Experimental investigation of particles produced by combusting blends of "high-quality" and "cost-competitive" biofuels in a tractor engine

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Background
- Biodiesel (n-alkyl-esters of fatty acids) and non-esterified vegetable oil popular drop-in fuels for agricultural machinery and road vehicles. Downside: cold performance, fuel stability, poor combustion at low loads, potential conflict with food production.
- HVO and synthetic fuels use a wider variety of feedstocks, but their present downside is their high cost.
- Alcohols can be produced inexpensively and with low embedded fossil energy from different agricultural residues. Downside: low cetane number and the resulting deterioration in combustion.
- Oxygenated fuels (alcohols, biodiesel, vegetable oil) offer a reduction in particulate matter due to oxygen content.
- Two of four butanol isomers - n-butanol and iso-butanol - are mentioned as a suitable fuels for spark ignition engines (for CI only when small share of butanol is used), can be produced from biomass at cost comparable to ethanol [Tao et al., Biofuels Bioprod. Biorefin., 8(1): 30-48, 2014], higher cetane number, lower hygroscopicity, lower aggressivity to materials compared to ethanol.

Goal: To explore the effects of introducing n-butanol, iso-butanol, HVO and rapeseed oil and their mixtures a fuel into a tractor engine on combustion, performance, and emissions. This poster focuses on particulate matter emissions.

Experimental
- A Zetor 1505 (EU Stage III) has been tested during 12 loaded points steady state operation (also including regimes of NRSC), idle and extended idle.
- Parameters of the engine: displacement 4,016 dm³, max. torque: 525 Nm @ 1500 rpm, power: 90 kW @ 2200 rpm, compression ratio 17.0:1, turbocharged with intercooler, in-line four cylinder, in-line injection pump.
- The engine was operated on idle, extended idle (1200 rpm and 20Nm) and four load levels (25%, 50% and 75% of torque when operated on diesel fuel) and full load at rated rpm (2200) and maximum torque rpm (1500).
- Exhaust gas pollutant were investigated by FTIR (Midac, CO, CO₂, NO, NO₂, N₂O, NH₃, acetaldehyde and formaldehyde).
- Size distribution spectra of particulate matter were analyzed in sample of exhaust gas taken from partial dilution tunnel by EEPS TSI 3090 without removing of volatile fraction.
- Gravimetric production was evaluated using a proportional particulate matter sampler.

Results and Discussion
- Addition of alcohols into diesel increased count of the nucleation mode particles and decreased the accumulation mode.
- The nucleation mode concentrations were lower for iso-butanol blends compared to n-butanol blends.
- All alcohols decreased PM production, i-butanol most effectively.
- Utilization of HVO caused increase of accumulation mode particle mass rising with lowering of load with weak effect on nucleation mode.
- RO utilization generally decreased PN accumulation mode at higher loads but increased PM at lower loads and idle.
- Addition of alcohols to rapeseed oil did not improve the problem of high particle emissions at low loads.
- Nearly no effect of both butanols on nucleation mode has been observed, i-butanol exhibited lower concentrations.
- Total particle production on alcohol blends was comparable or significantly decreased depending on used weight factors.

ISO 8178 C-1 (NRSC) averages 8-point non-road engine test

ISO 8178 C-2 averages (accent on lower loads)