PARTICLE NUMBER CONCENTRATION MEASUREMENTS DURING PERIODIC TECHNICAL INSPECTIONS

Assessments of Fleet Emission Reduction and the Influence of Particle Size Distributions

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Particle number measurements within periodic technical inspections: A first quantitative assessment of the influence of size distributions and the fleet emission reduction

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ABSTRACT

The enforcement of more stringent type approval emission standards de facto mandate manufacturers to equip vehicles with particle filters, which reduces the particle number concentration in automotive emissions to levels below typical ambient concentrations. Soon, the overall automotive particle emissions will be dominated by highly emitting vehicles with malfunctioned after-treatment systems, making tests of in-service compliance with emission standards inevitable. These tests are especially relevant for diesel-powered vehicles because broken diesel particle filters can increase the particle emissions by several orders of magnitude. For spark-ignition vehicles, the possible effect is significantly lower, and the implementation of corresponding tests is technically challenging. In this paper, particle number concentration measurements at idle speed for the identification of vehicles with malfunctioned particle filters have been studied. The results from a dedicated measurement campaign indicate that low cost equipment can be used for the identification of highly emitting diesel vehicles. The effectiveness of under-discussion instrument specifications has been evaluated employing simulations based on measured particle size distributions. Finally, an assessment of the potential impact of particle number measurements during periodic technical inspections on the fleet emission was performed. The corresponding results demonstrate that the enforcement of these measurements can reduce the overall particle emissions of the actual fleet by more than 30%.

1. Introduction

Particulate matter emitted by motor vehicles continues to contribute to air pollution, causing adverse health effects (Oberdörster et al., 2005; Brook et al., 2010; Peters et al., 2004; Watts et al., 2019; Hooftman et al., 2018; Li et al., 2016). Policymakers around the globe regulate particulate mass (PM) and particulate number (PN) emissions from internal combustion engine-driven vehicles to improve the air quality, and as a result, people's health and quality of living. Many of the current regulations are based on type approval testing (TAT). In these tests, the compliance of new vehicle models with emission regulations is checked, by testing a limited number of vehicles of the respective model. A well-controlled environment, high-end measurement equipment, and testing facilities guarantee a high degree of accuracy and reproducibility. However, these tests only ensure compliance with the emission standards at the beginning of vehicles' life cycles and well-defined driving conditions. In real-world situations, varying environmental conditions, aggressive driving, or malfunctioned exhaust after-treatment systems can lead to emissions that deviate significantly from the values determined during type approval testing (Faust and Harrison, 2013).

Boveroux et al. (2019) assessed the particle emissions of more than 300 EURO5 and EURO6 diesel vehicles. They found that the emissions of 15% of highly emitting vehicles are responsible for 97% of the total particle emissions of the studied fleet. The high particle emissions by this small fraction of vehicles are related to malfunctioned diesel particle filters (DPF). Yamada (2019a) showed that DPF failures did not significantly increase the emissions of CO, NO_x, CO_2, and non-methane hydrocarbons. Other studies demonstrated that functional DPFs not only reduce particulate emissions but also emissions of poly aromatic hydrocarbons (Hu et al., 2013; Heeb et al., 2008; Apicella et al., 2020). Hence, identifying the vehicles with malfunctioned DPFs and

