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Investigating the impact of copper leaching on combustion characteristics and particulate emissions in HPCR diesel engines

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ABSTRACT

Copper leaching in diesel fuel and its impact on combustion and emission characteristics of a Direct Injection High Pressure Common Rail (DI HPCR) diesel engine was investigated. This work was performed using a single cylinder Ricardo Hydra research engine fitted with a cylinder head, piston assembly, and crankshaft from a production 2.2 L DI diesel engine. A fuel conditioning device consisting of a helicoidally shaped copper duct and electromagnetic coils powered from the battery was installed along the fuel line just before the high pressure pump. A diesel fuel with a copper content of less than 0.2 ppm was used. Inductively coupled plasma mass spectrometry (ICP-MS) analysis showed an increase of copper content to 1 ppm when fuel flowed through the conditioning device prior to the injection and returned from the engine back to the fuel tank. Copper leaching from the conditioning device was confirmed using a bespoke test rig. Combustion characteristics were analysed *via* post-processing pressure measurements, while an AVL Smoke Meter was used to monitor particulate emissions. A pilot plus main strategy was used to achieve a target Brake Mean Effect Pressure (BMEP) typical of medium load. Soot reduction in the range of 7–14% was measured when the device was connected to the fuel line, compared to the baseline. The initiation and early development of combustion was also investigated using an unstirred, quiescent combustion chamber with optical access. High-speed photography showed that ignition probability was enhanced in presence of the fuel conditioning device.

1. Introduction

Recent predictions of the demise of the automotive internal combustion engine (ICE) have been greatly exaggerated, as hybrids are a key part of the long-term transport plan. Mild hybrids with clean ICEs are forecast to be popular in small and medium sized cars, while heavier commuter and heavy-duty long haul vehicles will still be reliant on diesel [1]. Regulations will continue to restrict further the exhaust emissions, with particular attention paid to new pollutants and particulate emissions. It is likely that particulates will be limited using new number and size-based metrics with thresholds as low as 10 nm or less [2]. Greater emphasis will also be given to pollutant emissions studies based on real-driving conditions, in contrast to defined test procedures.

While engine calibration over the Worldwide harmonized Light vehicles Test Cycle (WLTC) allows for the limits to be met, real driving emission, cold start and performance subsistence over the entire vehicle life constitute a real challenge [3]. More recently, these challenges have also been faced by modern gasoline direct injection (GDI) engines [4,5]. Researchers' efforts have been focusing on reducing formation of particulate matter (PM) *via* improving combustion chamber design, fuel injection strategies, combustion modes, and the development of new fuels [6–8] to be employed in new engine designs. However, considerable numbers of older diesel vehicles, agricultural machinery, construction vehicles, and other off-road applications currently in use are well behind with regards to Euro standards compliance [9]. In these types of applications, meeting stringent emissions legislations requires the addition of new technology to the older systems, aimed at either prevention or reduction of the formation of particulate matter.

Particulate filters (PFs) are effective when employed to trap particulate matter in the exhaust gas stream, but their use comes at the cost of increased backpressure and consequent decreases in engine efficiency and fuel economy [4]. Additionally, PFs must occasionally be

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