Shipboard characterization of particle and gas emissions from a Danish inland ferry

Morten K. Lykkegaard[1], Anne G. Hemmersam[1], Torben N. Jensen[2], Keld G. Nielsen[2], Henrik Tarp[2], and Mikael Poulsen[1]

[1] Center of Chemistry and Biotechnology, Danish Technological Institute, DK-8000 Aarhus C, Denmark
[2] Center of Sustainable Energy and Transportation, Danish Technological Institute, DK-8000 Aarhus C, Denmark

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Presenting author email: mly@dti.dk

Introduction

Several studies show that emissions from ship traffic influences the air pollution in port cities severely. Especially NO_x and ultrafine particle levels are reported to be elevated due to ship traffic in the harbor area and high NO_x and ultrafine particle levels are known to affect human health.

Mainly two ways for limiting the emissions from ships are presently being exploited, lowering of the sulfur content in the fuel and implementation of different types of emission reducing technologies such as filters and scrubbers. Regulation of sulfur content in fuel for ships entering the North Sea, which is an emission control area (ECA) zone is limited to 1% whereas the world wide average sulfur content in heavy fuel oil is 2.6%. Danish ferries are already running on marine diesel in which the sulfur content is limited to 0.1%. Emission data from single ships running on different types of fuel is highly needed in order to better understand the impact of reducing the sulfur level with respect to primary particle formation and gas emissions. However, to achieve reliable and precise emission data from single ships is a challenge, therefore only a limited number of studies are presently available.

In this study emission data from a Danish inland ferry running on marine diesel is presented

Experimental

All measurements were carried out onboard the Danish inland ferry connecting the island of Ærø with Fyn. The measurements were performed according to the ISO 8178 steady state method and at 4 points of engine load; 100%, 85%, 50% and idle. The nanoparticle size distribution and number concentration was measured using a scanning mobility particle sizer (SMPS) from TSI, Inc. in connection with a ASET 15-1 rotating disc dilutor connected with a thermal conditioner.

For particle mass measurement, particles from diluted exhaust gas were collected on quartz filters. Gas emissions (CO_2, CO, HC and NO_x) were measured using standard laboratory gas analyzer equipment.

Results

The emission data show NO_x levels at 8.33 g/kWh which is comparable to EURO 2 heavy duty diesel engine for vehicles and below the TIER II regulation for ships. NO_2 and SO_4 were found to be 0.99 and 0.01 g/kWh. CO and HC levels were measured and found to be within the specifications of EURO 5 or 6 for heavy duty engines for vehicles.

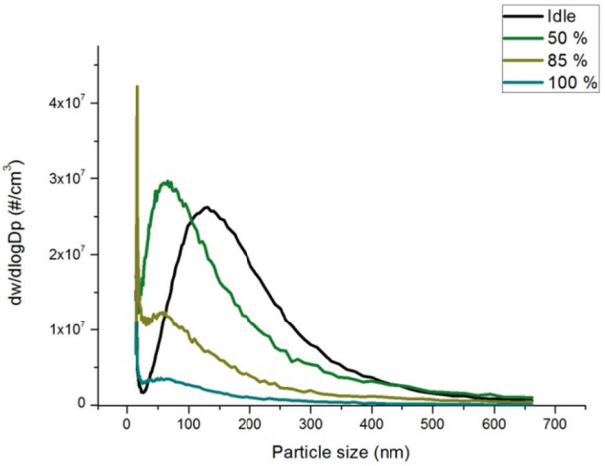

Fig. 1: Particle size distribution as a function of engine load, measured by SMPS in the size interval 15-680 nm

Parameter	Unit	
NO_x	g/kWh	8,33
NO_2	g/kWh	0,99
HC	g/kWh	0,23
CO	g/kWh	0,62
PM	g/kWh	0,22
SO_4	g/kWh	0,01

Tab. 1 Gas emissions averages as weighted after ISO 8178

The mean particle size was found to depend on engine load, but was below 150 nm during all engine loads. The largest particles were seen when the ferry was operating at idle in the harbor during load and unload. Particle number concentration was found to peak at an engine load of 50% and decrease at engine loads of 85% and 100%.