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MOTIVATION

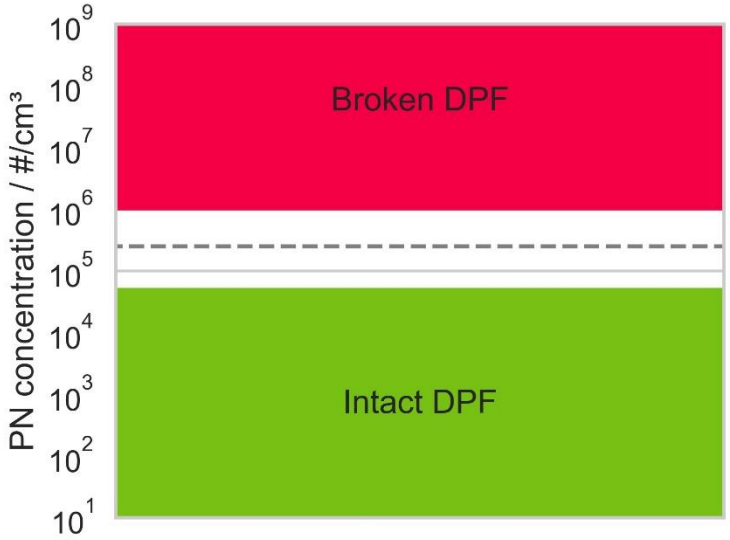
PROBLEM STATEMENT

- 15% high emitters cause 97% particle emissions [1]
- Heavy duty: DPFs removed for fuel economy
- → Identification of high emitters has high impact on air quality

[1] F. Boveroux *et al.*, "Feasibility study of a new test procedure to identify high emitters of particulate matter during periodic technical inspection," *SAE Tech. Pap.*, vol. 2019-April, no. April, pp. 2–9, 2019.

PN CONCENTRATION FOR IDENTIFICATION OF BROKEN DPF

Broken DPF	> 1 000 000 #/cm³
Intact DPF	< 50 000 #/cm³
Proposed Threshold	250 000 #/cm³
Max Overestimation	400%
Max Underestimation	-75%



