Measurement of PM emissions from ship engines: Effect of particle deposition in sampling equipment designed according to the ISO 8178 method.

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Background

ISO8178 is a commonly used reference method for measurement of particle matter (PM) emission from marine diesel engines. As described in ISO8178-1 (2006), PM measurement involves the sampling of a partial or full flow of the exhaust gas from the engine, followed by a dilution step in which the exhaust gas is cooled and subsequently sampled on a filter to a temperature of 42°C - 52°C. The dilution step involves the introduction of unheated pressurized air (required temperature: > 15°C) into a venturi nozzle in which the hot exhaust gas is introduced through a transfer tube. As shown in Figure 1, the pressurized air will cool the transfer tube nozzle, and this will lead to an increased deposition of particles in the unheated part of the transfer tube that is located inside the dilution tunnel.

In this study, we have tested a single-walled transfer tube nozzle design (according to ISO8178) in parallel with a double walled transfer tube design. The objective of this study was to assess the effect of the thermoforetic deposition and/or condensation inside the ISO8178 dilution tunnel.

Methodology

Two equipment were designed according to ISO8178-1 (2006) for partial flow sampling. They were identical except for their transfer tube nozzle (see Figure 1). Measurements were performed at MAN Diesel & Turbo's test facilities in Copenhagen. Sampling were performed over periods of 10-15 minutes with a dilution ratio of around 15. Sampling and weighing of filters was performed according to ISO8178-1 (2006).

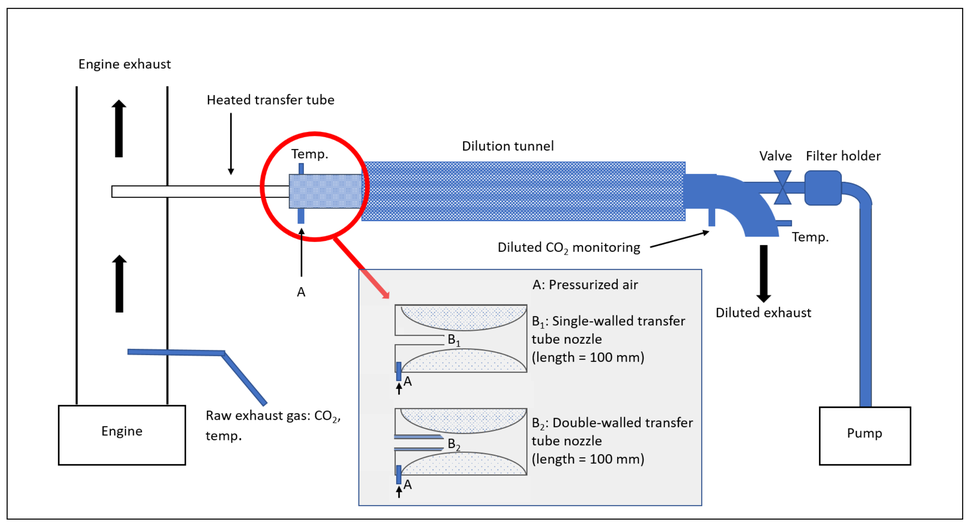

Figure 1. Sampling equipment for PM measurement with dilution tunnel designed according to ISO8178 (single walled nozzle), and modified with a nozzle having an insulated, double wall.

Results

For the measurements performed on HFO fuel, the PM results obtained with the single-walled transfer tube nozzle were 20% lower compared to the PM results obtained the double-walled transfer tube nozzle design. This is most probably caused by condensation of semivolatiles and/or an increased thermophoretic deposition of particulates in the single-walled tube nozzle inside the dilution tunnel. Pressurized dilution air is introduced into the venturi nozzle through "A" in figure 1, leading to a cooling of the single walled transfer tube. In the double walled transfer tube design, the transfer tube is insulated, and this will minimize thermoforetic deposition. With MGO (26 ppm S), the difference between the single-walled and double-walled transfer tube nozzle design were within the uncertainty of the measurement. With HFO (1.7 %S), about 20% particle mass is lost through condensation and/or thermophoretic deposition in the uninsulated, single walled transfer tube.

Figure 2. Measurement at MAN Diesel & Turbo's test engine with parallel sampling equipment.

