Physical and chemical characterization of the particles emitted by a DI SI engine with low- and zero-carbon fuels

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Because of its detrimental effects on human health and the environment, particulate matter (PM) released by internal combustion engines (ICEs) has long been a source of concern. Particle emissions can be greatly decreased by using low- or zero-carbon fuels like hydrogen. Because hydrogen lacks carbon in its structure, particle emissions from its combustion are frequently unexpected. The lube oil in this instance has a strategic impact on the formation of particles, as found in our previous papers [1,2]. In the current study, a comparison of particle and other hazardous pollutants emissions burning hydrogen and a carbon fuel like methane has been performed. The results on physical and chemical characterization of the emissions from the two different fuels were combined to enable a comprehensive investigation of the effects of lubricating oil.
A single-cylinder direct injection spark ignition engine running on hydrogen or methane was used for the experiments. Two operating conditions—2000 and 3000 rpm full load—were tested. An engine exhaust particle sizer connected to a single diluter was used to online characterize the number and size of particles. A condensation sampling line attached to the tailpipe collected the condensed exhaust and particles for off-line chemical characterization using various analytical techniques. Important information on the mechanisms underlying the emission of particles and highly hazardous PAHs was supplied by the spectroscopic and chemical analytical techniques. Soot particles were separated by the soluble organic fraction (SOF).
The amount of particles changes depending on fuel type and engine speed, indicating that the oil plays a different role depending on the environmental factors. Because of the increased temperatures in the combustion chamber that cause the oil film on the cylinder surfaces to burn or oxidize, particles grow as the engine speed and hydrogen fuel combination increases. However, the fuel has the main role. The particle concentration, in fact, increases with hydrogen because of the higher temperature reached in the combustion chamber.

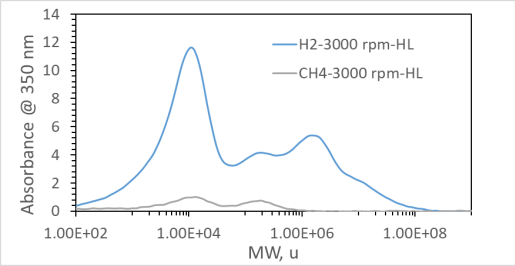

FIGURE 1. MW distribution profiles of the SOF samples from SEC with non-porous column of 3000 rpm samples

Figure 1 reports the molecular weight (MW) distribution assessed off-line on SOF using Size Exclusion Chromatography (SEC) for sample at 3000 rpm. When hydrogen is used as fuel instead of methane at 3000 rpm, there is a higher concentration of particles. Particles were not collected only at 2000 rpm with methane, but the soluble organic fraction's MW distribution indicates the presence of higher MW species at 3000 rpm and a lower concentration of PAH, indicating the role of high MW species in the soot inception.
This study demonstrated that using hydrogen as an ICE fuel can have a greater environmental impact than using a carbon fuel like methane. This highlights the need to optimize the combustion behaviour as well as the lubrication oil properties when the engine is fuelled with hydrogen.

[1] B. Apicella, F. Catapano, S. Di Iorio, A. Magno, C. Russo, P. Sementa, A. Tregrossi, B.M. Vaglieco, *Journal of Hydrogen Energy*, **2024**, *49*, 968–979.
[2] B. Apicella, F. Catapano, S. Di Iorio, A. Magno, C. Russo, P. Sementa, A. Tregrossi, B.M. Vaglieco, *Journal of Hydrogen Energy*, **2023**, *48*, 22277–22287.