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Title: Particulate emissions from a dual-fuel compression ignition engine utilising ethanol fumigation

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Extended summary:

Particle emissions, volatility and the concentration of reactive oxygen species (ROS) were investigated for a Pre-Euro I, 4-cylinder, Ford 2701C compression ignition engine to study the potential health impacts of employing ethanol fumigation technology. The dual-fuel system fitted to the test engine enabled vapourised ethanol to be delivered to the intake manifold. Engine testing was performed in two separate experimental campaigns. The first was conducted at 2000 rpm, full load, and the second at intermediate speed (1700 rpm) using four different load settings. For a particular load setting, all tests were conducted at the same brake load, so that any change in emissions was only due to the change in fuel, and not due to the different power output of the engine.

A Scanning Mobility Particle Sizer (SMPS) was used to determine particle size distributions, a Volatilisation Tandem Differential Mobility Analyser (V-TDMA), pre-selecting 80 nm accumulation mode particles, was used to explore particle volatility, and a new profluorescent nitroxide probe, BPEAnit, was used to investigate the particle-related reactive oxygen species (ROS) concentrations emitted by the test engine. BPEAnit is a weakly fluorescent compound, but it exhibits strong fluorescence upon radical trapping or redox activity [1]. This makes it a powerful optical sensor for radicals and redox active compounds, and can assist in determining the potential toxicological impact of particle emissions.

Particulate mass was significantly reduced, and the concentration of gas phase hydrocarbons increased considerably, with ethanol fumigation. Both of these factors contributed to the formation of a nucleation mode at full load operation with a 40% ethanol substitution. Previous research on ethanol blends [2-4]; using ethanol substitutions lower than that used in this study, demonstrate a reduction in the accumulation mode particle concentration, and a shift to smaller particles, without the presence of a nucleation mode.

Particle size was correlated with the peak combustion pressure and the ethanol fumigation percentage. As a result, fragmentation of agglomerates due to increased combustion pressures, and oxidation of the particle surface due to OH radicals emerge as two hypotheses that could explain the smaller particles that arise from ethanol fumigation technology.

The V-TDMA results showed that the percentage of volatile particles was increased by ethanol fumigation. Furthermore, particles were internally mixed at full load operation and were externally mixed at all other loads. Volatilisation curves indicated the presence of organic material, either derived from fuel or lubricating oil. The particle volume fraction remaining, plotted against the thermodenuder temperature, generally exhibited a more rapid decrease for tests involving ethanol.

Particle-related ROS emissions increased with decreasing engine load, for both neat diesel and ethanol tests, although ROS emissions were higher for the tests involving ethanol fumigation, except at idle mode. In addition, higher ROS concentrations were associated with the formation of a nucleation mode in the particle size distributions.

In conclusion, the smaller particles, the increased volatility, and the significant increase in ROS emissions from ethanol fumigation may provide a substantial barrier to the uptake of fumigation technology using ethanol as a supplementary fuel.

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