Advanced filter solutions for robust PN10 control to meet future BS 7 regulations

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Outline

Global 7 (BS 7/Euro 7/China VII) HD ATS system architecture

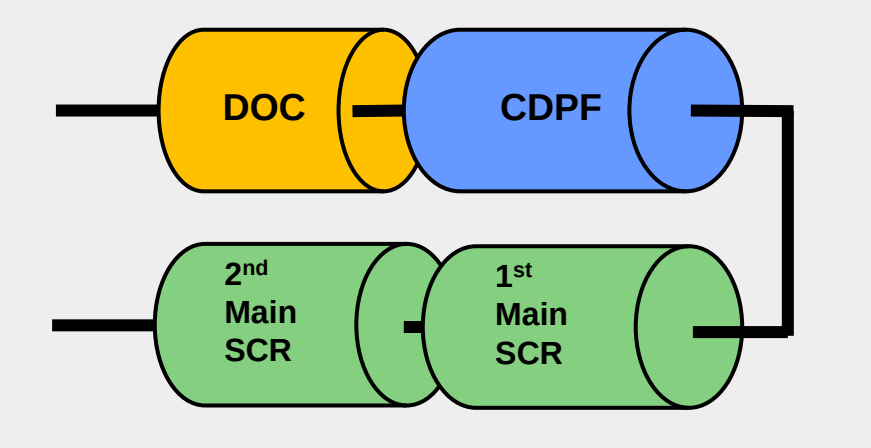
PN10 generation and removal

Filter design and soot cake break through

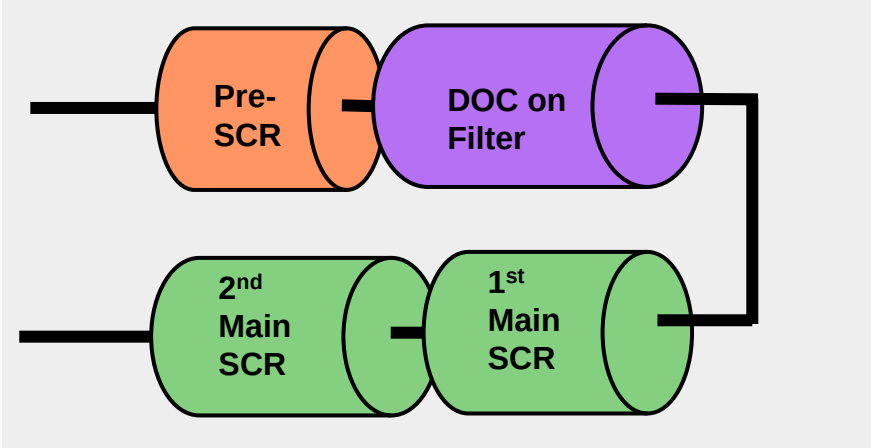
