Shipboard characterization of a wet scrubber system: Influence on particle number concentration, particle size distribution and chemical composition

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Introduction

Ultrafine particles are generally recognized to have an adverse impact on human health and an increasing focus is turned towards particle emissions from marine engines. Although regulations on NO_X emission from ships have been implemented and sulphur content in marine fuel is now limited to 1.0 % in emission control area (ECA) zones, emissions from ship traffic is still an important factor to consider, especially in harbour cities.

Mainly two ways of limiting the emissions from ships are presently being exploited: 1) lowering of the fuel sulphur content and 2) implementation of emission reducing technologies such as filters and scrubbers.

In this study emission data from a ship with a retrofitted wet scrubber system from Alfa Laval installed, optimized for removal of sulphur compounds, is presented. The effect of the scrubber operating in seawater mode on particle emission was tested during two days in February 2011 using two different heavy fuels (1.0 % and 2.3 % sulphur content). The main focus of this study was on measuring the particle number concentration and size distribution before and after the scrubber system, and in this content evaluate and compare different kind of particle measurement instruments.

Experimental

The main engine is a MAN B&W 9L60 MC-C 2-stroke Diesel engine and the maximum continuous engine load was 88-90 % during measure-ments.

For particle characterization before and after the scrubber system a Scanning Mobility Particle Sizer (SMPS) from TSI, an Electrical Low Pressure Impactor (ELPI) from Dekati and two handheld Condensation Particle Counters (CPC) from TSI were used.

A Rotating disc diluter from Matter Engineering with inlet heated to 150 °C was used for diluting the exhaust gas a factor of 600-700 before CPC measurements. For SMPS and ELPI measurements a dilution

system based on two ejector diluters was used. The first diluter was heated to 350 °C and the second was at ambient temperature. The total dilution factor was 136.

Results and conclusions

The results show that combustion particles from the ship have a bimodal size distribution, both before and after the scrubber system (figure 1 and 2). The two peaks in the bimodal particle size distributions measured by the SMPS system were found at 8-10 nm and 50-60 nm for 1.0 % S fuel and at 15-20 nm and 70 nm for 2.3 % S fuel.

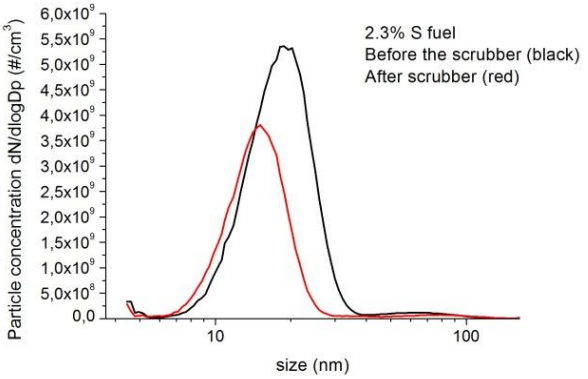

Figure 1: Particle size distributions measured by SMPS before and after the scrubber using 2.3 % S fuel.

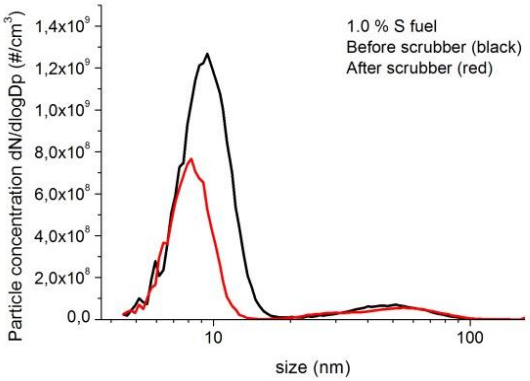

Figure 2: Particle size distributions measured by SMPS before and after the scrubber using 1.0 % S fuel.

Upon changing from 1.0 % S fuel to 2.3 % S fuel the total particle number concentration was found to increase by a factor of 4.8-6.4. Particle number concentrations measured in the size interval 20-1000 nm using SMPS, ELPI, and CPC were found to be in generally good agreement.

