Comparison of methods for measuring black carbon in medium speed diesel engine exhaust

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Black carbon (BC) is a by-product of anthropogenic (e.g. fossil fuel) and natural incomplete burning (wild fires). Being a strong absorber of solar radiation it is a key component in global warming, and due to its health effects, an important factor of air pollution. Diesel engines are one anthropogenic source of BC. E.g. the contribution of marine diesel engines on global BC emission and arctic ice retreat are being studied with theoretical models. However, there is a gap of knowledge between the parameters required by the models and the current measurement results of ship derived BC. A link between the climate model parameters and measurement methods commonly used in engine laboratories is needed.

Filter smoke number (FSN) is a common filter-based absorption method that detects the filter blackening caused by engine exhaust smoke. FSN requires substantial empirical corrections to derive BC mass (Northrop et al., 2011). Multi-angle absorption photometer (MAAP) is a filter-based instrument that measures the aerosol black carbon concentration at the wavelength of 670 nm. MAAP utilizes a combination of reflection and transmission measurements together with a radiative transfer model to yield the BC concentration (Petzold and Schönlinner 2004). The aim of this study was to compare the two filter-based methods in measuring black carbon concentration of diesel exhaust.

The measurements were performed in the emission laboratory of Wärtsilä Finland Oy in October 2011. The tested engine was a medium speed diesel engine and the used fuel was ultra-low sulphur diesel fuel. Eight engine load points were tested in two consecutive days. Each load point was tested for approximately 30 min. The data averaging time for the MAAP was 1 min and the flow rate was 10 lpm. A default absorption cross-section of 6.6 m^2 g^{-1} was used for the MAAP. The dilution ratio was in range 38–604. FSN was measured directly from the undiluted samples. In addition to BC, particle size distributions of diesel exhaust were measured with two scanning mobility particle sizers (SMPS), particle chemical composition with soot particle aerosol mass spectrometer (SP-AMS; http://www.aerodyne.com/products/soot-particle-aerosol-mass-spectrometer-sp-ams) and particle mass concentration with Tapered element oscillating microbalance (TEOM).

The measured BC concentration from the MAAP varied from 1 to 30 µg m^{-3} corresponding to the undiluted BC concentrations of 0.2–2.1 mg m^{-3}. BC from the MAAP and FSN correlated very well for the whole concentration range (Figure 1). On average the MAAP gave 27% lower values than the FSN. Black carbon constituted 43% of the particle mass measured by the TEOM on average, with the BC fraction ranging from 14 to 77% depending on the engine load. Organic compounds composed slightly lower fraction of the particle mass than BC; the mass percentage of organics was 33% on average. The rest of the particle mass either chemical components not measured by the AMS, or particles larger than ~1 µm in diameter that were included in the TEOM mass concentration but not in that of the AMS because of different cut-offs in AMS and TEOM sampling inlets.

The results obtained in this study indicated that the FSN method is comparable with the MAAP for measuring BC emission of medium speed diesel engine.

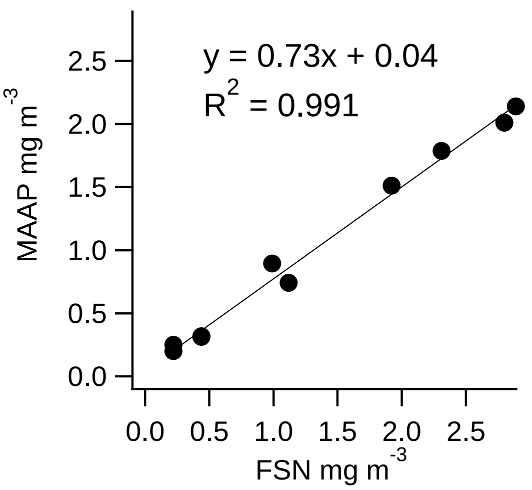

Figure 1. The comparison of black carbon concentrations measured by the MAAP and FSN.

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Northrop, W. F., Bohac, S. V., Chin, J.-Y. and Assanis, D. N. (2011) *J. Eng. Gas Turbines Power*, **133**, 102804-102806.

Petzold A. and Schönlinner M. (2004) *J. Aerosol Sci.* **35**, 421-441.