Summary

Global 7 (BS 7/Euro 7/China VII) HD ATS system architecture

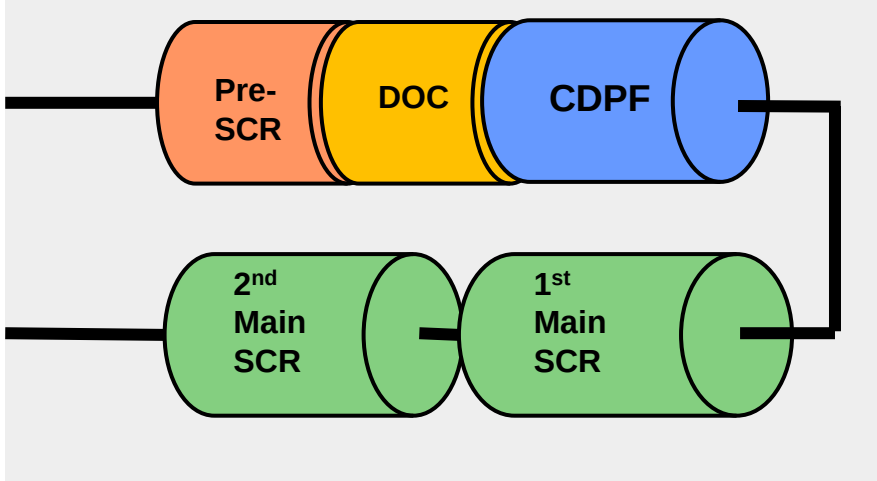
Single Dosing, CDPF



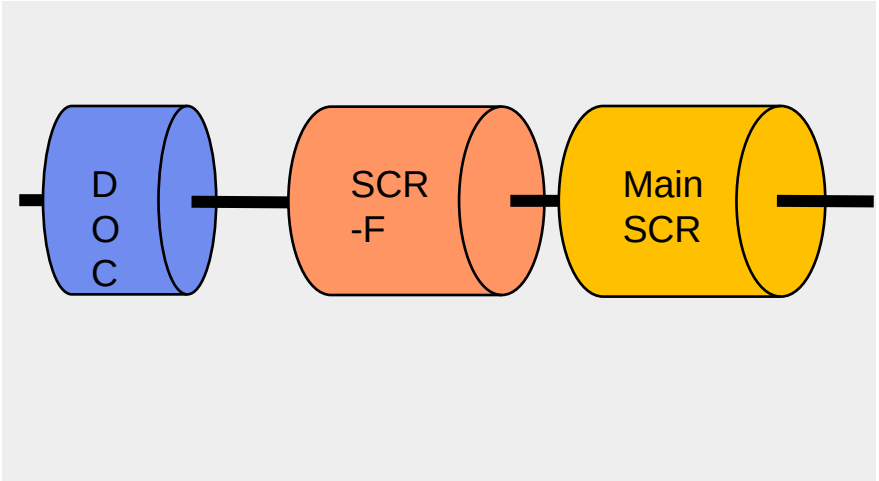
Dual Dosing, DOC-F



Dual Dosing, CDPF



Dual Dosing, SCR-F



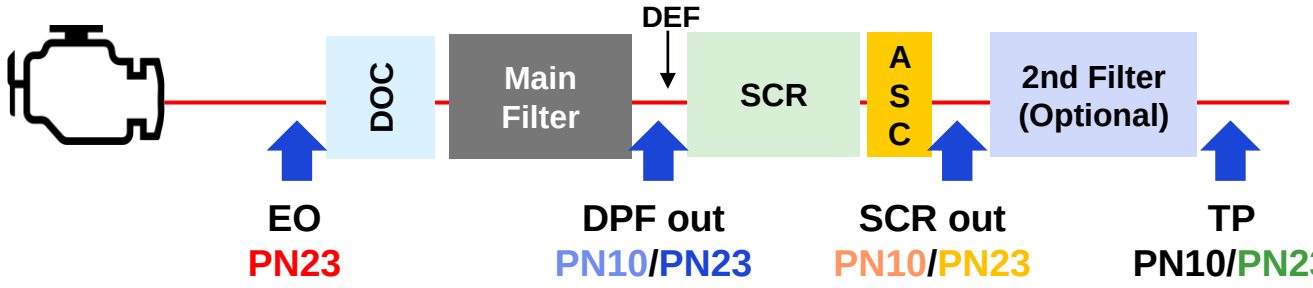
PN10 generation and removal

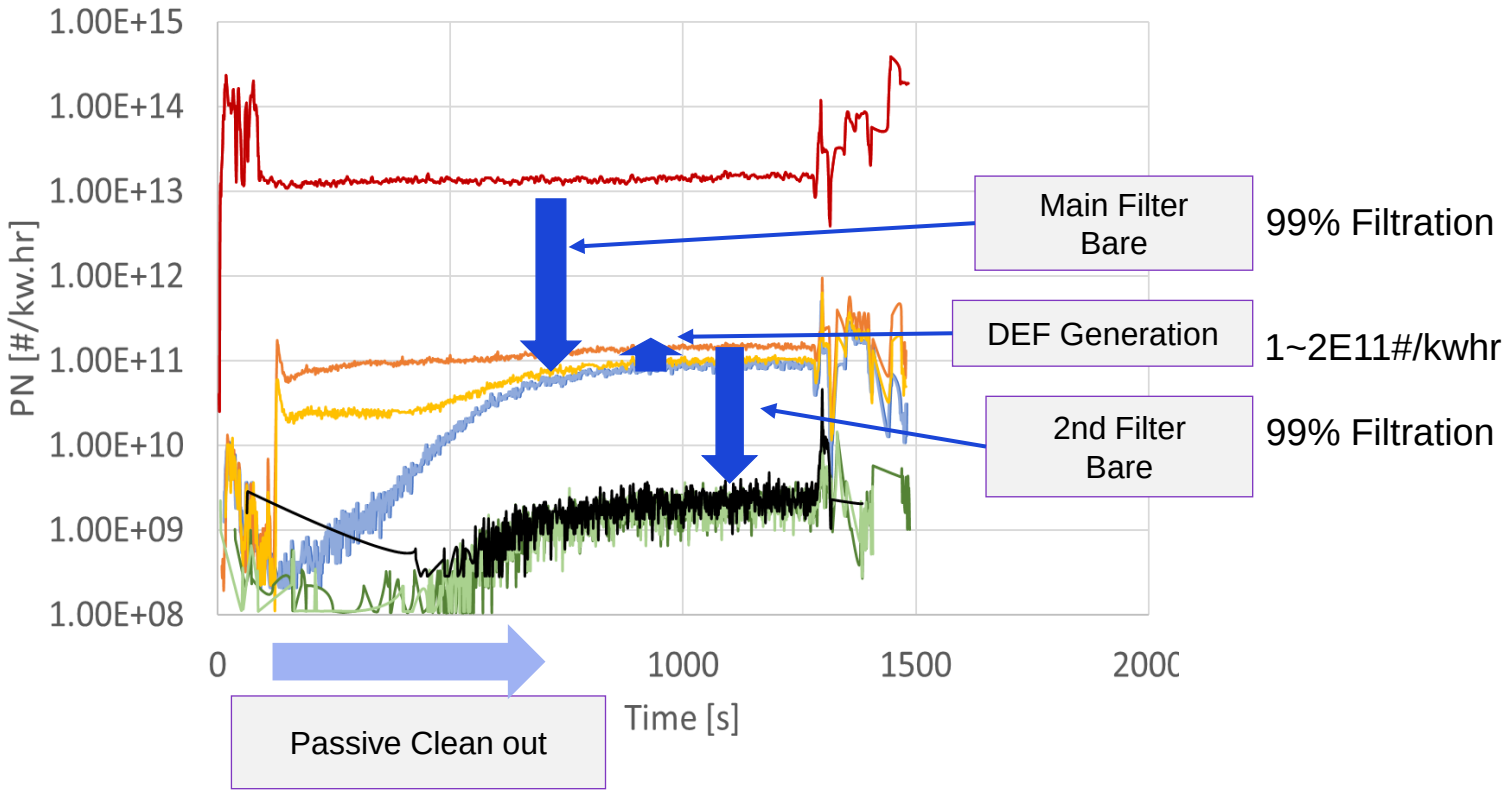
Source of PN10:

- Crankcase emission
- Engine out
- DEF dosing

PN10 particles can be effectively removed using filters.

- The example used a Euro VIe diesel truck with single urea dosing, tested on a chassis dyno.
- An ultra-high-filtration main filter can reduce soot PN10 slip to below 1E11 #/kW-hr.
- A 2nd filter is optional to further reduce DEF PN10.





Mamakos, et. al., Atmosphere 2022(13)
Mamakos, et. al., Vehicles 2023(5)

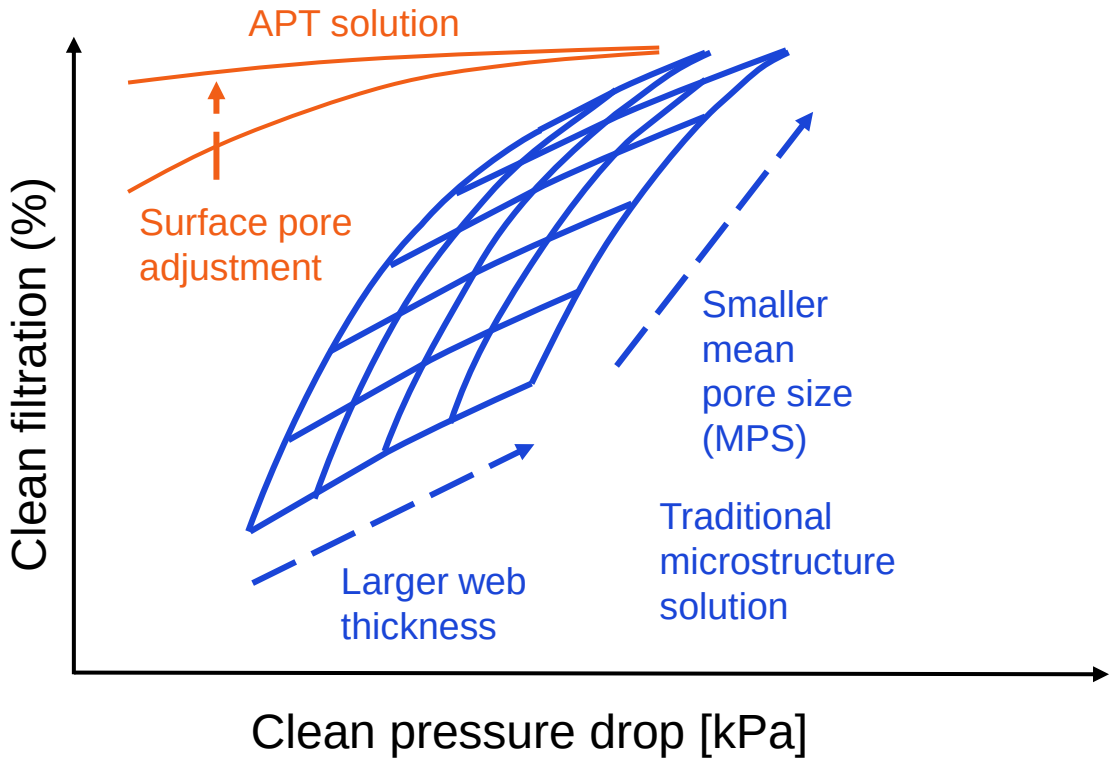
Main filter design options

Filter design parameters that have an impact on filtration and pressure drop:

- Traditional microstructure approach
  - Pore size distribution (d10/d50/d90) and porosity
  - Web thickness
- Surface pore engineering approach
  - APT, Accelerated Purification Technology

These parameters also impact the filter performance matrix:

- Thermal mass
- Coat-ability (increase in pressure drop; increase in deep-bed response; production variability)
- Ash storage
- Mechanical strength