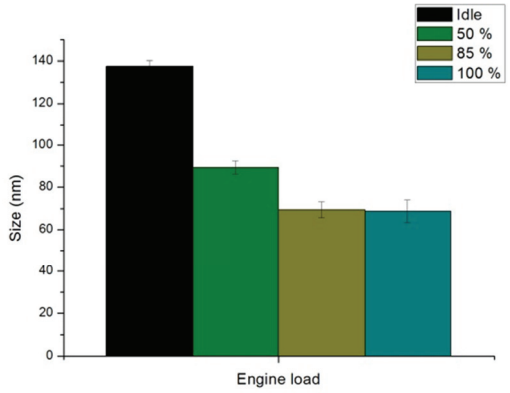

Fig. 2: Mean particle size with standard deviations as a function of engine load

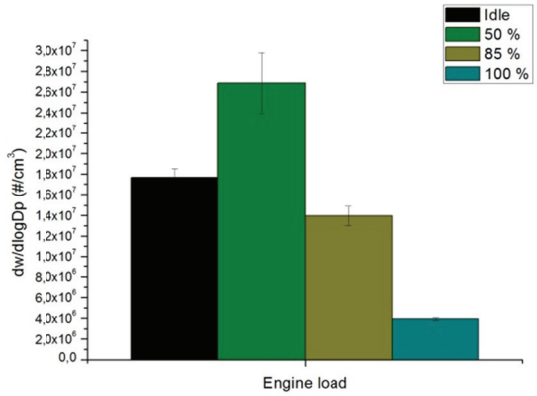

Fig. 3: Mean particle number concentration with standard deviations as a function of engine load

Conclusion

A scanning mobility particle sizer was applied with success for characterizing nanoparticles in the ferry exhaust gas. All emission data were in addition below the TIER II limit for ships.

This work was supported by the Danish Ministry of the Environment, Environmental Protection Agency and part of collaboration between Danish Technological Institute, Ærøfærgerne A/S and Dinex A/S.

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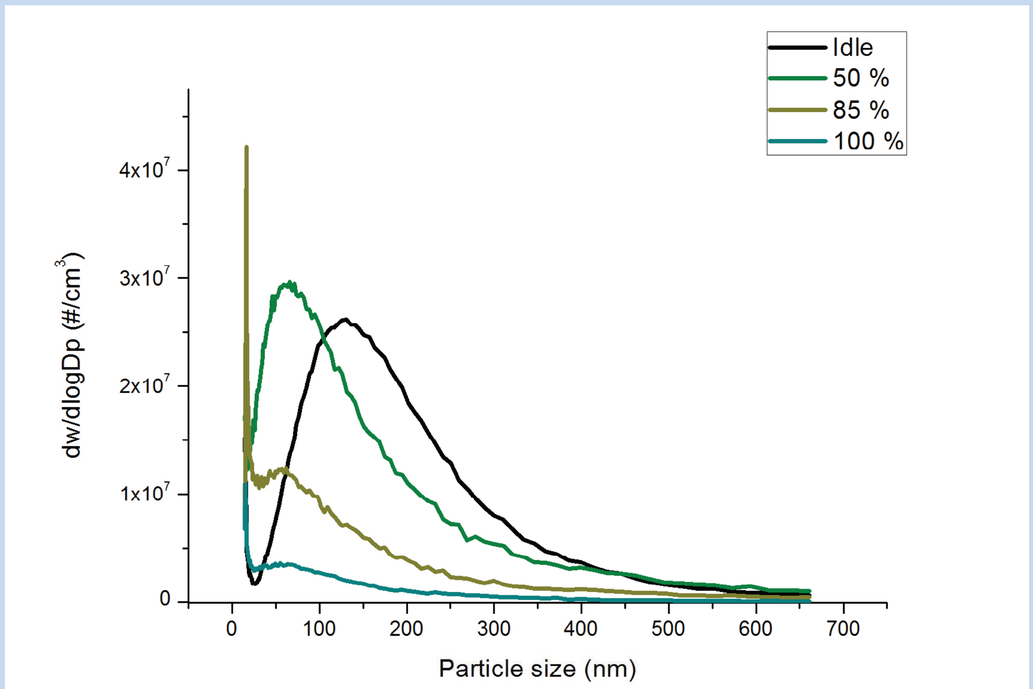
Sample	Parameter	Method	Result	Unit
Diesel fuel	Cetane no.	DIN EN ISO 5165	45.9	-
	Density (15C)	DIN EN ISO 12185	856	kg/m^3
	Sulfur content	DIN EN ISO 20884	262	ppm
	Ash content	DIN EN ISO 6245	0.006	% (m/m)
	Water content	DIN EN ISO 12937	18	mg/kg
Lubrication oil	Density (15C)	DIN EN ISO 12185	891.5	kg/m^3
	Sulfur content	DIN EN ISO 20884	2193	ppm
	Ash content	DIN EN ISO 6245	1,05	% (m/m)
	Water content	DIN EN ISO 12937	19	mg/kg