It was found that the scrubber system decreases the emitted particle number concentration (#/cm^3) by 30-55 % averaged over a 1 hour measurement period for specific operating conditions (figure 3).

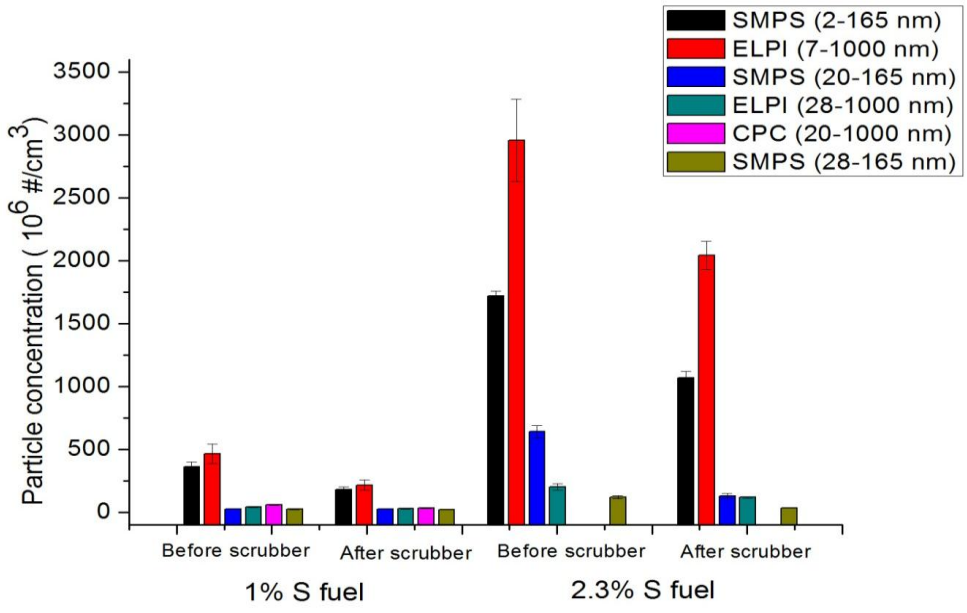

Figure 3: Comparison of PN concentration measured by SMPS, ELPI and CPC for 2.3 % S fuel and 1.0 % S fuel. (SMPS: mobility diameter, ELPI: aerodynamic diameter)

Elemental analyses was performed on particles >200 nm aerodynamic diameter by SEM with EDX. It was found the mass based carbon content of the particles was reduced by 50-60 % after the scrubber. After the scrubber increase in the percentage of sulphur, sodium, silicon, iron, nickel, chromium, vanadium, and magnesium in the particle mass was observed.

The chemical composition of the salt containing particles measured after the scrubber resembles that of the fuel oil better than that of sea water, indicating that the salt particles formed in the scrubber are condensates of the fuel.

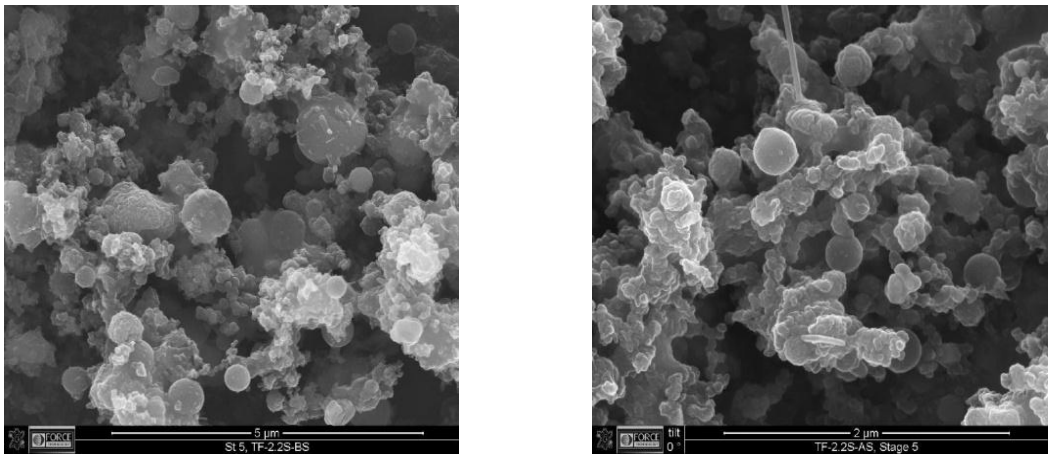

Figure 4: Representative SEM images of particles collected on ELPI stage 5 (260-380 nm) before and after the scrubber using 2.3 % S fuel. Note the different scaling