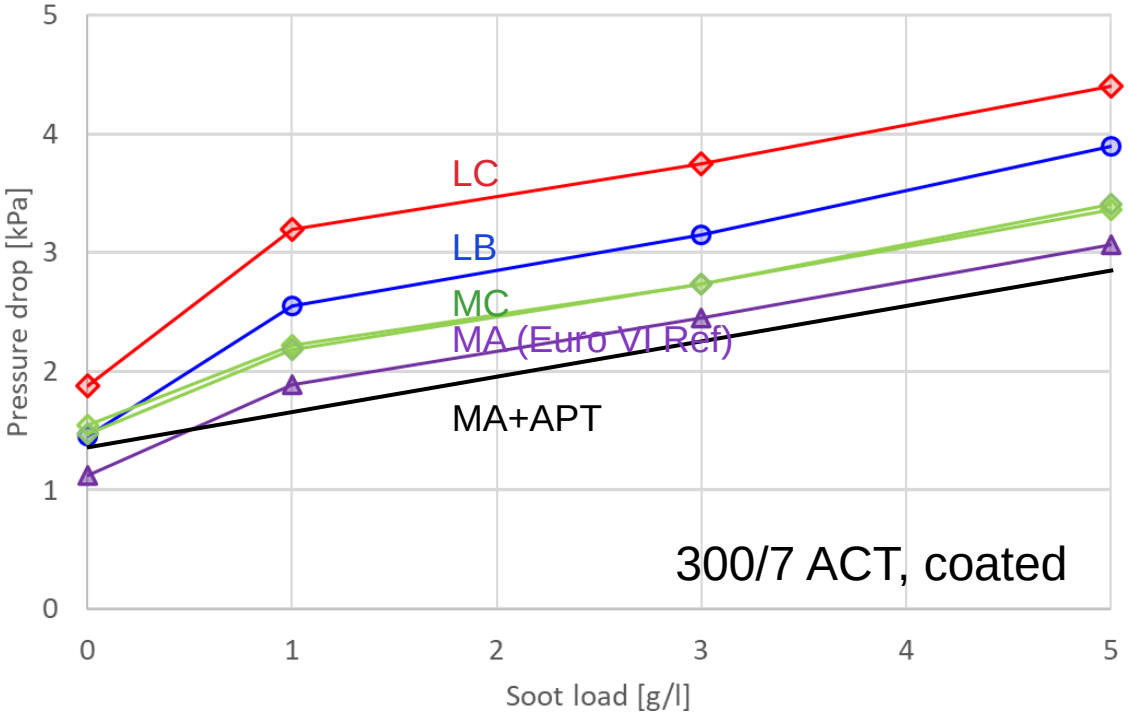
	A: Med/High MPS	B: Low/Med MPS	C: Low MPS
L: Low Porosity	LA (Euro VI ref)	LB LB+APT	LC
M: Med Porosity	MA (Euro VI ref) MA+APT		MC

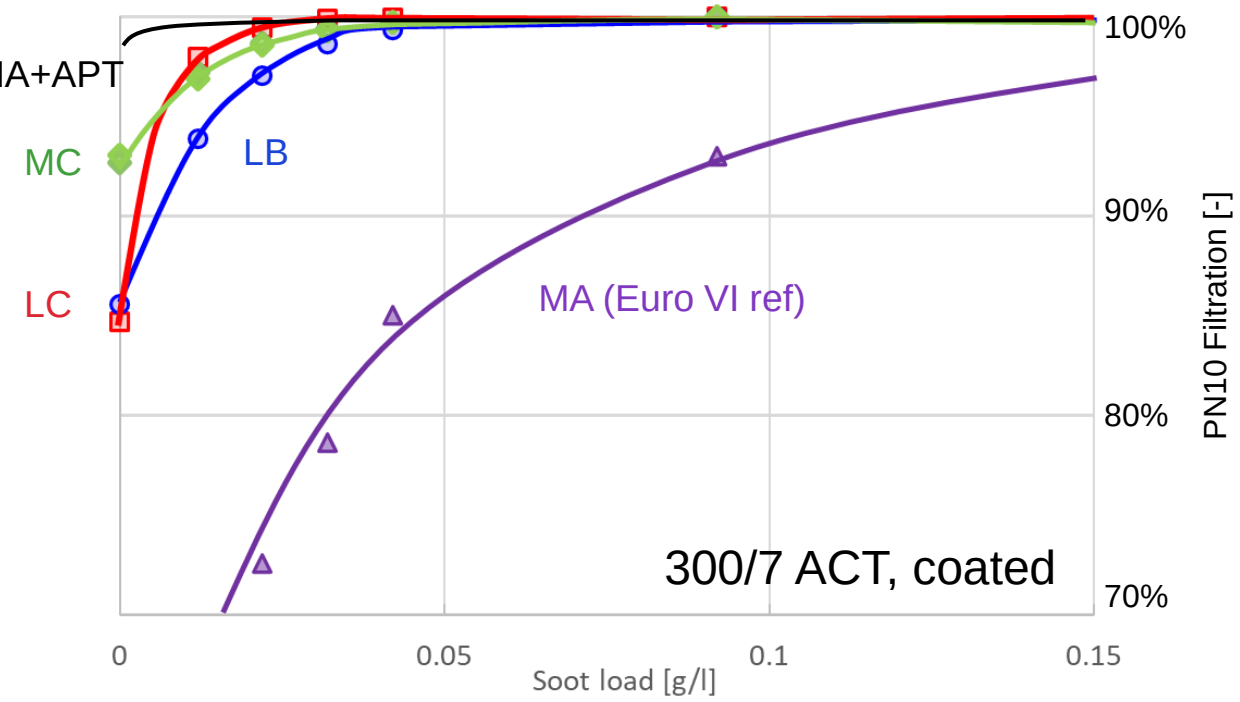
Filtration and pressure drop performance