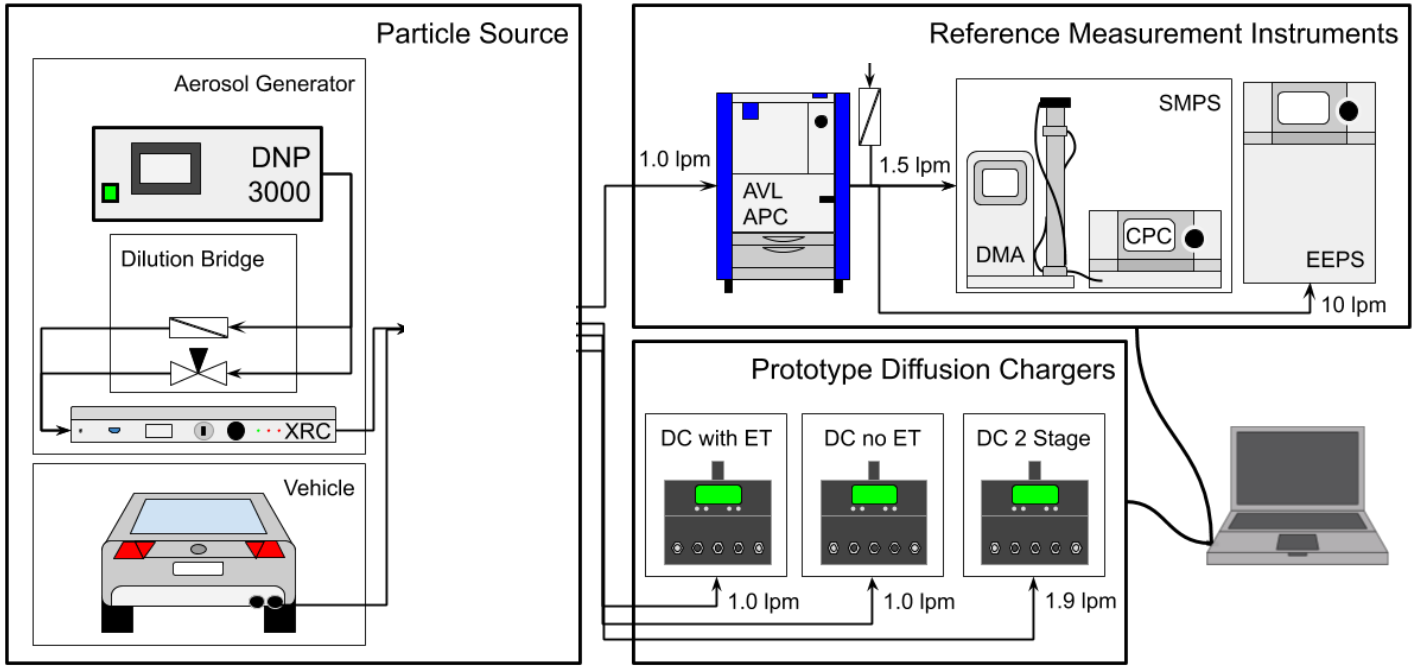
AIM OF THIS STUDY

- Test prototype PN instruments
  - Compare with PMP equipment
  - Validate categorization (high/low emitter)
- Evaluate under-discussion instrument specifications
  - Collect size distribution data
  - Evaluate counting efficiency limits
- Assess potential impact of PN PTI measurements
  - Simulate scenarios of DPF aging, fleet age distribution, PTI schedule

