EVALUATION OF THE IMPACT OF AN ACCELERATED ASH LOADING TECHNIQUE ON HEAVY DUTY ATS PERFORMANCE

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Highlights

- Accelerated ash loading of the DPF with oil doped fuel.
- Comparison of the artificial ash properties with ash from the field.
- Ash loading effect on overall system performance.

1. Introduction

Diesel particulate filters (DPFs) are increasingly employed in on- and off-road applications for reducing particle emissions to a level demanded by the tightening emission regulations worldwide. Besides soot particles, incombustible matter derived from the inorganic additives in oil are effectively trapped by DPFs as ash. Over the vehicle lifetime, ash accumulation and the consequent impact, namely, increased pressure drop due to flow restriction is a major concern since it is detrimental for the engine performance, fuel economy and may necessitate frequent filter service or worse, replacement [1,2]. Hence, understanding ash accumulation in the DPF as it occurs during real operation in the field is crucial for mitigating the above mentioned risks. However, in order to accumulate ash equivalent to full-useful-life (FUL) usage, significant time is needed. For this reason, several methods for accelerated ash loading of diesel particulate filter have been investigated in literature [3]. Ash generation with an engine-bench is widely implemented for accelerated ash loading investigations, this procedure may involve artificially spiking the ash-generating additives in oil or oil injection in inlet manifold or doping of fuel with oil. However, the representativeness of these methodologies in terms of good correlation to real field ageing is still a key issue. In this work, we employed the technique of doping the fuel with a fixed percentage of oil in order to achieve accelerated ash loading and oil poisoning of the aftertreatment system (ATS) components. Engine test bench approach was used in order to reduce the influencing variables on the ash formation. Two different FPT production engines- Cursor 11 and 13 fitted with full ATS were used to assess several important characteristics such as ash morphology and distribution in the filter, pressure-drop and ATS performance in correlation to field-aged components that have accumulated high mileages exceeding 400,000 km. A detailed post-mortem analysis (PMA) is ongoing to compare properties such as composition, packing density, porosity, particle size, etc. of the accelerated-loaded ash with the ash collected from the real field-aged sample.

2. Methods

The test engines were Cursor 11 and 13 with power ratings of 356 kW and 412 kW, respectively. Both the engines were equipped with Euro VI ATS constituting diesel oxidation catalyst (DOC), Diesel Particulate Filter (DPF), selective catalytic reduction catalyst (SCR) and ammonia slip clean-up catalyst (CUC). The oil was mixed with the fuel upstream of the engine and the oil/fuel mass ratio was adjusted to 0.4-0.6% in order to achieve an ash loading in the filter corresponding to FUL usage, limiting in the meantime the duration of oil-doped fuel exposure to 300 h. A special cycle conceived to achieve high ash amount loading was develop: it mainly consisted of (i) a low temperature soot+ash loading step, (ii) partial soot regeneration, followed by, (iii) high load step mimicking active regeneration. This cycle was repeated to total 300 h. Intermittent weighing of the DPF was performed to determine the ash load. The back pressure of the system was continuously monitored to trace its evolution as a function of ash collected in the DPF. Intermediate catalysts performance checks by legislative homologation cycle, namely WHTC (world harmonized transient cycle) and ammonia sweep experiments were performed to investigate the performance of the ATS in response to the ash loading and poisoning. Visual inspection with fiberscope was performed to assess the ash morphology and distribution in the DPF channels during the ashing process. Several PMA methods, namely ICP-OES, SEM, XRD, etc are ongoing to investigate the properties of the artificially loaded ash in relation to the field-ash.

3. Results and discussion

Accelerated ash loading by fuel doping with oil led to deposition of ash whose weight was well correlated to the theoretical ash content determined on the basis of fuel consumption. A steep increase of the pressure drop across the filter was observed during the (i) step of the cycle which was restored partially after the regeneration step (iii). Fiberscope investigations revealed fluffly ash particles present as larger-sized agglomerates in comparison to the ash from the field that was more densely packed. Moreover, the accelerated ash-loaded DPF exhibited a more uniform ash layer over the channel length leading into a smaller plug (~3 cm) at the end, while, the field-aged DPF consisted mainly of longer ash plugs (5-6 cm) at the rear end of the substrate with the majority of the channel length bearing very little ash deposit. ATS performance evaluation revealed that the DOC is largely unaffected by the accelerated exposure of additives from the oil, however, a slight drop of the DPF performance, in terms of NO oxidation to NO_2 was observed. This may be attributed to the partial clogging of the active washcoat area on the DPF. The 300 h of ashing did not affect the overall DeNOx performance of the ATS which indicated that the DPF is effective in capturing the poisons from the combusted oil, thus, preventing their entry into the downstream SCR component.

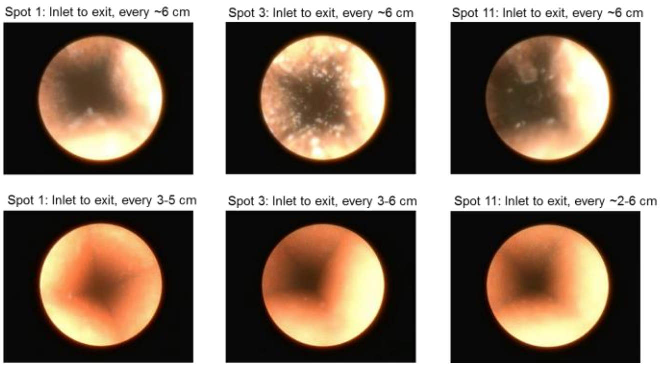

Figure 1. Fiberscope investigation of inlet DPF.

4. Conclusions

Accelerated ash accumulation tests utilizing fuel doping were conducted in order to understand and analyze the ash formation, comparison with the real field sample and eventual impact on catalytic performance of ATS. A special ashing cycle was developed to mimic ash distribution as it occurs in the field. The consequent impact on the pressure drop, ash properties and ATS performance were elucidated. First, it can be concluded that ash accumulation only slightly impacts on catalytic activity of DPF through a reduction of NO oxidation activity to NO_2. Ash accumulated during cycle with oil doped fuel were found different from real ash in compactness and distribution thus suggesting that more frequent high load operation may be necessary to harness the high mass flows and temperatures towards the formation of the compacted ash plugs that are characteristic of the field-aged DPFs.

References

[1] Dittler, A., SAE Technical Paper 2012-01-1732, 2012.
[2] Barris, M., Reinhart, S., and Wahlquist, F.. "The Influence of Lubricating Oil and Diesel Fuel on Ash Accumulation in an Exhaust Particulate Trap", SAE Technical Paper 910131, 1991.
[3] Sonntag, F. and Eilts, P., SAE Technical Paper 2016-01-0939, 2016.

Keywords

Artificial accelerated ash loading, fuel doping with oil, back pressure increase, oil poisoning