The APT option (MA+APT) provides the best pressure drop and filtration trade-off.

The low MPS and medium porosity option (MC) is the best among the traditional microstructure options.

	A: Med/High MPS	B: Low/Med MPS	C: Low MPS
L: Low Porosity	LA (Euro VI ref)	**LB** LB+APT	**LC**
M: Med Porosity	**MA (Euro VI ref) MA+APT**		**MC**



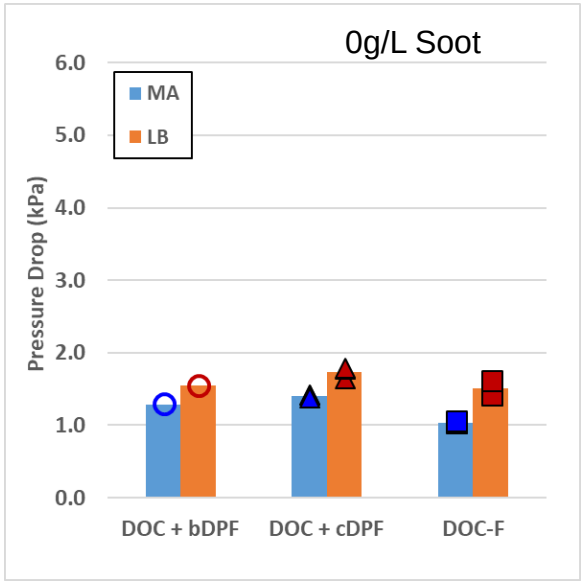


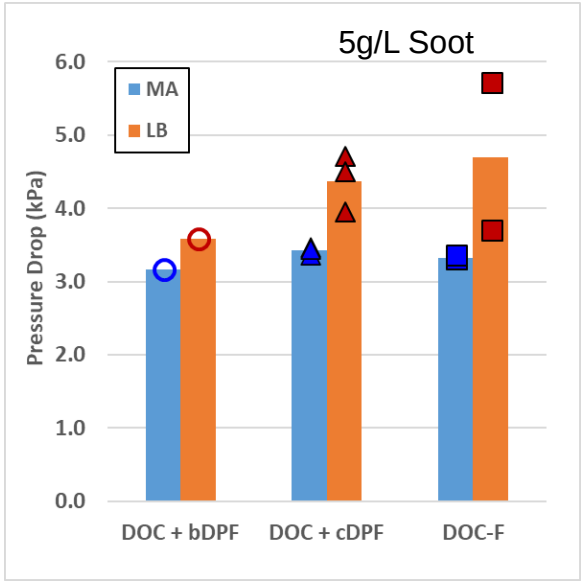
The base filter materials can be used with various coating technologies

