NPC ETHZ June 2016

Berne University of Applied Sciences
Biel-Bienne | Switzerland
AFHB | IC-Engines and Exhaust Gas Control

Particle Number Reduction of GDI-Cars with GPF's

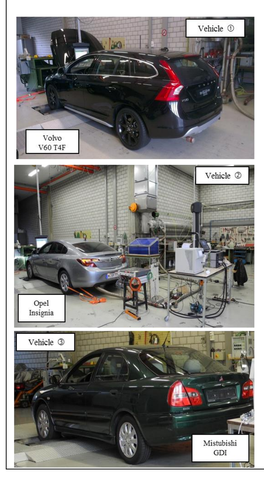
J. Czerwinski, P. Comte AFHB, University of Applied Sciences, Biel-Bienne, CH
N. Heeb, EMPA
A. Mayer, TTM

Abstract

The nanoparticles (NP) count concentrations are limited in EU for Diesel passenger cars since 2013 and for gasoline cars with direct injection (GDI) since 2014. The limit for GDI was temporary extended to 6 x 10^{12} #/km (regulation No. 459/2012/EU).
Nuclei of metals as well as organics are suspected to significantly contribute especially to the ultrafine particle size fractions, and thus to the particle number concentration.
The invisible nanoparticles (NP) from combustion processes penetrate easily into the human body through the respiratory and olfactory pathways and carry numerous harmful health effects potentials.
In the project GasOMeP (Gasoline Organic & Metal Particulates) metal-nanoparticles (including sub 20nm) from gasoline cars are investigated for different engine technologies.
In the present paper some results of investigations of nanoparticles from five Di gasoline cars are represented. The measurements were performed at vehicle tailpipe and in CVS-tunnel. Moreover, five variants of "vehicle – GPF" were investigated.
The PN-emission level of the investigated GDI cars in WLTC without GPF is in the same range of magnitude very near to the actual limit value of 6.0 x 10^{12} #/km. With the GPF's with better filtration quality, it is possible to lower the emissions below the future limit value of 6.0 x 10^{11} #/km.
There is no visible nuclei mode and the ultrafine particle concentrations below 10mm are insignificant.
Some of the vehicles show at constant speed operation a periodical fluctuation of the NP-emissions, as an effect of the electronic control.

Tested vehicles and driving cycles

INVESTIGATED VEHICLES



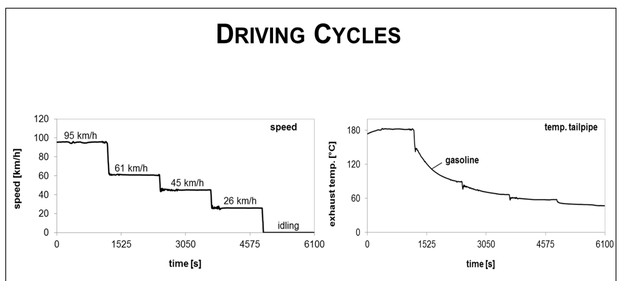
Vehicles ①②③	Volvo V60 T4F ①	Opel Insignia 1.6 EcoFlex ②	Mitsubishi Carisma 1.8 GDI ③
Number and arrangement of cylinders	4 / in line	4 / in line	4 / in line
Displacement cm³	1596	1598	1834
Power kW	132@ 5700 rpm	125@ 6000 rpm	90@ 5500 rpm
Torque Nm	240@ 1600 rpm	260@ 1650-3200 rpm	174@ 3750 rpm
Injection type	DI	DI	DI
Curb weight kg	1554	1701	1315
Gross vehicle weight kg	2110	2120	1750
Drive wheel	Front-wheel drive	Front-wheel drive	Front-wheel drive
Gearbox	a6	m6	m5
First registration	27.01.2012	2014	05.2001
Exhaust	EURO 5a	EURO 5b+	EURO 3

INVESTIGATED VEHICLES

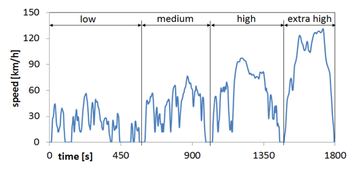
DIESEL

Vehicles ④⑤⑥	Opel Zafira Tourer ④	VW Golf Plus ⑤	Peugeot 4008 1.6HDi STT ⑥
Engine code	A16XHT	CAV	9HD / 9H05
Number and arrangement of cylinders	4 / in line	4 / in line	4 / in line
Displacement cm³	1598	1390	1560
Power kW	125 @ 6000 rpm	118 @ 5800 rpm	84 @ 3600 rpm
Torque Nm	260 @ 1650 - 3200 rpm	240 @ 1500 rpm	270 @ 1750 rpm
Injection type	DI	DI	DI
Curb weight kg	1678	1348 - 1362	1462
Gross vehicle weight kg	2360	1960 - 1980	2060
Drive wheel	Front-wheel drive	Front-wheel drive	Front-wheel drive
Gearbox	m6	m6	m6
First registration	22.07.2014	01.02.2010	12.04.2013

