The VERT GPF-Retrofit Program for Cleaner Urban Mobility: Nanoparticle Emissions Reduction via Filtration within the HORIZON Europe AeroSolfd Project

L. Rubino[1], A. Mayer[1], T. Lutz[1], J. Czerwinski[1], L. Larsen[1]

[1]VERT Association, Aemetstrasse 3 CH- 8166 Niederweningen, Switzerland

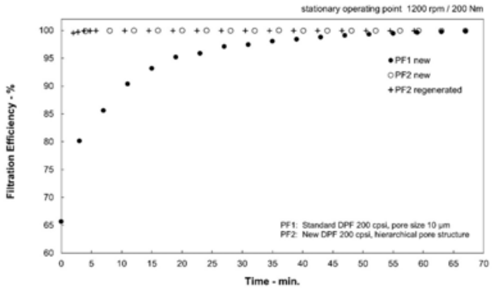
Emissions of ultrafine and nanoparticles from petrol engine combustion are a threat to human health and the environment. Clean urban mobility is the main goal of the HORIZON Europe AeroSolfd project launched by the European Commission in 2022 that runs over a three years period until mid-2025. AeroSolfd will deliver affordable, adaptable, and sustainable retrofit solutions to reduce not only tailpipe exhaust emissions from gasoline engines, but brake emissions and pollution in semi- closed environments. The Swiss-based VERT association, within AeroSolfd, focuses on reducing tailpipe emissions of gasoline vehicles by using the best available retrofit filtration Technology (BAT), and in particular the best available GPF technology, using an uncoated CORNING ceramic multicell wall-flow filter. VERT, with its member partners HJS, CPK, BFH and CORNING, investigates the performance and delivers a TRL 8 GPF-retrofit system for future market applications. The VERT GPF-retrofit system showed excellent performance with filtration efficiency over 99% on standard cycles (WLTC & RDE) as well as on road. Fifty gasoline vehicles, both GDI and PFI engines, have been retrofitted in Germany, Switzerland, Israel and Denmark; the GPF retrofit system performance is continuously monitored for all vehicles over a period of 6-8 months and no issues have been observed in any of the 50 vehicles in terms of filter regeneration or increased fuel consumption or secondary emissions. A NPTI testing campaign of 1000 gasoline vehicles is also conducted in AeroSolfd, confirming a dirty-tail phenomena for the Swiss petrol fleet. The GPF-retrofit application is succesfully reducing nanoparticle emissions, providing a fast solution to the adverse health effect of nanoparticles from gasoline engines in congested urban areas and for controlling global warming. The final results of the overall VERT GPF-retrofit project and the NPTI testing campaign are presented.

AeroSolfd: Advancing Air Quality through Retrofitted Gasoline Particulate Filters – Insights from Laboratory and Real-World Evaluations

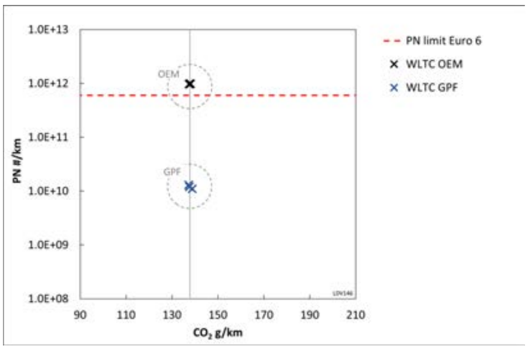
D. Engelmann[1], T. b. defined[1]

[1]Laboratory for Powertrain and AFHB

The *AeroSolfd* project, an EU-funded initiative, focuses on improving air quality by reducing atmospheric particle emissions. In response to the growing challenges posed by air pollution and its impact on environmental and human health, the project aims to generate robust scientific data and develop practical solutions. A primary objective is the implementation of Gasoline Particulate Filters (GPFs) as retrofit solutions for in-use light-duty vehicles (LDVs) to mitigate particulate emissions effectively.



