Particulate matter emissions from a winter operation of a modern on-road diesel engine powered by heated rapeseed oil

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Introduction

Diesel engines powered by liquid fuels move the world, but also release, directly in the streets, nanoparticles hazardous to human health. New fuels and engine technologies must therefore be evaluated carefully for their effect on particle emissions.

Neat vegetable oils, typically used for the production of biodiesel, are often used as motor fuels, despite their use falling short of being widespread due to adverse effects on engines. One of such adverse effects is the inferior combustion of vegetable oils at low engine speeds and loads resulting in increased emissions of particulate matter (PM), while PM generally decrease at moderate and higher rpm and loads (Czerwinski 2008, Vojtisek-Lom 2009). The increase in PM emissions was attributed primarily to higher viscosity of rapeseed oil compared to diesel fuel, causing worse atomization of the fuel, and worsened evaporation in the combustion chamber, leading to a less complete combustion; the decrease in PM to the differences in chemical structure of rapeseed oil, notably the absence of aromatics and about 10% by weight oxygen content.

To decrease PM emissions, majority of currently produced diesel engines use a Common-Rail (CR) injection system. In a CR system, multiple injections are performed, with the timing and quantities of fuel injected controlled and optimized for petroleum diesel fuel. While this approach greatly reduces PM emissions when operating on diesel fuel, a question arises as to its performance with vegetable oils for which it is not optimized. Higher PM were reported by Dorn (2007).

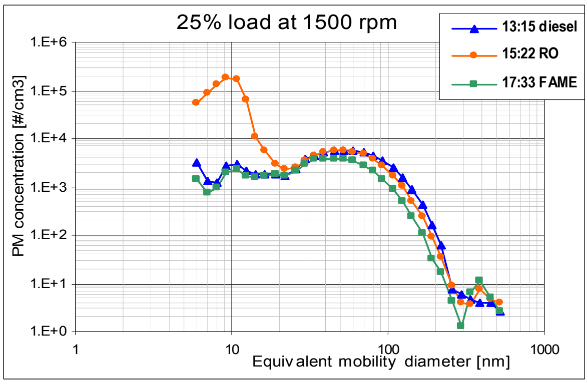
Experimental

In this study, a 4.5-liter, 130 kW, four cylinder, turbocharged Cummins ISBe4 medium truck/bus engine with a Bosch CR injection system was tested on an engine dynamometer during steady-state operation. The engine was operated without any exhaust gas aftertreatment system on diesel fuel, neat biodiesel (FAME) and heated RO. The exhaust was routed in an improvised full-flow dilution tunnel, part of which was located outside of the laboratory. PM mass emissions were measured by the gravimetric method. Particle size distributions in the range of 5-500 nm were measured by EEPS spectrometer (model 3090, TSI, St. Paul, MN, USA). The testing was performed during the winter at outside temperatures 265-270 K and engine intake air temperatures 285-290 K.

The dilution apparatus and its operating temperature were favorable for nucleation and condensation of particles. No efforts were taken to evaporate volatile matter from the particles by a thermodenuder or by diluting with heated air. Therefore, this experimental setup was considered to represent reasonable worst-case scenario of an engine operated during the winter.

Results and discussion

The particle number emissions for FAME were typically similar to tens of percent lower compared to diesel fuel in all size ranges. For RO, particle concentrations were between diesel and FAME above 20-30 nm, but markedly higher at lower diameters with a strong nanoparticle peak (see figure below for an example). These small particles are believed to be organic carbon which would be in gaseous form at higher temperatures. Total particle number emissions for RO were compared to diesel lower at full load but higher at all other regimes. The effect on total PM mass over ESC and WHSC cycles was not uniform and relatively small. With the exception of the nanoparticle peak which is subject to future discussions, no major adverse effects on PM emissions were observed during operation of a modern CR diesel engine on heated RO.



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