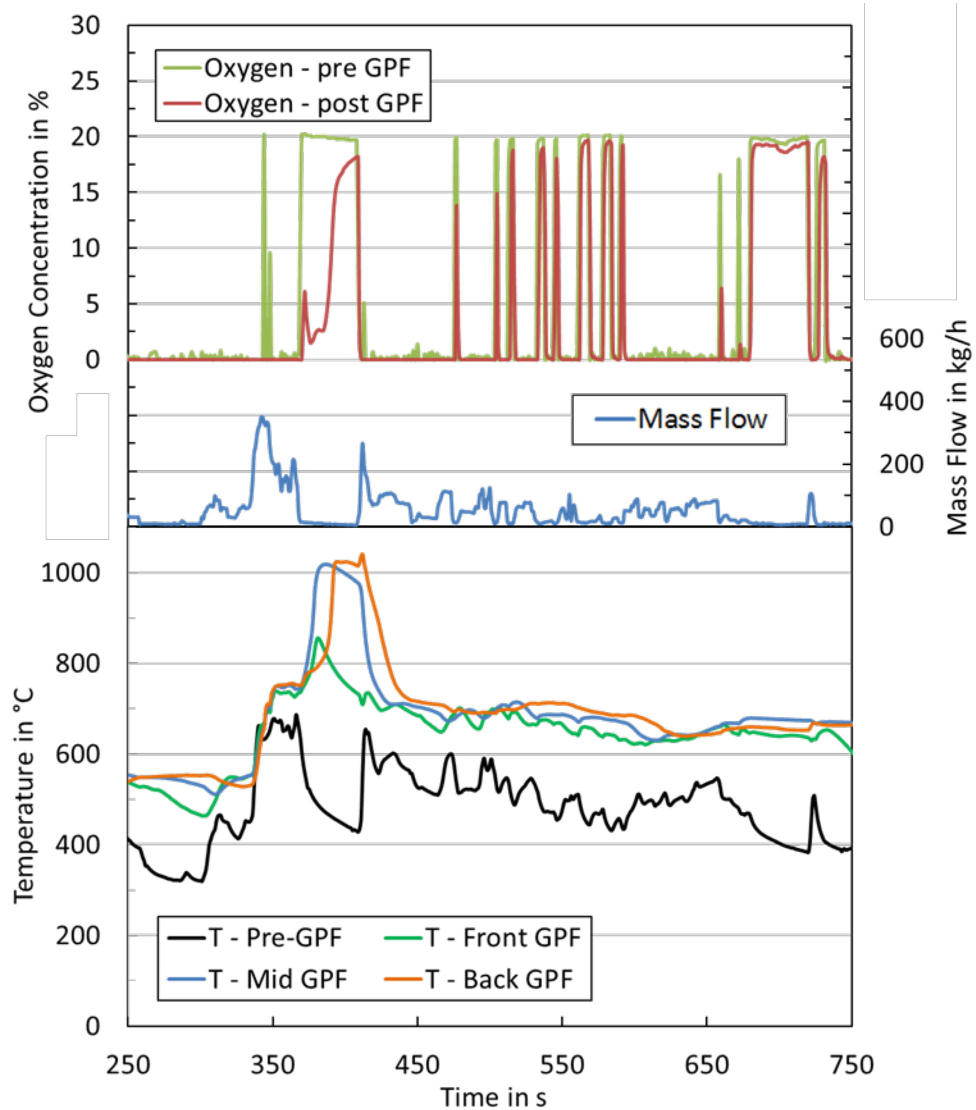




GPF With Integrated Three Way Catalyst Functionality

On Road Fuel Cut Test

- Lab scale testing according to “add on” systems showed similar trend for maximum filter temperature
  - Additional oxidation of CO to CO_2 during soot burn due to coating
- On-road fuel cut testing performed to validate lab scale experiments
  - Soot load 4.8g (diesel soot)
  - Optimized GPF design in 4.66 x 6” in close coupled position
  - Full load acceleration on the Autobahn until T_{inlet} = 700°C
  - Intended engine fuel cut



Summary

Advanced Particulate Filter Technologies for DI Gasoline Engine Applications

- Continuing efforts for further CO_2 and PN reduction create a challenging environment for vehicles equipped with DI gasoline engines
- Gasoline particulate filters will be an enabler to meet these challenging targets either as an alternative *or* as a supplement to improved combustion recipes
- Gasoline particulate filters can be designed:
  - As an “add on” solution to an existing after treatment system
  - As a gasoline particulate filter with integrated three way catalyst functionality
- Optimized designs for gasoline particulate filter applications

	"Add on" GPF	TWC Integrated GPF
Cell Density	200cpsi	200/300cpsi
Wall Thickness	8mil	Optimized
Material	Cordierite	Cordierite
Porosity	Medium	High

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