Real-World Evaluation of Emissions From Light-Duty GDI Vehicle Equipped with GPF Using PEMS

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Introduction

Many studies have shown that the atmospheric pollution levels of particulate matter (PM) are not decreasing despite the introduction of stricter vehicle emission regulations. The difference between conditions of the type approval cycles defined by the vehicle emission regulations and the real driving can contribute to the differences between expected and actual pollution levels. This has led to the introduction of in-use vehicle emission monitoring and regulations by means of portable emissions systems (PEMS). With recent developments in the US and the European Union (EU), PEMS is becoming an important regulatory device. Both the Environmental Protection Agency (EPA) and the California Air Resource Board (CARB) have begun testing the ability of PEMS to accurately measure real driving emissions.

There is currently a widespread concern about the actual particulate emissions of gasoline direct injection (GDI) vehicles, which have dynamically penetrate the US market and are expected to eventually replace the less efficient port fuel injection (PFI) vehicles. Although GDI engines are knows to significantly improve fuel economy and lower greenhouse gas emissions (GHG) when compared to PFI engines, they produce higher PM emissions due to the direct spray of gasoline into the combustion chamber. This leads to locally rich, diffusion-governed liquid fuel combustion that creates more PM formation. Gasoline particulate filters (GPFs) are an effective route to reduce the PM mass and the number of ultrafine particles under a range of driving conditions and at the same time meet California's PM mass emission standards.

Objectives

The objective of this study is to examine the PM mass, black carbon, and gaseous emissions of a current technology GDI vehicle during on-road testing with and without a catalyzed GPF. The vehicle was tested in triplicated in downtown Los Angeles, Mt. Baldy, 1-10 Highway, and in San Diego. The four routes were designed to be broadly different in order to differentiate vehicle operating effects on the exhaust emissions. The results of this work will be discussed in the context of the impact of GPF and driving patterns on tailpipe emissions and fuel economy.