DRIVING CYCLES

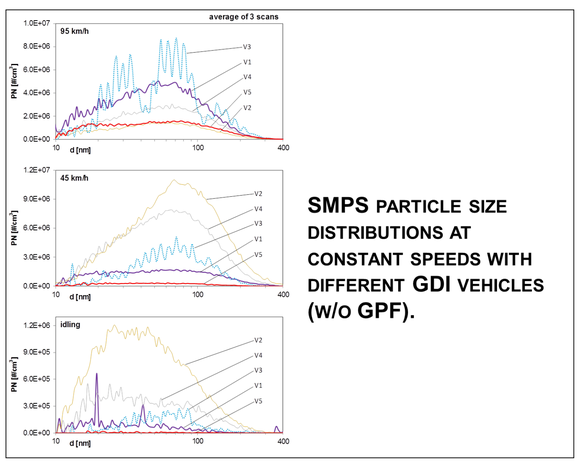


SSC steady state cycle and tailpile temperature of vehicle 1



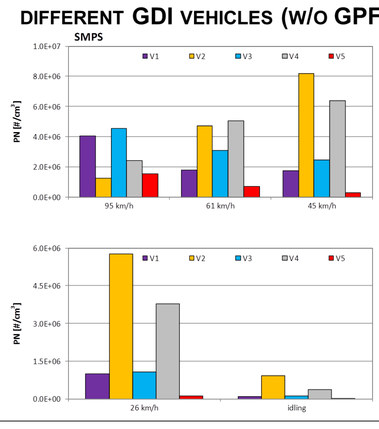
WLTC driving cycle

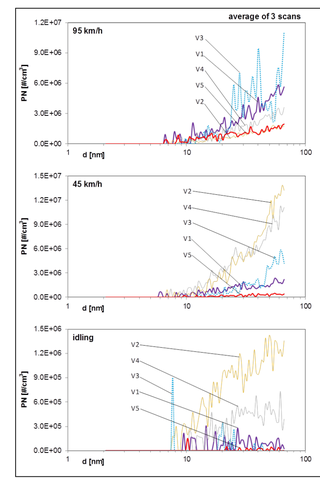
Results at steady state operation SSC



SMPS PARTICLE SIZE DISTRIBUTIONS AT CONSTANT SPEEDS WITH DIFFERENT GDI VEHICLES (W/O GPF).

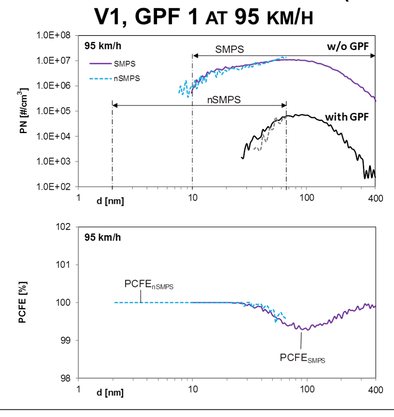
INTEGRAL PN EMISSIONS AT CONSTANT SPEEDS WITH DIFFERENT GDI VEHICLES (W/O GPF).



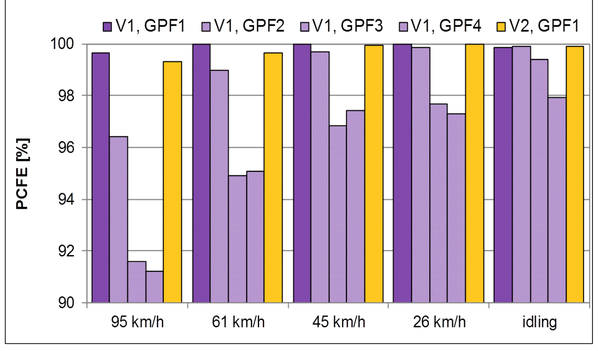


nSMPS PARTICLE SIZE DISTRIBUTIONS AT CONSTANT SPEEDS WITH DIFFERENT GDI VEHICLES (W/O GPF).