Tab. 1: Analysis of fuel and lubrication oil



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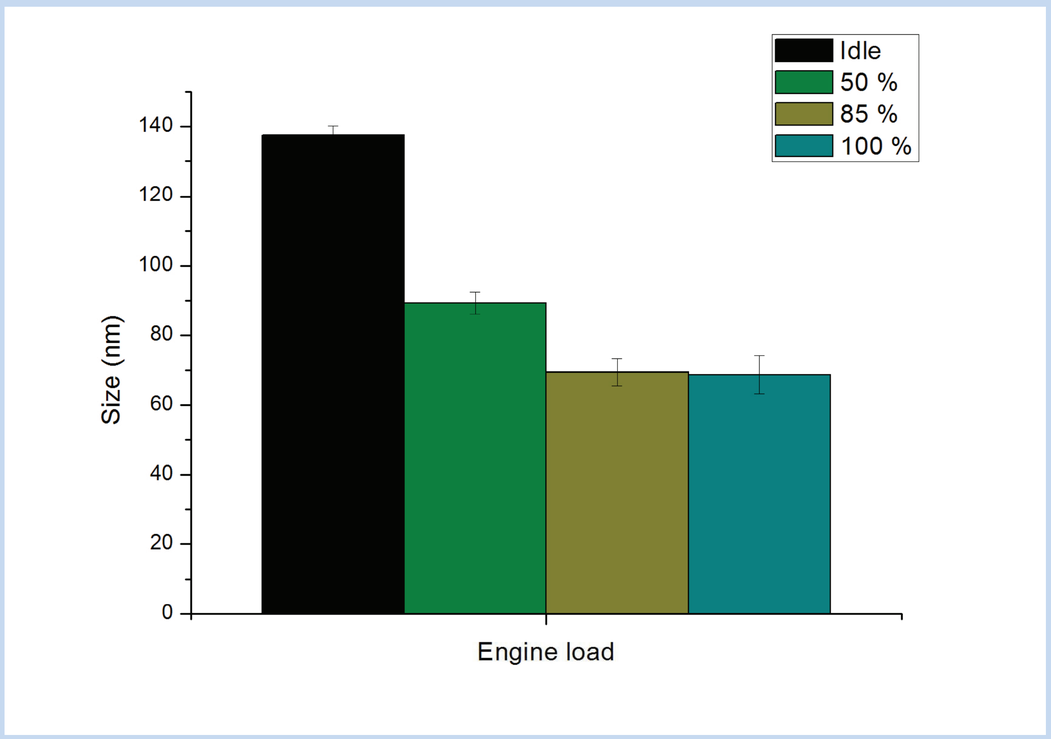

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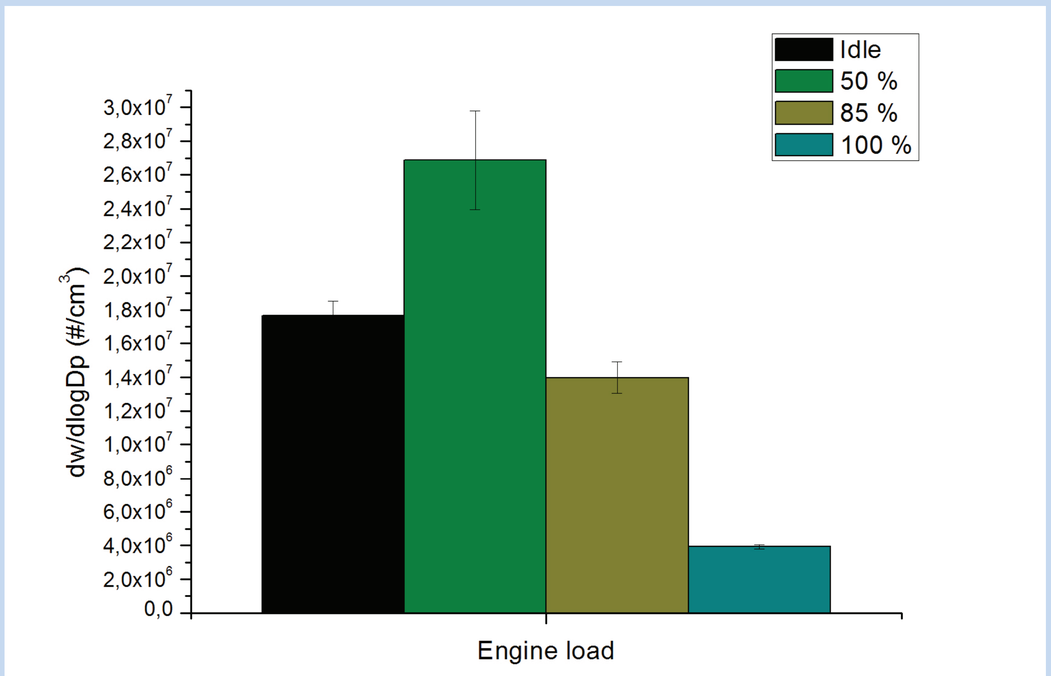

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