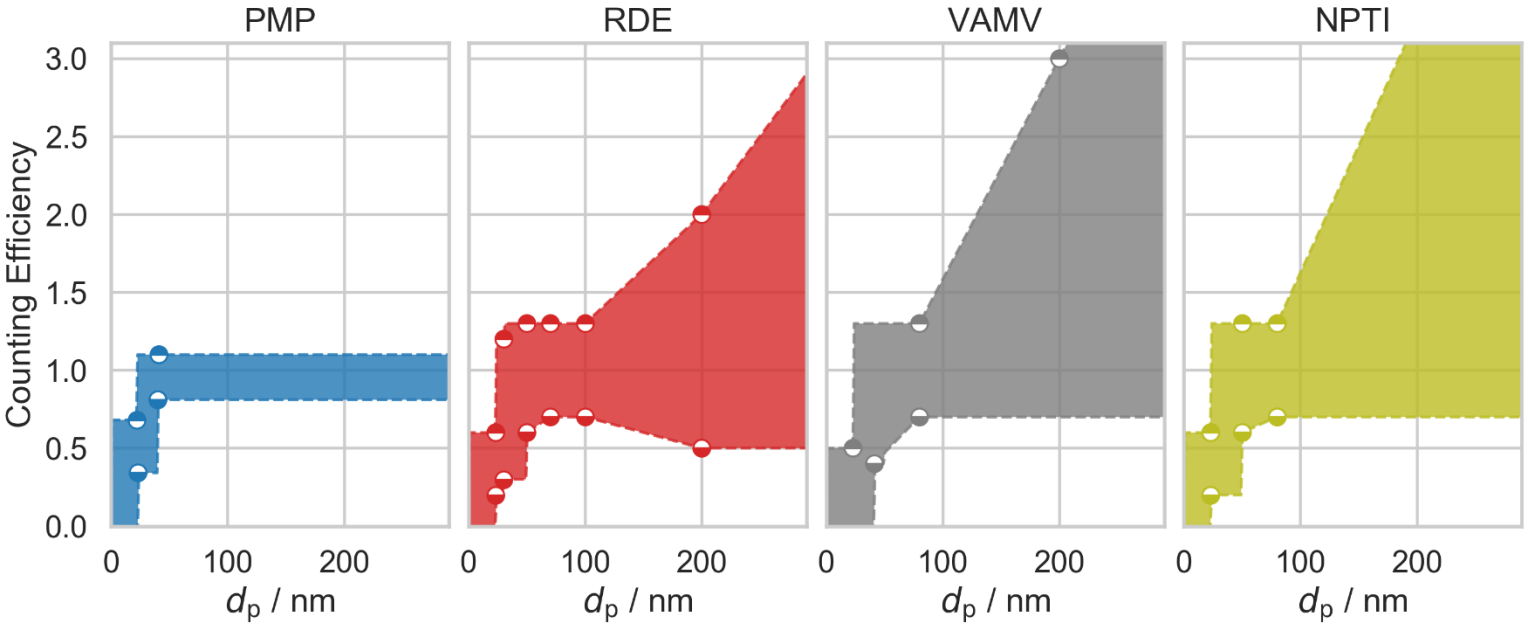
METHODS

EXPERIMENT AND INSTRUMENT SPECIFICATION EVALUATION

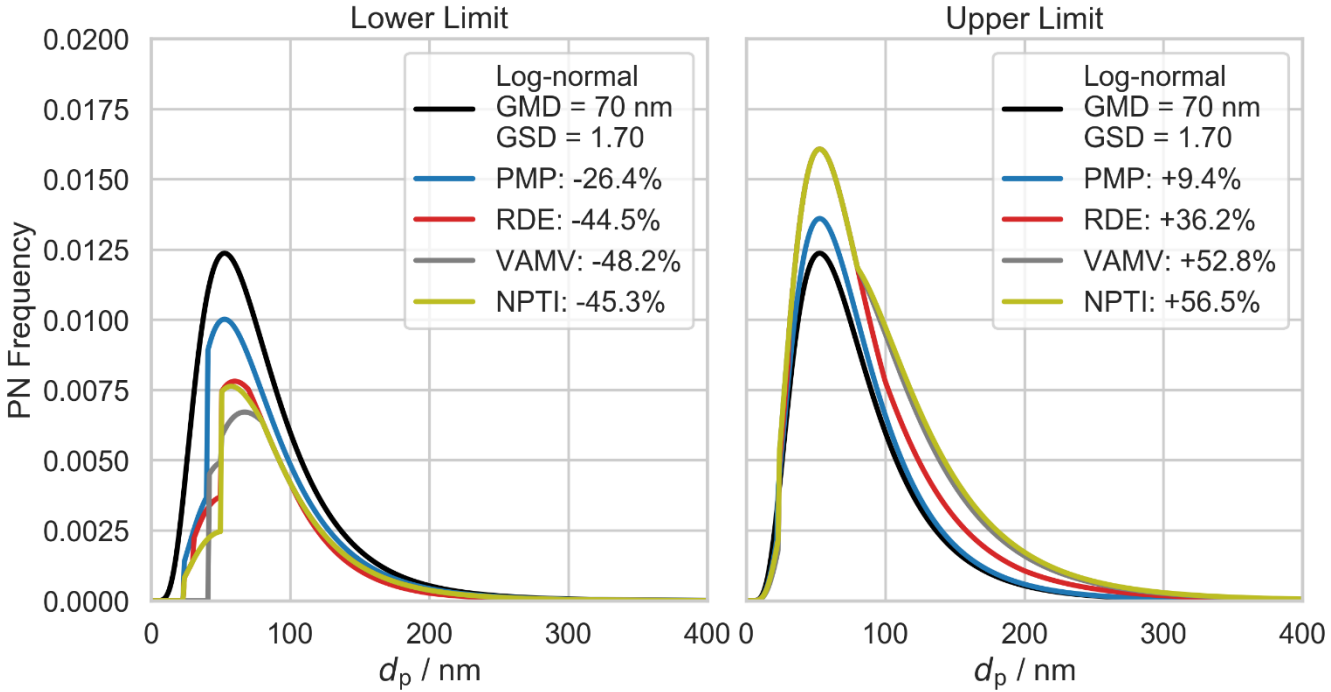
EXPERIMENTAL SETUP



COUNTING EFFICIENCY SPECIFICATIONS



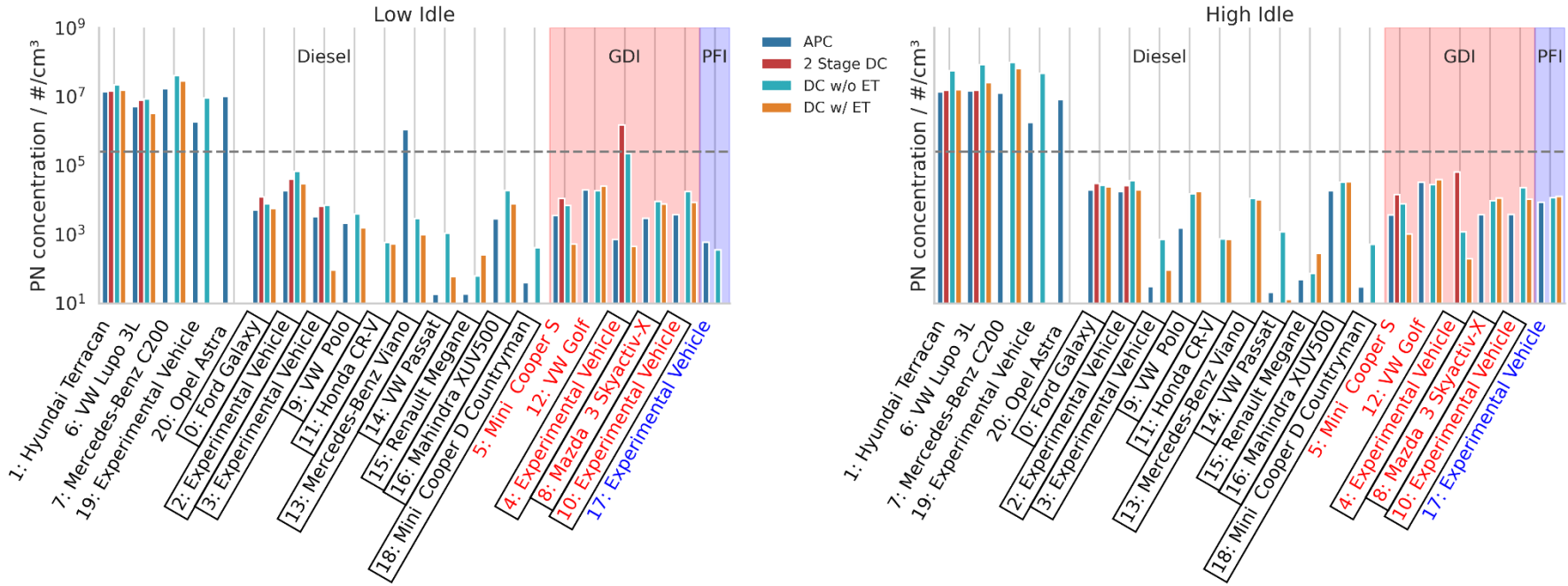
