The impact of the dual-fuel ethanol-diesel combustion system on size, number, morphology, and chemical features of the emitted soot

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The need to reduce fossil fuel dependency and the stringent legislations on environmental and greenhouse gas emissions from diesel engines are the main drivers for researchers in the study of alternative combustion modes and non-conventional fuel sources.
In the field of second generation biofuels, ethanol is receiving considerable attention as a valid alternative to fossil oils in internal combustion engines thanks to its storage facility, availability and handling. The most common use of ethanol is for gasoline engine applications, but the interest in burning ethanol in diesel engine is increasing [1]. Like other oxygenated biofuels, ethanol can significantly contribute to the particulate emission reduction, thus appearing very interesting for soot critical conditions, like diesel engine high/full load operations [2,3]. Several methods and systems have been examined in order to evaluate the applicability of ethanol in compression ignition engines; these include dual fuel (DF) injection systems [2,4] and direct injection of alcohol-diesel fuel emulsions or blends. In DF configuration, the port fuel injection (PFI) of ethanol is coupled with the direct injection (DI) of the conventional diesel fuel [2]. Despite many advances the exploiting of the full potential of the DF approach, still requires research efforts.
This study aimed to characterize the impact of the dual-fuel ethanol-diesel combustion system on size, number, morphology, reactivity and chemical features of the emitted carbonaceous particles [5]. These aspects are relevant on the design and management of the engine-DPF system of a potential DF ethanol-diesel engine.
The tests were conducted on a single cylinder research engine provided with a modern architecture and properly modified in a DF configuration. The selected test points, critical in terms of soot emissions, were representative of the medium speed (2000 rpm) and medium/high load (7-12 bar IMEP) operating conditions and are significant in the typical operation area of the automotive diesel engines performing the New European Driving Cycle (NEDC). The operating points were performed using engine calibration parameters (injection, boost, swirl, etc.) and exhaust recirculation gases (EGR) values derived from the real Euro 5 compliant four-cylinder engine of equal unit displacement [5].
Besides the well-known effects of DF ethanol-diesel system on regulated engine raw pollutant emissions (HCs, CO, NOx and PM), ethanol fumigation is very effective also in the reduction of the number of the emitted particles. Moreover the oxygen increment at the exhaust using ethanol could have a beneficial impact on the DPF performances.
Overall, the chemico-physical characterization of soot particles clearly indicates that soot features, including the oxygen incorporation and morphology, slightly vary with the increasing amount of injected ethanol, even at high ethanol loading (Figure 1). The thermal stability of soot occurs in the range of 500-550 °C, as typically estimated for other diesel soot [6,7].

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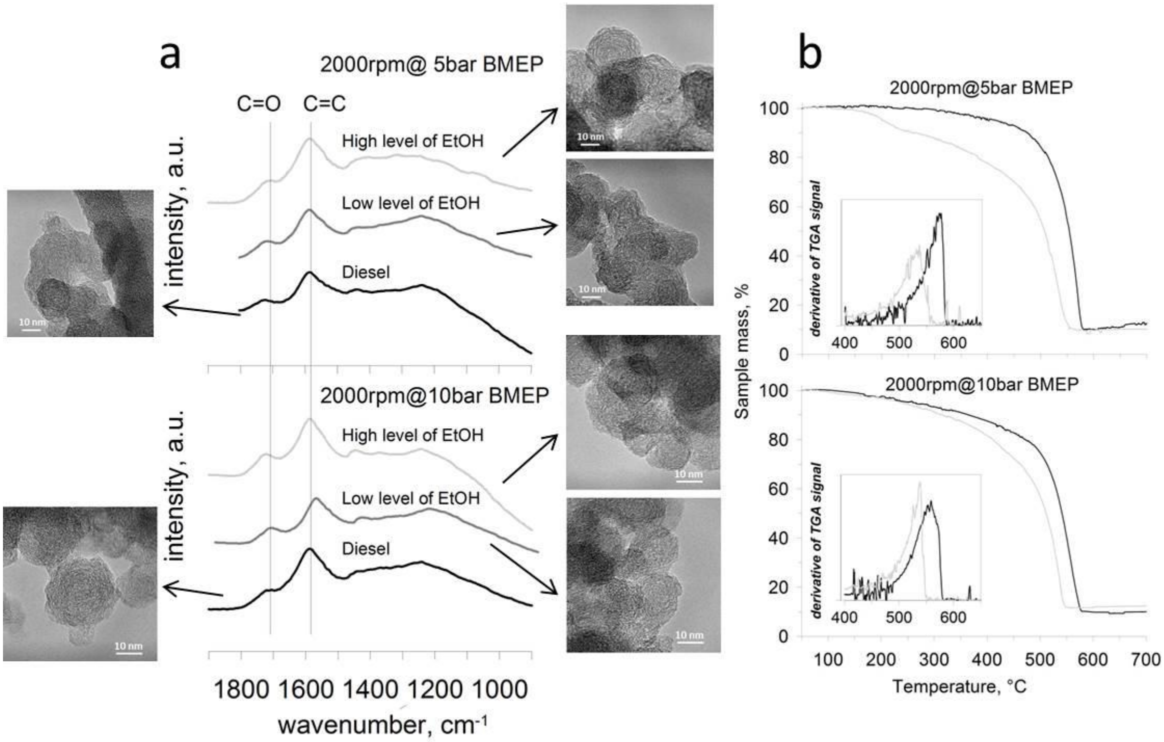

Figure 1. *a) ATR-IR spectra and HRTEM of diesel soot at different loads and ethanol level; b) TG plots in oxidative environment (air) and derivative (inset) of soot emitted at different loads and ethanol level.*

UV-Visible investigation indicates that diesel soot appears, in both the two operating conditions, as high-graphitized soot with a specific absorption (6-8 m^2/g in the UV and 3-4 m^2/g in the visible) comparable to those of carbons with a high graphitization degree and a good level of structuration (furnace carbon blacks, mature soot from benzene laminar flame [6]).

References

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