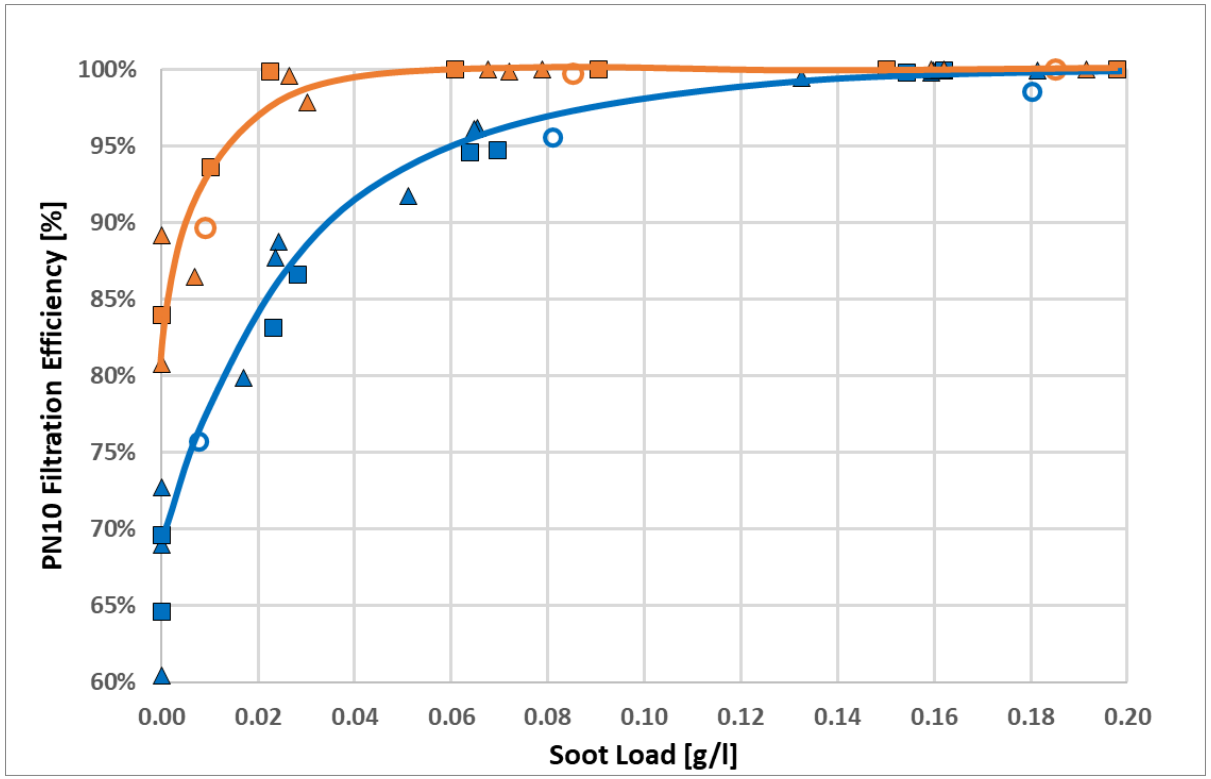
The base filter material drives the filtration and pressure drop performance.

Some sensitivity to coating is observed for the low porosity filter samples, suggesting room of optimization.

Filter	DOC + bare DPF	DOC + coated DPF	DOC on DPF
MA (Euro VI ref)	○	▲	■
LB	○	▲	■