ANYLYTICAL EVALUATION OF COUNTING EFFICIENCY REQUIREMENTS



RESULTS

PN CONCENTRATION, COUNTING EFFICIENCY, IMPACT

PN CONCENTRATION

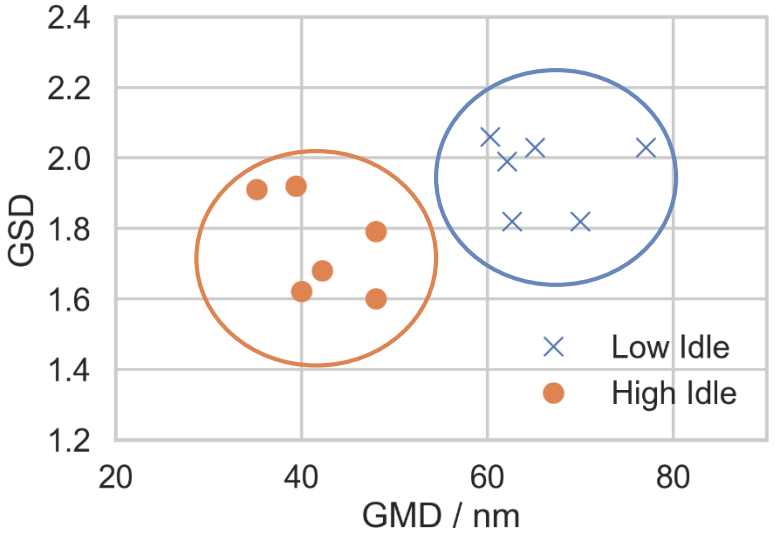


PARTICLE SIZE DISTRIBUTIONS

Clusters for low and high idle