EXAMPLE OF PSD'S WITH SMPS & nSMPS AND PARTICLE COUNTS FILTRATION EFFICIENCY (PCFE) WITH V1, GPF 1 AT 95 KM/H



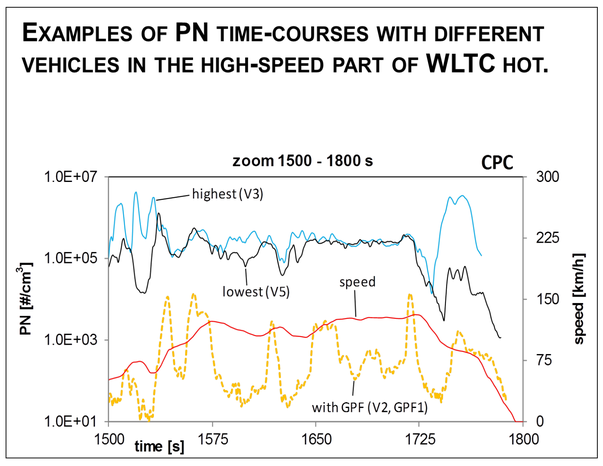
FILTRATION EFFICIENCIES PCFE AT CONSTANT SPEEDS WITH DIFFERENT GPF'S (SMPS DATA).



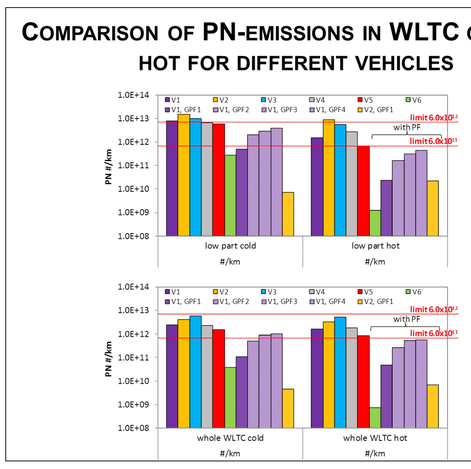
PCFE ... Particle Counts Filtration Efficiency

Results at Transient operation WLTC

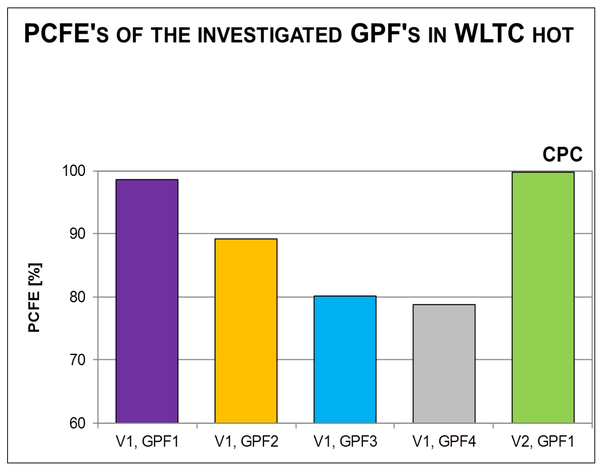
EXAMPLES OF PN TIME-COURSES WITH DIFFERENT VEHICLES IN THE HIGH-SPEED PART OF WLTC HOT.



COMPARISON OF PN-EMISSIONS IN WLTC COLD AND HOT FOR DIFFERENT VEHICLES



PCFE'S OF THE INVESTIGATED GPF'S IN WLTC HOT



Conclusions

- the PN-emission level of the investigated GDI cars in WLTC without GPF is in the same range of magnitude very near to the actual limit value of 6.0 x 10^{12} #/km
- with the GPF's with better filtration quality it is possible to lower the emissions below the future limit value of 6.0 x 10^{11}#/km
- the filtration efficiency of GPF can attain 99% but it can also be optimized to lower values – in this respect the requirement of "best available technology for health protection" should be considered

Conclusions

- generally there is a very good accordance of PSD's measured with both systems SMPS and nSMPS in the common size range (10-64 mm)
- for the vehicles with gasoline DI, there is no increase of PC's in nuclei mode (below 10 nm) at the measured constant speeds, the particle counts below 10 nm are negligible
- due to the electronic regulation of the engine the NP-emission of some vehicles (here vehicle 3) are periodically fluctuating

Further information; jan.czerwinski@bfh.ch, pierre.comte@bfh.ch