“Excess” emissions of particulate matter from EU gasoline engines

M. Vojtisek[1,2], M. Pechout[2], L. Dittrich[2], V. Beránek[1]

[1] Center for Sustainable Mobility, Czech Technical University in Prague, CZ 16607, Czech Republic
[2] Faculty of Mechanical Engineering, Technical University of Liberec, CZ 461 17, Czech Republic

Keywords: Combustion, Spark ignition engine, particulate matter, off-cycle, real-world emissions, DieselGate
Presenting author e-mail: michal.vojtisek@fs.cvut.cz

Particles emitted by internal combustion engines constitute one of the major health hazards. Carcinogenic particles, mostly tens of nanometers in diameter, are emitted in the immediate vicinity of urban inhabitants, and in many areas, constitute most of the particle number concentrations found on the streets at breathing levels. When inhaled, they efficiently deposit in human lung alveoli and penetrate through cell membrane into the blood.

Historically, emissions legislation pertaining to the type approval of new vehicles was the most effective measure to reduce vehicle emissions per km driven. While the emission limits were decreasing, the laboratory conditions to which the limits are applicable remained more or less the same. In the European Union (EU), the relative low power levels at which the engine is operating throughout the currently used NEDC driving cycle, the increasing sophistication of engines and exhaust aftertreatment and their control, the competitive nature of the automotive market, and the lack of regulatory oversight, has lead to a condition where the ratio of the emissions during real driving to the emissions measured during the type approval cycle is increasing.

On automobile diesel engines, high emissions of particulate matter (PM) and nitrogen oxides (NO_x) are associated primarily with high-power operation at higher speeds and loads than those encountered during the NEDC. In many cases, high emissions of NO_x were observed even during regimes normally covered during the NEDC, due to deliberate manipulation of the engine controls by the manufacturers. A formal accusation of one specific manufacturer by the US EPA of such practice became known as “DieselGate”.

In this paper, the phenomena of “excess” emissions is investigated for spark ignition (gasoline, petrol) engines and for PM.

An emerging direct injection spark ignition (DISI, also known as GDI – gasoline direct injection) engine technology, now comprising tens of percent of the gasoline engines sold, has been reported to have substantially higher PM emissions compared to the port fuel injected (PFI) engines. “Enrichment” conditions, where excess fuel is injected into the engine to provide a little additional power and to reduce exhaust gas temperatures at maximum loads, have been known to drastically increase PM emissions. PM from gasoline engines has been reported to contain more carcinogenic polyaromatic hydrocarbons compared to diesel PM.

While diesel PM emissions have been addressed by now a widespread use of particle filters on new vehicles, both the technology and the legislation on gasoline engine emissions has been lagging and only recently, particle emissions limits have been imposed on gasoline engines.

In this paper, results of particle emissions measurements done by the authors under real driving conditions on the road, and under different than type approval conditions on a chassis dynamometer, are summarized and reviewed, with the following conclusions:

1. The PM emissions from gasoline engines, both port and direct injection, are substantially elevated during “enrichment”, where the engine is operated with excess fuel. Such conditions are not covered by the type approval procedures (neither existing nor proposed). Enrichment for additional power has been expressly prohibited in the United States.
2. The PM emissions from gasoline engines may be substantially elevated during highly transient operation, notably in cases where excess fuel is injected to avoid a drop in performance.
3. A large share of particles was smaller than 23 nm and a large share of particles was volatile. Therefore, the current type approval procedure for particle number measurement (Particle Measurement Programme), where only non-volatile particles are counted, with 50% counting efficiency at 23 nm, detects only a small fraction of total spark ignition engine particles.

Small non-road engines, currently subject to only very lenient gaseous emissions standards, and no PM limit at all, pose an additional and major problem.

Overall, gasoline engine PM emissions under real world driving conditions are higher than during type approval test conditions, and cannot be considered harmless or negligible.

This work was supported by EU LIFE program (LIFE10 ENV/CZ/651, www.medetox.cz) and by Czech Ministry of Education project LO1311.