20th ETH Conference on Combustion Generated Nanoparticles, Zurich, June 13-16, 2016

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 oils) 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.

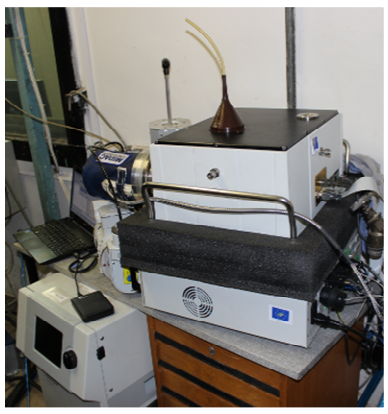
Acknowledgments: This work was sponsored by the EU LIFE+ programme, project LIFE10 ENV/CZ/651 – MEDETOX, Innovative Methods of Monitoring of Diesel Engine Exhaust Toxicity in Real Urban Traffic

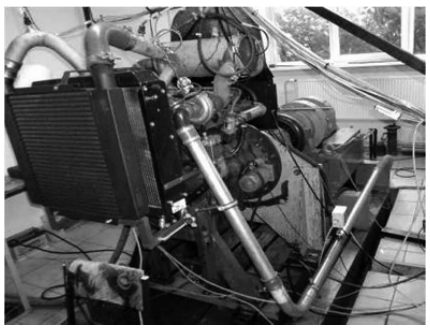
Experimental

- 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 dm^3, 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_2, CO, NO, NO_2, N_2O, NH_3, 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

Fuels tested

Diesel	**Diesel fuel (reference)**
E10	10% ethanol
nBu16	16% n-butanol
iBu16	16% i-butanol
nBu16-B10	16% n-butanol, 10% biodiesel (FAME)
Diesel	**Diesel fuel (reference)**
iBu16-B10	16% i-butanol, 10% biodiesel (FAME)
E10-B10	10% ethanol, 10% biodiesel
HVO (100)	Hydrotreated veg. oil (NExBTL)
RO (100)	Rapeseed oil (fuel-grade)
RO-nBu16	16% n-butanol, rapeseed oil
RO-nBu16-B20	16% n-butanol, 20% biodiesel, RO
Diesel	**Diesel fuel (reference)**
HVO5-B5	5% NExBTL, 5% biodiesel
E10-B10	10% ethanol, 10% biodiesel
nBu15-B16	16% n-butanol, 15% biodiesel (FAME)
HVO50	50% NExBTL
HVO50-B50	50% NExBTL, 50% biodiesel
Diesel	**Diesel fuel (reference)**
RO-iBu16	16% isobutanol, rapeseed oil
RO-iBu16-B20	16% isobutanol, 20% biodiesel, RO