Routes

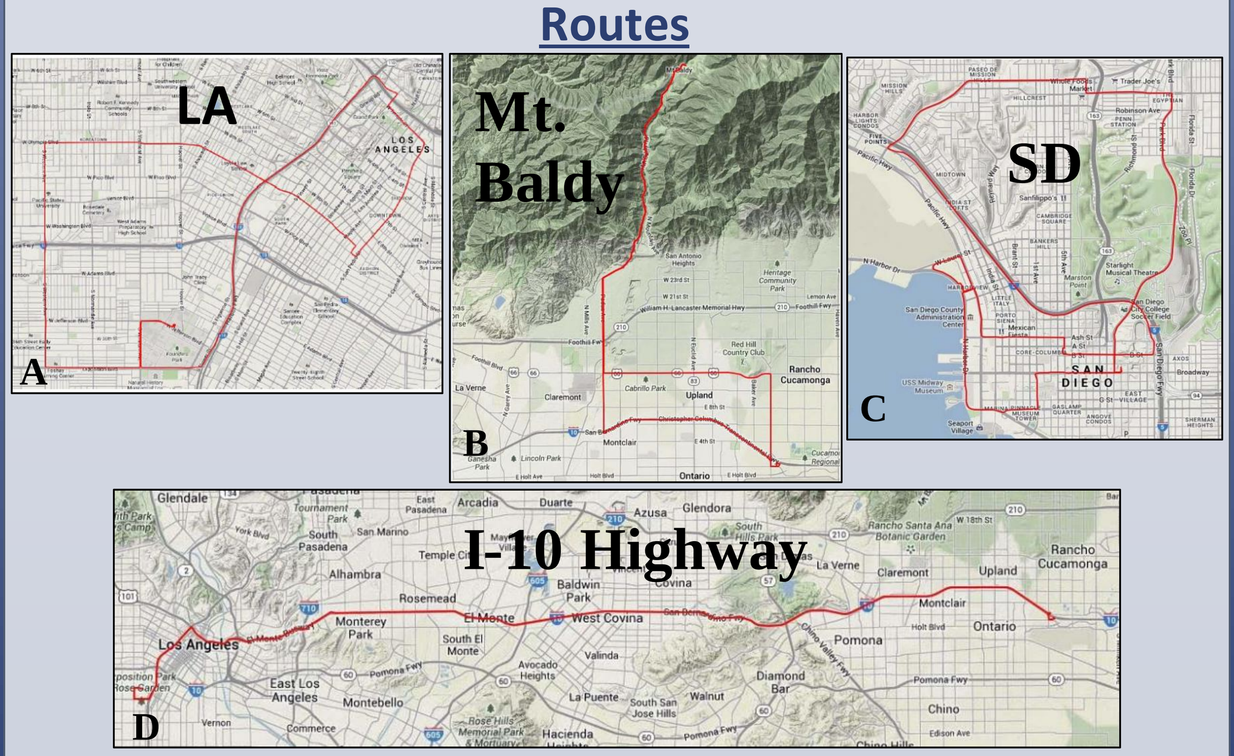


Figure 1. Test routes for Downtown Los Angeles (a), Mt. Baldy (b), Downtown San Diego (c), and I-10 Highway (d).

Set Up and Instruments

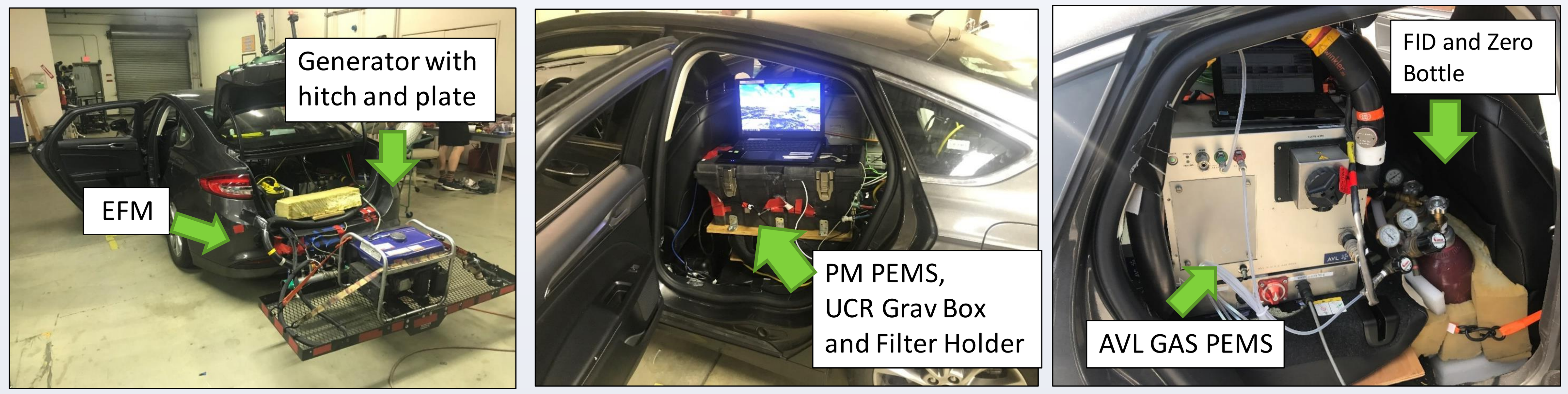


Figure 2: Set-up of instruments inside the test vehicle (2017 Ford Fusion)

Not Pictured: AVL Micro Soot Sensor and NTK Compact Emissions Meter

Results

Figure 3: Comparison of GPF and non-GPF after treatment for the 4 routes based on soot mass (A), PM (b), THC (c), NOx (d), and CO2 (e) emitted per mile as well as fuel consumption (f).

% Difference with GPF	LA	I-10 Highway	Mt. Baldy	SD
Soot (mg/mi)	-99.30%	-99.13%	-99.19%	-93.90%
PM (mg/mi)	-88.55%	-84.15%	-92.27%	-67.32%
THC (g/mi)	-31.17%	3.48%	33.77%	-2.36%
NOx (g/mi)	-6.18%	-47.41%	-22.60%	-14.12%
CO2 (g/mi)	1.46%	-10.01%	3.91%	33.29%
Fuel Economy (mi/gal)	-1.40%	2.27%	-4.18%	-24.32%

Table 1: Percent difference of the average soot mass, PM, THC, NOx, and CO2 emitted as well as fuel economy with and without a GPF over the 4 different routes