This work was supported by the Danish Agency for Science, Technology and Innovation and is part of the innovation consortium NaKIM

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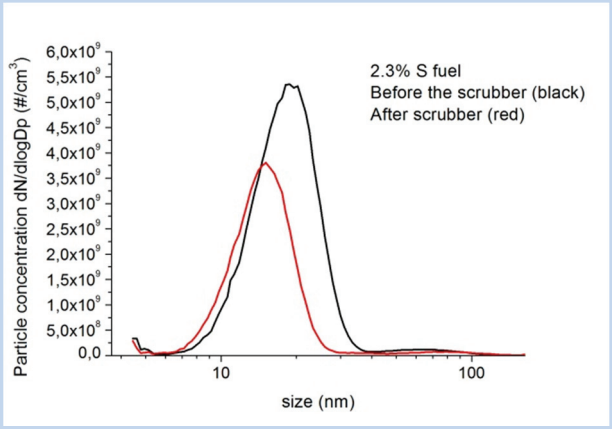

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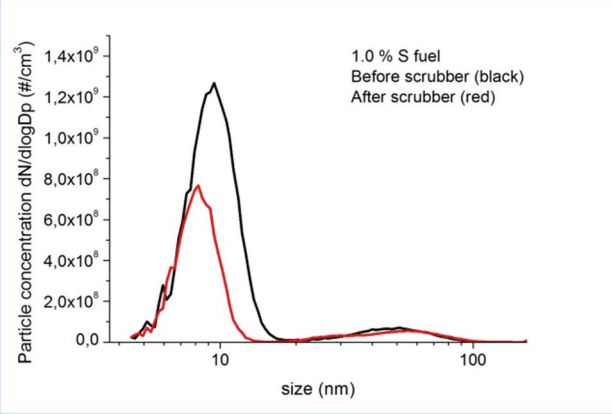

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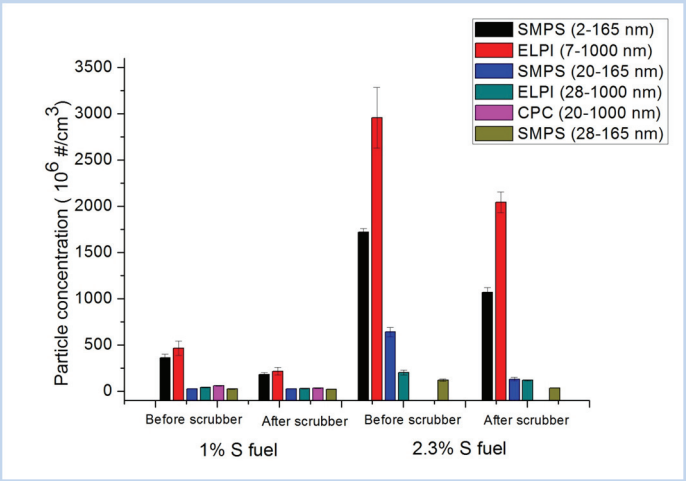

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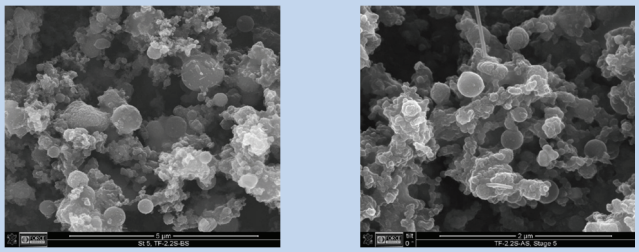

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