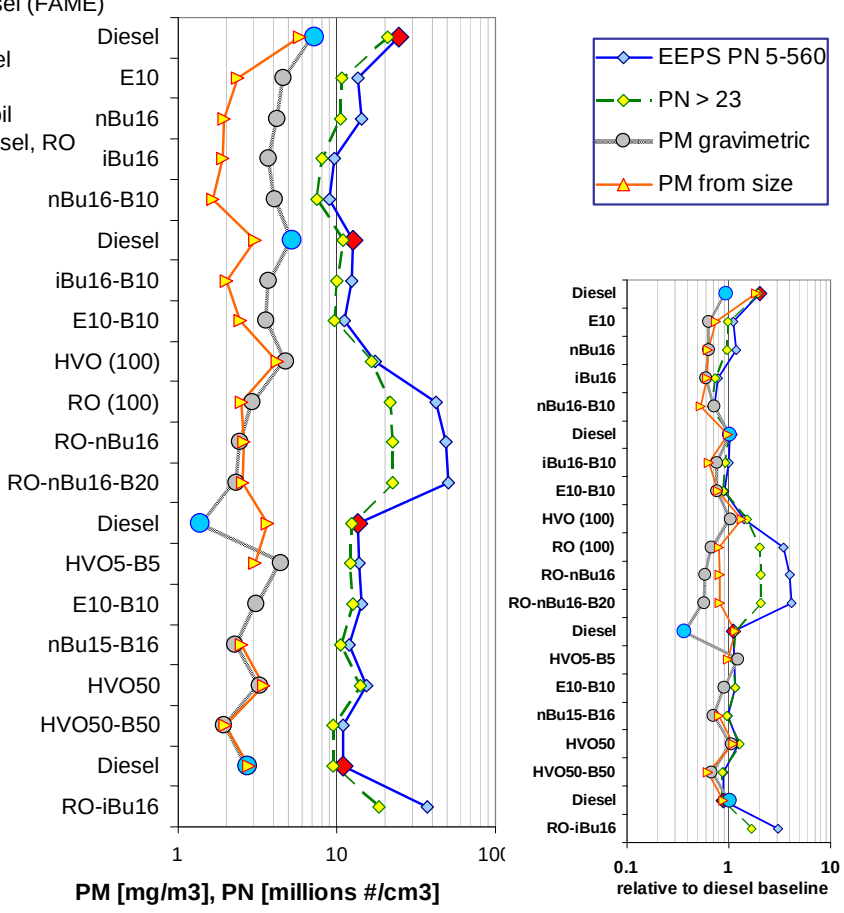




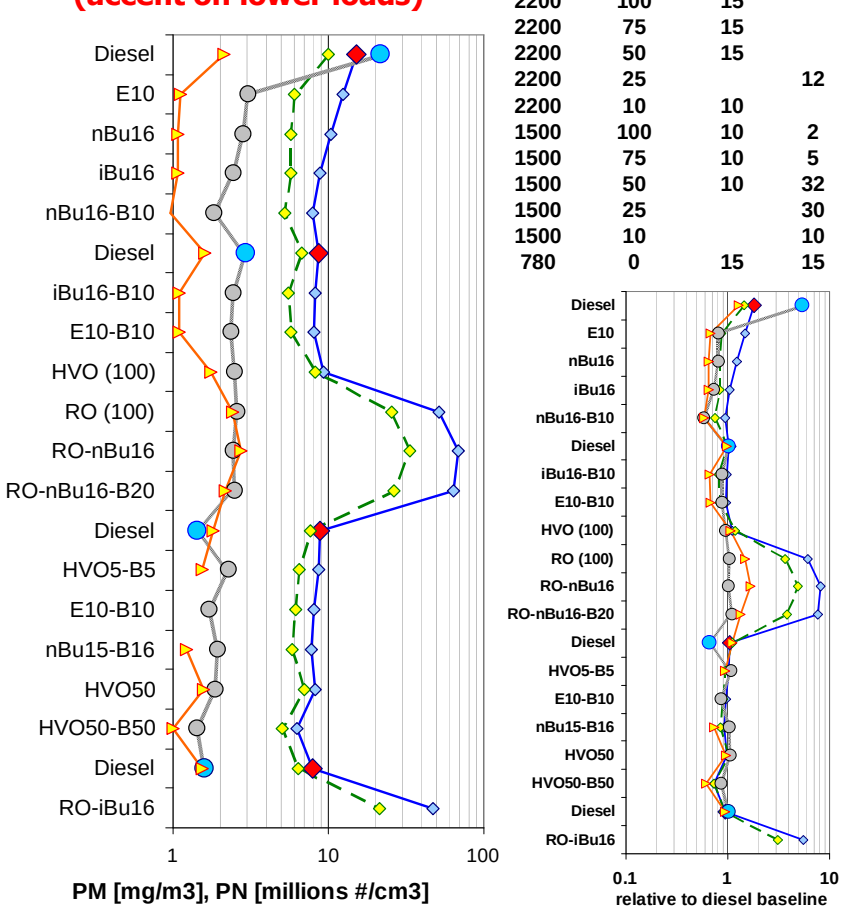
Results and Discussion

- 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 raising 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)



engine rpm	torque [%]	weight factors C1 [%]	C2 [%]
2200	100	15	
2200	75	15	
2200	50	15	
2200	25		12
2200	10	10	
1500	100	10	2
1500	75	10	5
1500	50	10	32
1500	25		30
1500	10		10
780	0	15	15