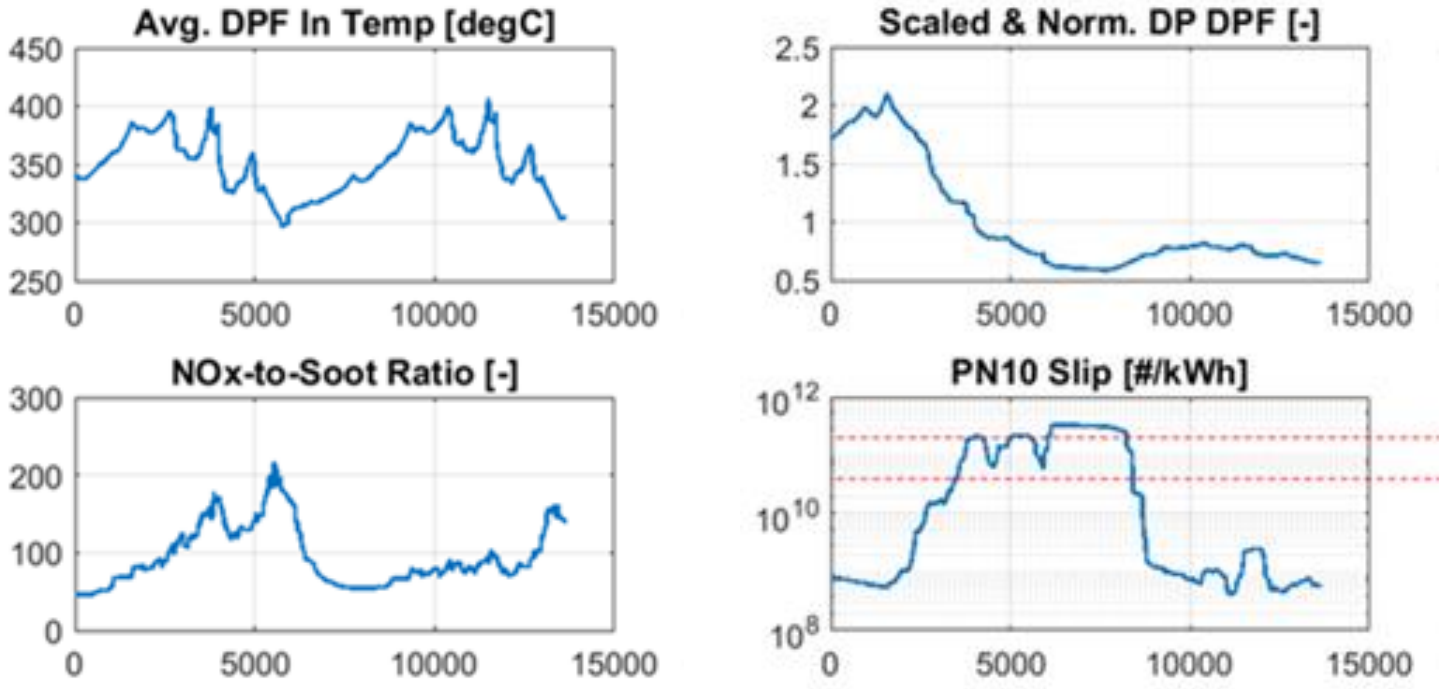


Dam, et. al., SAE 2025-01-8479

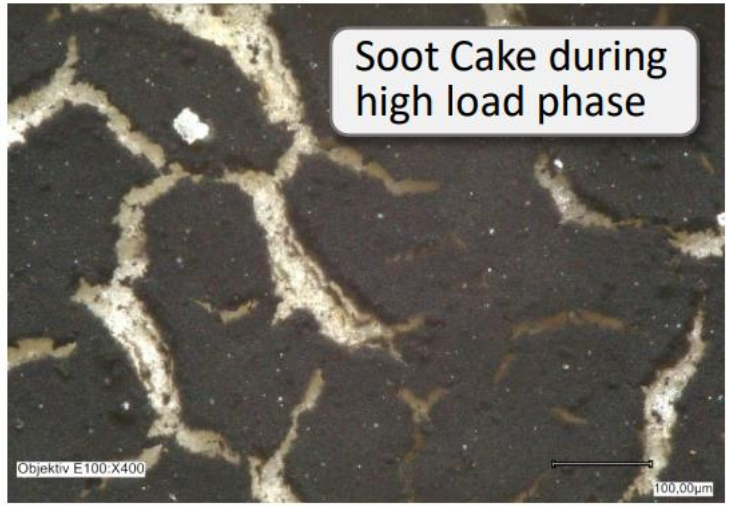
Fast burning (passive or active) can lead to soot cake breakdown and high PN10 soot slip

Fast soot burning leads to an uneven soot cake, and a rapid drop in pressure drop, resulting in soot slip spikes.

The typical worse-case scenario is a high-load ISC cycle with a pre-loaded filter.



Viswanathan, et. al., SAE 2023-01-0386



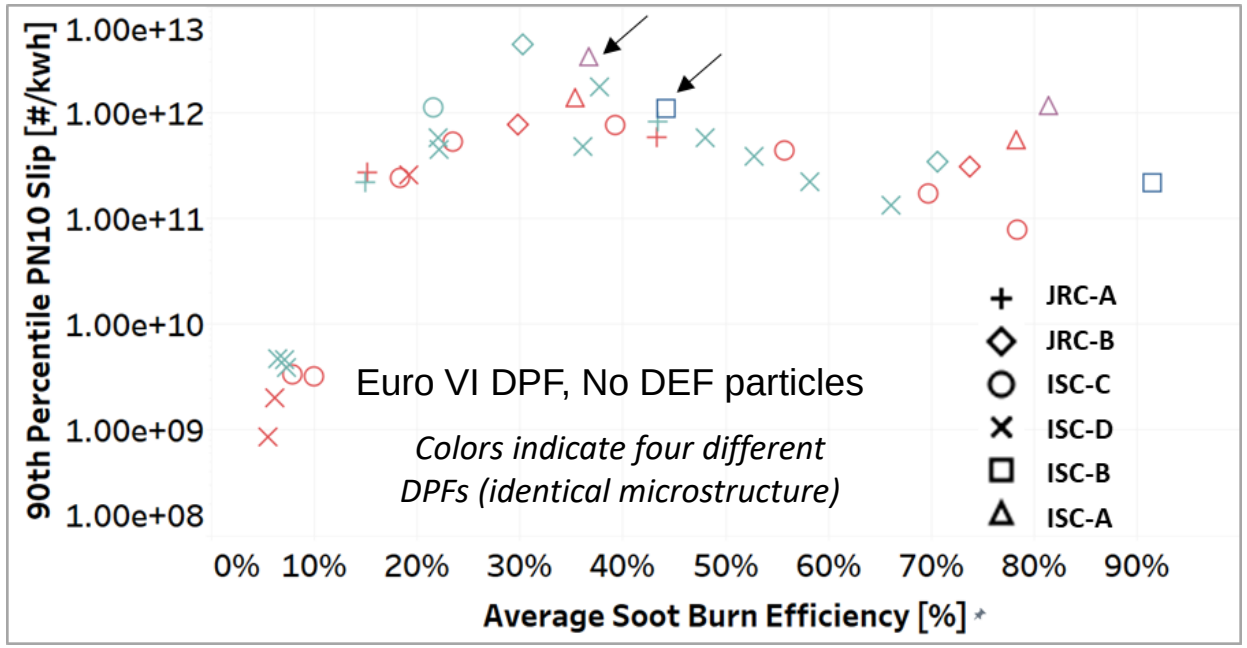
Geisselmann, 2023 SAE HD Gothenburg

A partially regenerated filter has more slip

Adapted multiple RDE cycles and field cycles and tested on a light-medium duty engine. The cycles used cover a wide range of NOx/soot ratio and temp profile.

A partially regenerated filter has more slip, less dependent on cycle.