Larger sizes for low idle

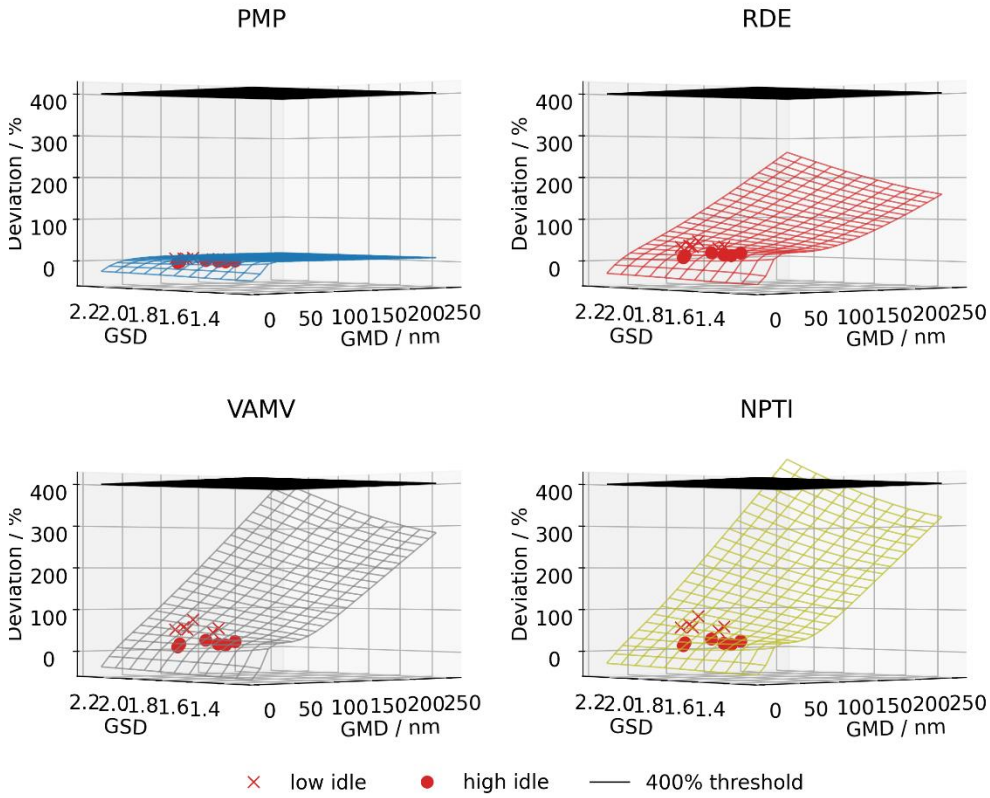
Longer residence time in high concentration regions



OVERESTIMATION

Overestimation is not critical for measured distributions and other realistic cases