Key results stem from an in-depth measurement campaign conducted at the BFH Exhaust Emissions Test Center on four representative vehicles. The campaign evaluated non-aged GPFs to establish a baseline for long-term performance monitoring and after six months and several thousand kilometers of use. The vehicles, comprising two with direct petrol injection and two with intake manifold injection, were tested under laboratory conditions using the Worldwide Harmonized Light Vehicles Test Procedure (WLTC) and Steady State Cycle (SSC), as well as in real driving environments (RDE). Comprehensive analyses were performed to assess the reduction in particle numbers and evaluate potential impacts on gaseous emissions. Fourier-Transform Infrared Spectroscopy (FTIR) was employed to analyze non-regulated emissions, capturing both gaseous and particulate data before and after the installation of GPFs. Preliminary findings demonstrate the GPFs' significant effectiveness in reducing particulate emissions with no observable adverse effects on gaseous emissions.Moreover, the project extended its scope by equipping fleets in Germany, Switzerland, Israel, and Denmark with retrofitted GPFs and data loggers. These fleets are monitored over the long term to evaluate the filters' real-world performance, durability, and operational impact under diverse driving conditions.



Health Impact of Nanoparticles emitted by in-use Gasoline Engines reduced by GPF Retrofit Life Cycle Analysis and the resulting Benefit/Cost Ratio

A. C. Mayer[1]

[1]VERT-Association

Worldwide health impact by traffic related toxic emissions polluting the breathing air is dominated by nanoparticle emissions of petrol engines, which is still widely neglected. Particle filters with efficiencies close to 100% are available and could be used in all fleets at very low cost even as retrofit of in-use petrol vehicles as the EU-AeroSolfd project has demonstrated 2022-2025.

However, since classic epidemiology still refers to PM2.5 as the official metric for the dose/effect factors, it is difficult to provide numerical evidence for the health impact when using such filters because the eliminated overall particle mass of these numerous but very small particles has only very little gravimetric influence on the mass of PM2.5.

Using a non-classic approach to estimate the health impact of these nanoparticles based on the particle number concentration, size and substance, we can estimate the contribution of these filters on worldwide traffic related mortality and with WHO monetary assumptions we can conclude on health cost.

Including all important elements of a life cycle analysis with respect to internal and external cost from the time of retrofit to final waste disposal we can conclude on Benefit/Cost of this technical measure and we are coming to values >50 if all vehicles are retrofitted and >>100 if the high emitters are selected by dirty tail analysis and retrofit is only concentrated on those high emitters.

Next-generation gasoline particle filters: Impact on genotoxic compounds, assessment of risks for secondary poisoning

N. Heeb[1], M. Zennegg[1], K. Zeyer[1], J. Mohn[1], P. Comte[2], M. T. Göpfert[2], Y. Zimmerli[2], D. Engelmann[2], L. Rubino[3], T. Lutz[3], A. Mayer[3]*, L. C. Larsen[3]*

[1]Empa, [2]UASB, [3]VERT

Abstract: Particle filters (PFs) have become the most efficient and reliable technology to abate particle emissions of diesel engines. PFs are increasingly applied on gasoline vehicles (GPFs) with direct injection (GDI) and multi-point injection (MPI) engines. These engines have high particle number emissions, often exceeding the current PN emission limit of $6x10^{11}$ particles/km.

In the EU Horizon Europe framework project AeroSolfd the next generation of gasoline particle filters were retrofitted and tested on two Euro-6b vehicles, one equipped with a GDI-engine (VW Golf TSI 1.4 L, 92 kW), the other with an MPI-engine (Fiat 500X 1.6 L, 91 kW). Both widely used vehicles were tested under transient driving in the cold- and hot-started WLTC cycle and in a steady-state cycle.

For each vehicle, retrofitted particle filters of the type of multi-cell wall-flow Cordierite filters were integrated in the tailpipe systems. Both vehicles were studied on the chassis dynamometer in standard configurations without filters and with retrofitted filters.