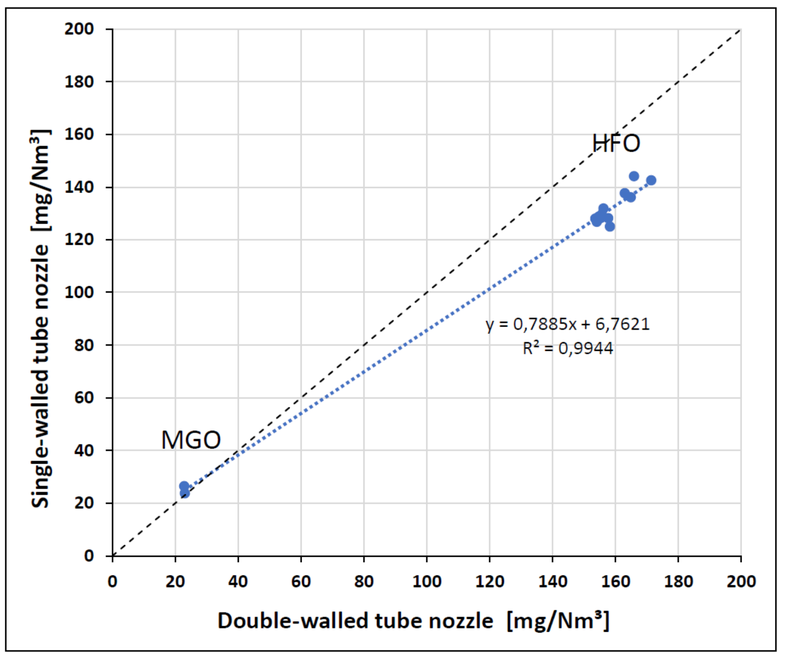

Figure 3. PM results obtained with equipment designed according to ISO8178 (single walled transfer tube) and with modified double walled transfer tube: Correlation plot showing results obtained with MGO fuel (26 ppm S) and with residual fuel (1.7 % S).

Conclusion

The measurement of PM as described in ISO8178-1 is only proven to be effective for combustion of fuels with a sulfur content less than 0.8% (ref.: ISO8178-1 (2006), section 3.1). However, the ISO8178 standard has been widely used for sulfur contents up to 3.5%. The results of this study clearly show that partial flow PM sampling according to ISO8178 should be equipped with a double walled transfer tube nozzle when measurement is performed on large diesel engines running on low grade, residual fuel with a high sulfur content.

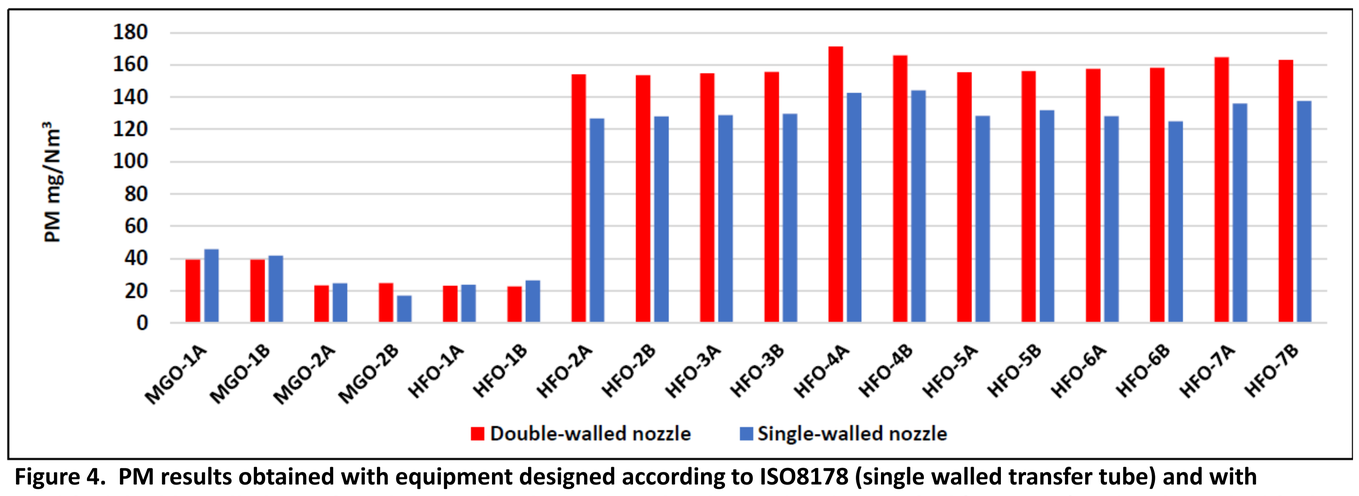

Figure 4. PM results obtained with equipment designed according to ISO8178 (single walled transfer tube) and with modified double walled transfer tube: Bar plot showing results obtained with MGO fuel (26 ppm S) and with residual fuel (1.7 % S).

Acknowledgement

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