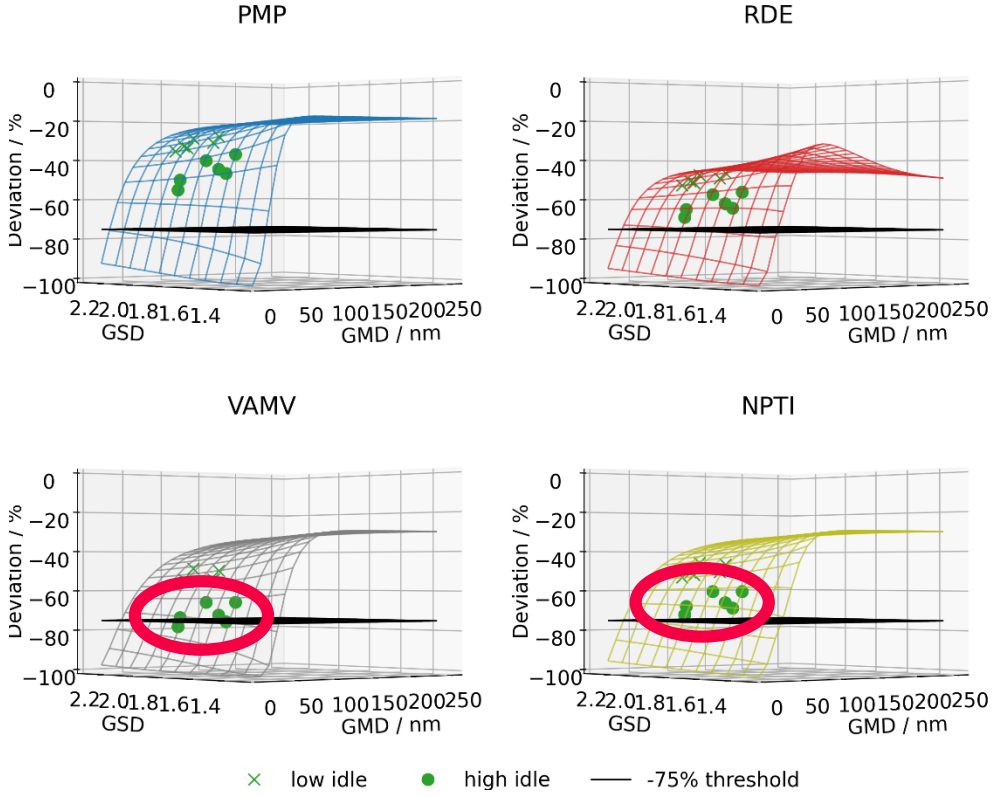
All specifications guarantee exclusion of false fail scenarios



UNDERESTIMATION

Smaller particle sizes in high idle raise the risk of false pass scenarios in extreme cases