A comprehensive characterization of gaseous, liquid and solid exhaust constituents was performed. The focus was on toxic, carcinogenic and mutagenic compounds such as polycyclic aromatic hydrocarbons (PAHs), nitrated PAHs (nitro-PAHs), polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs).

Particle number emissions of the MPI vehicle (Fiat 500X) were $1.0x10^{11}$ and $0.4x10^{11}$ particles/km in the cWLTC and hWLTC, respectively. Considerably lower PN emissions of $0.03\text{-}1.0x10^{10}$ particles/km were observed in the SSC. PN emissions of the GDI-vehicle (VW Golf TSI) were 5- to 10-fold higher, at $6.1x10^{11}$ and $6.2x10^{11}$ particles/km in the cWLTC and hWLTC. PN emissions of the GDI-vehicle in the SSC were higher too compared to the MPI-technology.

The higher PN emissions of the GDI- compared to the MPI-vehicle also affected PN filtration efficiencies in the cold- and hot-WLTC, which reached 95.8% and 95.1% for filter F1 on the MPI-vehicle and 98.3% and 98.4% for filter F2 on the GDI-vehicle.

We conclude that both retrofitted filters are highly efficient with respect to nanoparticle emissions, indicating that soot particles are retained and possibly converted in these filters.

This brings us to the question how emissions of semi-volatile genotoxic compounds like PAHs, nitrated PAHs and PCCD/Fs are affected by these filters? It has to be mentioned that the up-take of these toxic compounds via the alveolar system of the human lung occurs via inhalation of combustion-generated nanoparticles with particle sizes of 10-200 nm. These nanoparticles offer enough surface area to adsorb semi-volatile compounds at lower temperatures, what has been described lately as the Trojan horse effect.

We will report on the effects of next-generation particle filters for gasoline vehicles on the emissions of genotoxic compounds and assess the risks of a secondary formation of these pollutants in the filters.

In-use gasoline cars retrofit with a particle filter – Israeli experience

D. Buntin[1], A. Ben Ari[1], B. B. Ben-David Holtzer[1], V. Baybikov[1], A. Mayer[1], J. Czerwinski[1], L. Tartakovsky[1,2]*

[1]Technion – Israel Institute of Technology, Haifa 3200003, Israel, [2]Presenting author, email: tartak@technion.ac.il

In the framework of the AeroSolfd EC Horizon project, two in-use gasoline cars were retrofitted with a gasoline particle filter (GPF) produced by HJS. To monitor the filter health, the cars were instrumented also with CPK data loggers that allowed monitoring backpressure and GPF temperature values.

The cars were tested before GPF installation, immediately after installation, three months after start of the road test, and at the test end (half a year after test initiation). The cars were tested at four operating modes: low and high idle with and without air conditioner switched-on.

No sensible influence of GPF installation on operation of the car's catalytic converter and its effectiveness was observed. The measured gaseous pollutant concentrations were similar in the car with and without GPF. The measured data confirm no negative influence of GPF retrofitting on the noise level of tested cars. Moreover, the obtained data in most of tests show a tendency of slight noise reduction after GPF retrofit. There is no indication of any negative influence of the retrofitted GPF on gaseous pollutant concentrations and noise level as compared to the OEM-installed filter.

Both tested cars demonstrated quite stable PN emission behavior during the six months of the test period. In absolute majority of tests GPF demonstrated a very high effectiveness in PN emissions mitigation. The calculated values of PNFE for both tested cars at four investigated operating modes during the six months of the test duration were usually higher than 97%. Comparison of the results of particle number concentration measurement in the VW Golf cars with a retrofitted and an OEM-installed GPF allows us arriving to a conclusion that the car with a retrofitted filter emits similar amounts of particle matter at all tested regimes.

There were no indications on the backpressure rise during the six-month's test in both tested vehicles. However, half-a-year test duration is not long enough to assess in a reliable manner a durability of the retrofitted gasoline particle filters.