INVESTIGATION OF SIZE DISTRIBUTION AND SPECTRAL RESPONSES OF DIESEL ENGINE EMITTED CARBONACEOUS PARTICULATE USING MULTI WAVELENG PHOTOACOUSTIC SPECTROSCOPY (4λ-PAS) AND SINGLE MOBILITY PARTICLE SIZER (SMPS)

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Abstract
This work discuss some results of the extended measurement campaign focussing the in-situ microphysical characterisation of the emitted diesel particulates of different fuel types at diferent operational condition of diesel engine. For measureemnt of the spectral repsonses and the size distribution of the diesel emission customised multi wavelength photoacoustic spectrometer and single commercially single mobility particle sizer were uesd. Basee on the size distribution data we experimentally demonstarte that at idle the emitted aerosol assembly have bimodal distribution in all type of fuel and working point of engine. We also demonstarte that the spectral responses of the diesel aerosol is characterisits for the type of fuel and the operational condition of engine. Using posterior temperature treatement we manifest that especially at idle the volatile fraction of the emitted aerosol can dominantly removed above 150C temeperature. Finally, we also experimentalla demonstarted that the biodiesel content of the diesel fuel even in its relatively small blending even in a relatively small (<7%) mixing ratio can significantly modify the climate and health relevant microphysical feature of the diesel emission.

Introduction
Due to their adverse health and climate impact the diesel particulate matter (DPM) have been of great scientific concern today. The diesel emitted particulates are one of the dominant source of light absorbing carbonaceous particulate matter (LAC), which is the second most important climate relevant atmospheric constituent [1]. Through its small size with high number-concentration, high surface area per unit volume and adsorption ability to toxic substances DPM is one of the most harmful air pollutant too. Despites of its importance, both the climatic and the health effect of DPM is quiet uncertain. Therefore, the diesel engine emission is under prestigious scrutiny in versatile perspectives recently starting from further understanding the fundamentals and causality in scientific sides, through the better characterisation of DPM in methodological and instrumental side, ended by reduction of tailpipe emission in engineering side.

The diesel soot is a complete mixture of organic and inorganic carbonaceous composites which show high versatility in size, and in chemicophysical properties. Moreover, since, the particulate dispersed in air are continuously interact with its local ambient some ambient factors such as vapour-particle inter-conversion and photochemical activities can strongly modify the actual feature of the investigated particulates. Due to the dynamically changing vapour-particles ratio in the highly reactive and turbulent active zone of engine exhaust, the representative and reproductive sampling and the precise as well as accurate measurements of the emitted carbonaceous particulate assembly is one of the major challenges in this field presently

The new emission standards can be complied solely by modern diesel engines equipped with complicated after treatment system. However, further restriction in emission in this way it is limited by its durability and maintenance. One of the alternatives for further restriction of emission is the development of fuel.

In this study, some results of the extended measurement campaign focussing on the size distribution and spectral responses of diesel emission of different fuel and biofuel using customizes multi-wavelength photoacoustic spectrometer (4λ-PAS) and single mobility particle sizer are presented. We experimentally demonstrated that the size distribution of diesel engine is dynamically changed with engine operational parameters We also demonstrated that the absorption responses quantified by the AAE (Aerosol Angström Exponent) can also shows differences at different engine operational condition.

Experimental

During the measurements direct engine out emission of the test engine (four cylinder EURO 4 PC diesel engine, 2 litres turbo charged, common rail injection system) was measured directly after the turbocharger. The exhaust gas was sampled before the after treatment equipment (catalyst, DPF) meaning that we investigated the raw engine emission which describes the combustion process not considering the effectiveness of the exhaust gas after treatment system.

The engine was powered by commercial diesel fuels according to EN 590 standard in biofree version (B0) and with FAME (B7). The engine was operated at three carefully chosen conditions. Idle mode (820 rpm, 0 Nm torque) and medium and high engine loads (3000 rpm at 100 and 280 Nm torque, respectively). The optical absorption coefficient were measured with our self-developed multi-wavelength photoacoustic spectrometer (4λ-PAS) at 1064, 532, 355 and 266nm wavelengths [2].The absorption spectra were quantified by the AAE (the slope of the absorption spectra in log-log representation) value deduced from the measured absorption values. The number sizedistribution was determined by a Scanning Mobility Particle Sizer (SMPS equipped with a Vienna-type DMA+CPC, Grimm Aerosol Technik GmbH & CO., with a size range of 10,1-1093 nm). Butcher type low-flow thermodenuder units were applied for posterior temperature treatment of the exhaust particulates. The thermodenuder units were operated at three temperatures (40°C, 150°C and 300°C). The temperature aftertreatment units were stationed after the extended exhaust pipe of the engine (Fig.1)

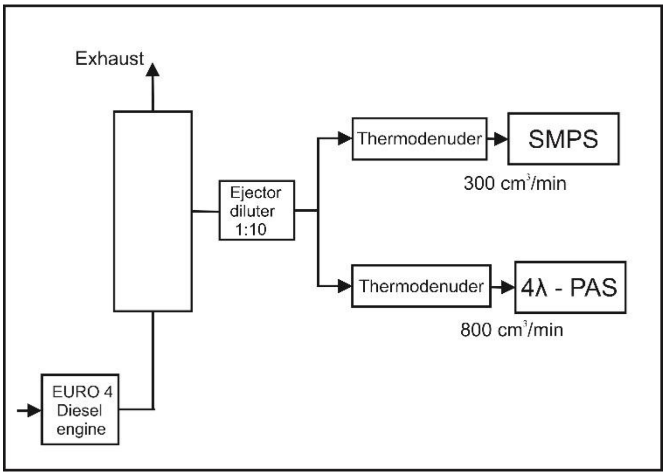

Fig.1: The schematic figure of the experimental set up including diesel engine, mixing chamber, dilution system, thermodenuders, multi wavelength photoacoustic instrument and single mobility particle sizer.