→ recommendation for low idle

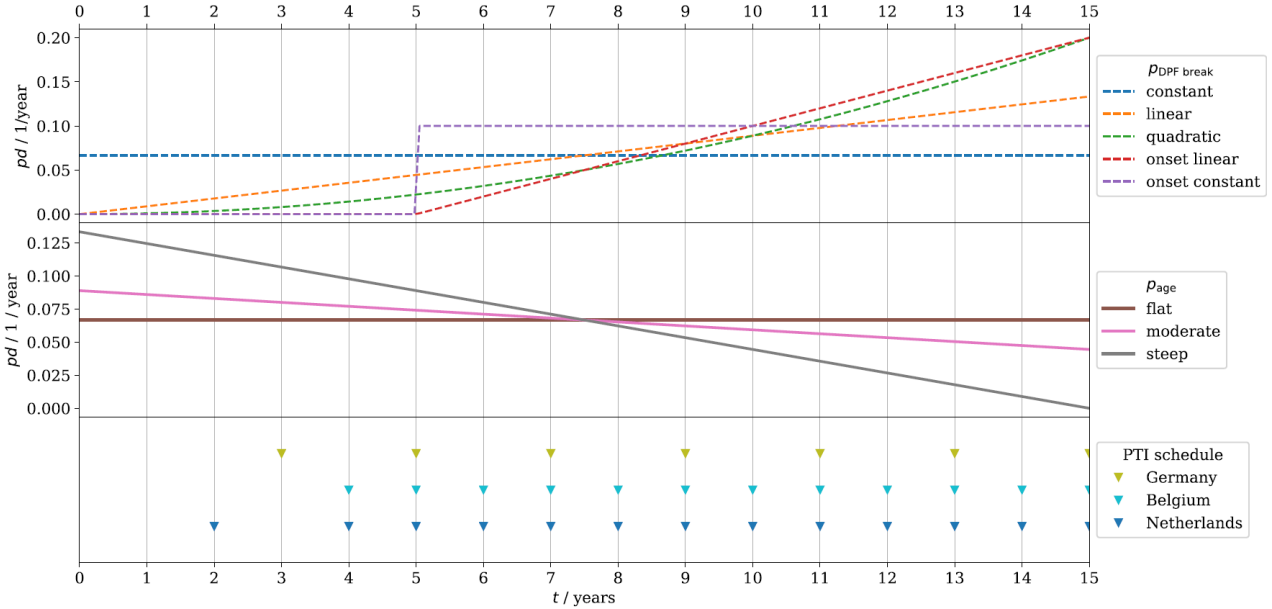


IMPACT ASSESSMENT
CALCULATION OF REDUCTION OF TIME IN CIRCULATION WITH BROKEN DPF

DPF break probability

Fleet age distribution

PTI schedule



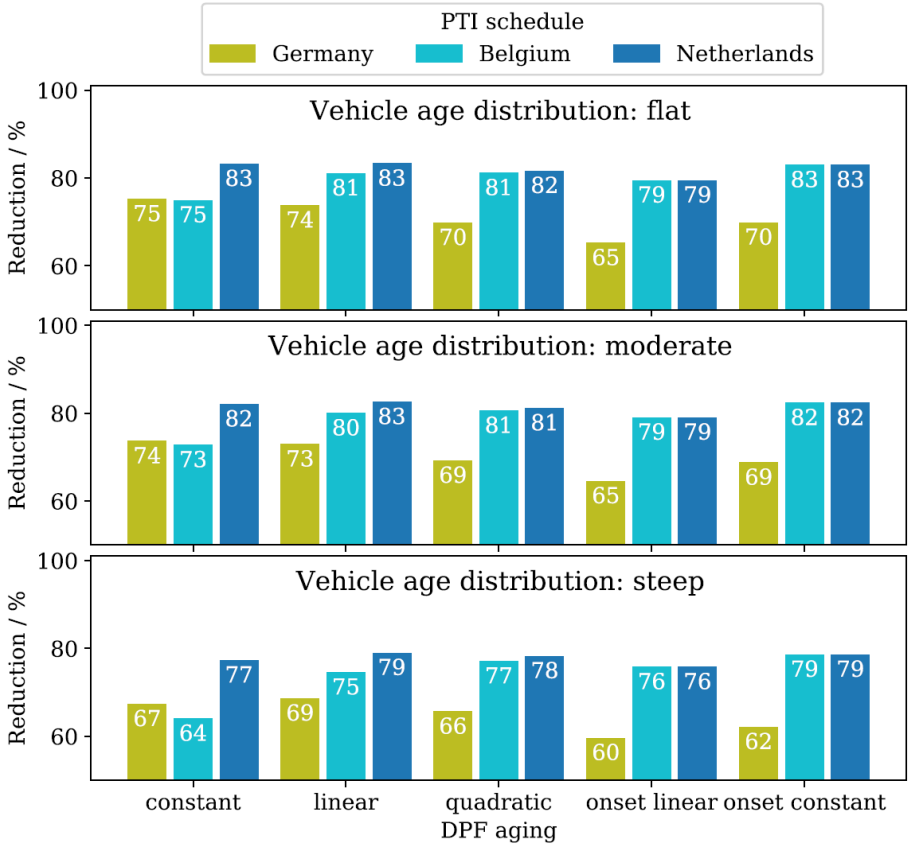
IMPACT

Maximum reduction 83%

Minimum reduction 60%

DPF aging behavior unknown but limited influence

Doubling PTI frequency 15% further reduction



CONCLUSION

- Identification of high emitters (no DPF) with prototype equipment
- Under-discussion specifications effective for expected size distributions
- Larger particle sizes in low idle yield more accuracy
- Fleet emission reduction can exceed 80%

AVL DITEST COUNTER

- PN instrument based on advanced diffusion charging
- Compliant with
  - NPTI speficifations (NL)
  - VAMV swiss clean air act
  - under-discussion instrument specifications in Germany (PTB-A)
- Available by November 2021 for NL
- More information online
  https://www.avlditest.com/index.php/de/counter.html

THANK YOU FOR YOUR ATTENTION!

ANY QUESTIONS??

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