Cycle	JRC-A	JRC-B	ISC-A	ISC-B	ISC-C	ISC-D
DPF inlet Temp. [°C]	278	321	330	380	308	272
NOx-Soot Ratio [-]	~300	~300	~280	~300	~480	~300



RDE cycle

Field cycle

Viswanathan, et. al., SAE 2024-01-2382

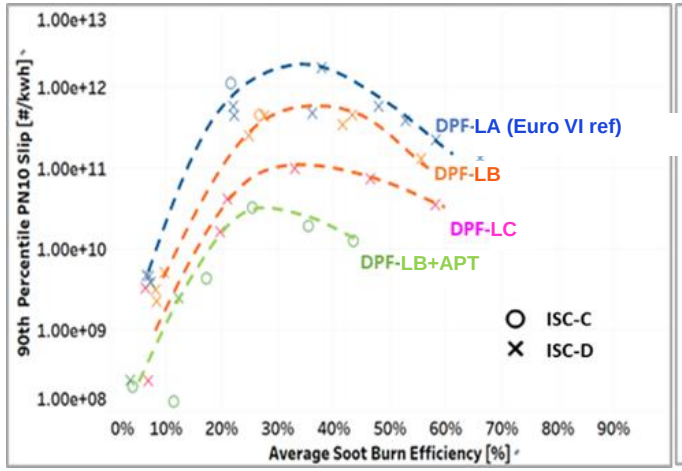
Impact of cycle conditions on PN10 soot slip

High soot slip is observed in one or two cycles with strong passive regeneration. In cycles that are less passive, it takes longer to observe the PN10 slip spikes. Another worst-case scenario is testing right after active regeneration.

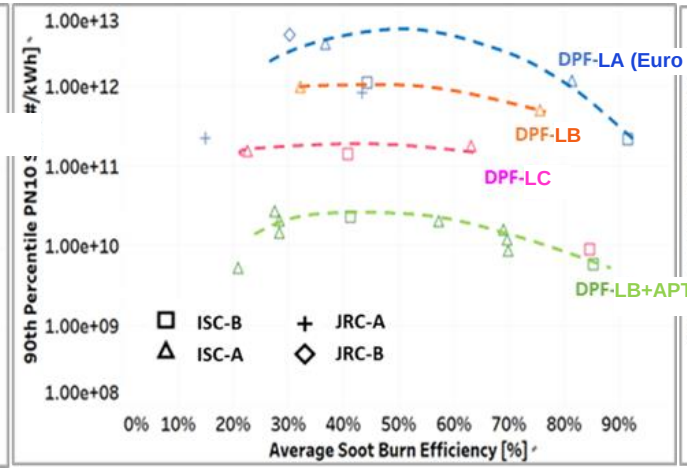
Advanced filter technologies can reduce soot slip by orders of magnitude.

	A: Med/High MPS	B: Low/Med MPS	C: Low MPS
L: Low Porosity	**LA (Euro VI ref)**	**LB** **LB+APT**	**LC**
M: Med Porosity	MA (Euro VI ref) MA+APT		MC

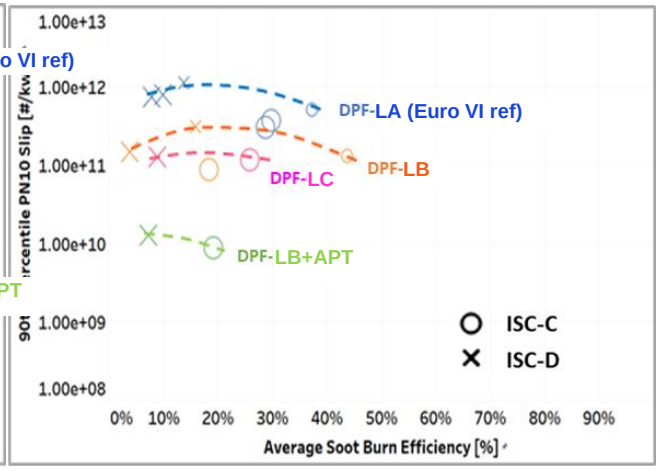
Preload
Less Passive Cycle



Preload
Strong Passive Cycle



Pre-load
After Active Regeneration



Viswanathan, et. al., SAE 2024-01-2382

300/9 ACT, coated

Conclusions

To meet the regulatory requirements of Global 7 standards, OEMs are exploring various technical approaches, including single-dosing and dual-dosing systems, as well as different DPF technologies such as CSF, DOC-F, and SCR-F.

This study highlights the importance of filter design in controlling PN10 emissions. Advanced filter technologies offer strong potential for reducing emissions and improving robustness across different operating conditions.

Several design elements affect filtration and pressure drop for the main filter; among them, pore microstructure adjustment, web thickness, and surface pore modification are most effective in improving filtration.

- The surface pore modification technology (APT) provides the best trade-off between pressure drop and filtration.
- The low MPS and medium porosity option is the best among the traditional microstructure options.
- Various coating technologies can be applied to the base filter materials, which are crucial in determining the filtration and pressure drop performance.

Fast soot burning can cause uneven soot distribution and increase PN10 slip. Worst-case scenarios include high-load cycles with pre-loaded filters or testing immediately after active regeneration.

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