Conclusion

Downtown LA Route

- Urban driving – low vehicle speed with stop and go operation
- Significant decrease in PM (88%) and soot (99%) with GPF

I-10 Highway Route

- Highway driving – high speed and stop and go patterns during rush hour
- Significant decrease in PM (84%) and soot (99%) with GPF
- Significant decrease in NOx (47%)

Mt Baldy Route

- Uphill/downhill driving – steep road grades and medium to higher speed vehicle operation
- Significant reduction in PM (92%) and soot (99%) with GPF
- Decrease in NOx (22%)
- Increase in THC (33%)

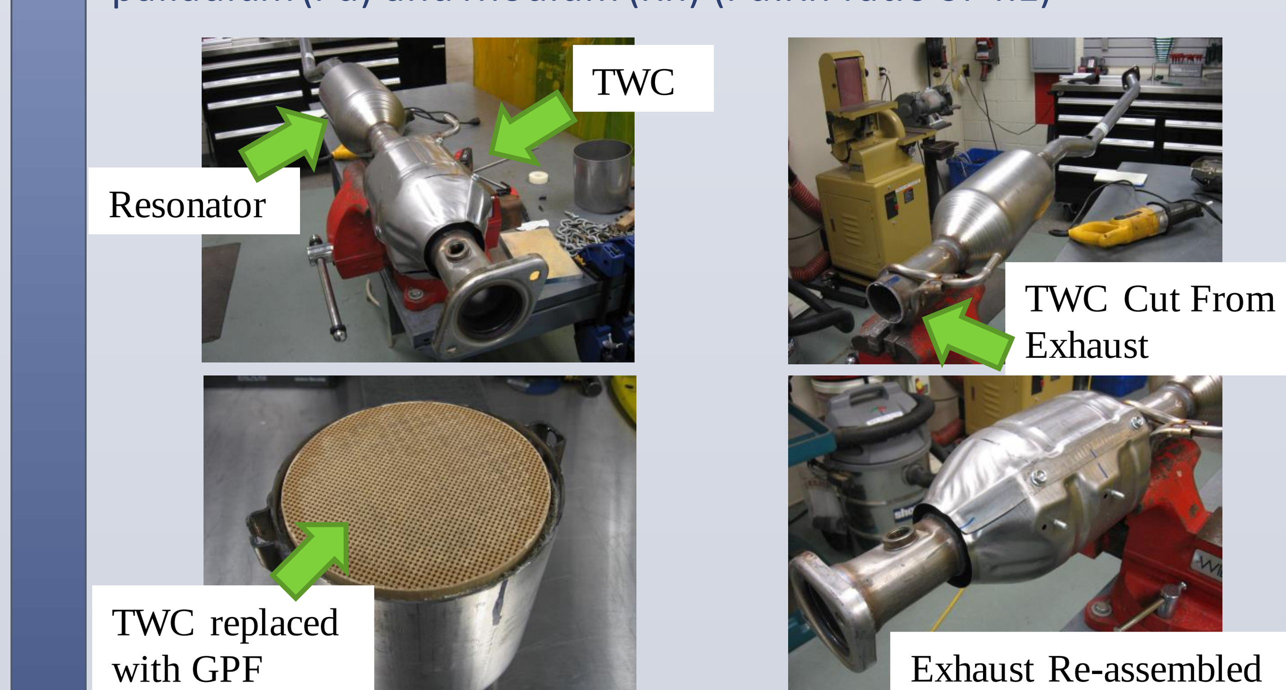
Downtown SD Route

- Urban driving – low vehicle speed with stop and go operation
- Significant decrease in PM (67%) and soot (93%) with GPF
- Slight decrease in fuel economy (24%) with an increase in CO2 emitted (33%) when GPF equipped
- No statistical difference in NOx or THC emitted

Catalyzed GPF proved very useful in decreasing PM and soot in any driving condition. Emissions with the GPF shpwed a decreasing trend in NOx emissions with little effect on fuel consumption and CO2 emissions. Interestingly, THC emissions vary a lot and are shown to increase with GPF in some routes while decreasing in others.

Gasoline Particulate Filter

GPF had a TWC washcoat with approximately 1.0 g/L loading of palladium (Pd) and rhodium (Rh) (Pd:Rh ratio of 4:1)



Refrences

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