Results and discussion

The measured number size distribution data was analyzed using a simple lognormal multi peak fitting algorithm. The Based on the measured data we confirm experimentally that regardless of the operational conditions of the engines the emitted total number concentration of B7 is always higher than that of B0. We also demonstrated that at 0 torque the size distribution shows bimodal distribution in bot type of fuels, while at higher torque it shows a simple monodisperse size distribution (Fig.2).

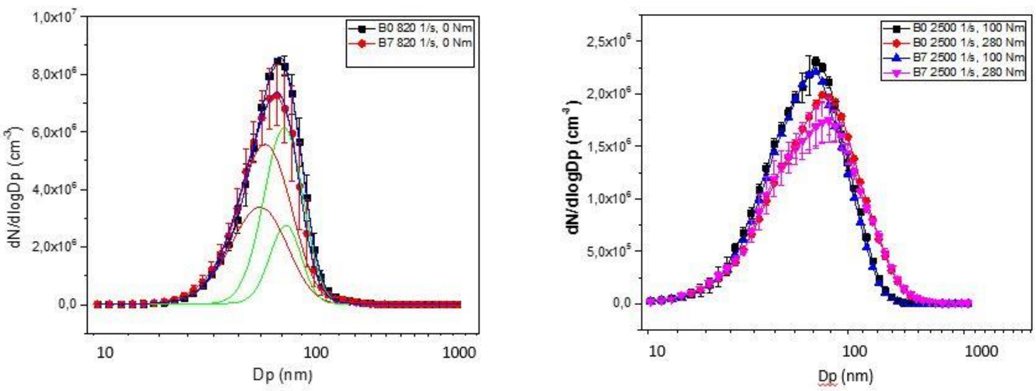

Figure 2. The number size distribution of diesel emission measured at idle (left) and at higher torques (right) at three different engine working point.

Moreover, transforming the number size distribution to volume size distribution the authors also realized that while the total number concentration is decreased towards the higher torques, the total volume concentration behaves reversely. It is a simple consequences about the increasing relative weight of bigger particulates in the spectrum towards the higher torques. The measured data also shown that increasing the temperature in posterior sample treatment procedure the count median diameter and the size concentration is become smaller simple because of the removal of the volatile pieces of the investigated particulate.

The AAE deduced from the measured optical absorption coefficients at the operational wavelengths of the photoacoustic instrument shows that increasing the torque of the engine resulted in decreasing AAE values regardless of the fuel type and temperature of the posterior sample treatment. The decreasing AAE value means that at higher torque the weight of the elemental or black carbon fraction increased in the organic and inorganic mixture of the emitted aerosol (Fig.3).

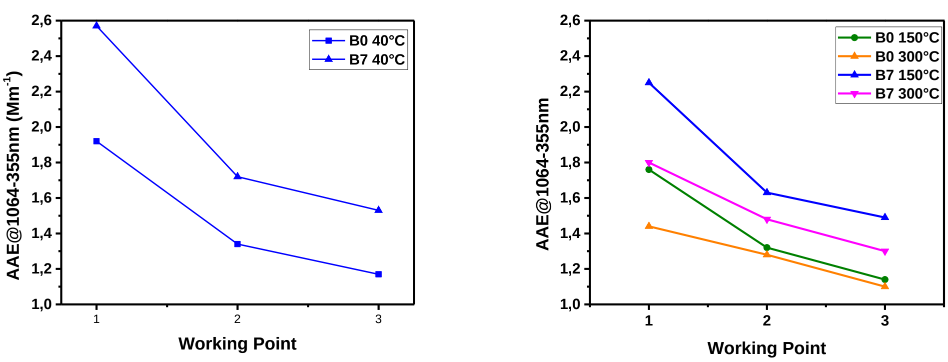

Fig.3. The AAE value of the emitted aerosol assembly measured at reference temperature (left) and higher temperatures (right) of B0 and B7 fuels at three different working points.

Another message of Fig.3 is that B7 fuel has always higher AAE value regardless of the operational condition of engine or temperature of the posterior treatments. This simple means that blending even small amount of biofuel to BO resulted in remarkable higher inorganic organic ratio of the emitted particulate. Finally, Fig.? also shows that at any working point of engine most of the volatile fraction of the particulate can only be removed at higher temperature (>150C).

Conclusion

This study discuss some results of the intensive measurement campaign focusing on the microphysical characterization of diesel emitted carbonaceous particulate matter using different type of fuel and operational condition of engine. We also demonstrate some results regarding the thermal evolution of emitted particulate using posterior sample treatment.

Through this study we experimentally demonstrated that multi wavelength photoacoustic responses can serve climatic and chemically relevant information. Combining the multi wavelength photoacoustic instruments with commercially used single mobility particle sizer opens up novel and powerful methodologies for in-situ characterization of diesel engine emission.

Acknowledgements

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