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Impact of Gasoline Performance Packages on Particulate Emissions in Direct Injection Spark Ignition Engine

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Direct injection spark ignition (DISI) engines deliver higher efficiency combined with lower fuel consumption and reduced CO_2 emissions than their port fuel injection (PFI) counterparts. As a result of this advantage, the DISI technology became very popular over the last two decades. However, deposits can potentially form in the injectors. In that case, the combustion efficiency of the affected DISI engines may deteriorate over time and this situation could result in higher emissions and fuel consumption as well as lower power output. The treatment of base fuel with gasoline performance packages (GPP) that contain a deposit control additive (DCA) helps improve this situation by either keeping the injectors clean or removing the formed deposits. A publication issued in 2021 claims that high GPP dosages lead to higher instantaneous particulate emissions than base fuel, suggesting a midrange optimal concentration. Since such high dosages are typical for certain branded premium fuels marketed in Europe and Asia, it became necessary to complement these investigations. This paper presents the results obtained in a programme aiming at evaluating the impact of GPP dosage on particulate emissions in a VW EA 111 engine.

The VW EA 111 engine (BLG type, 1.4 L, 125 KW, Euro 4) and the tentative CEC TDG F-113 procedure (test duration of 48 hours, steady state conditions) were used in this programme. The measurement of particulate emissions was carried out continuously during the operation of the engine by applying an APC^{plus} device from AVL. Two EN 228 compliant base fuels (E0 and E10) were used. Two types of GPP based on different DCA technologies were evaluated. The first one contains polyisobutene amine (PIBA), the second polyetheramine (PEA), both commercial products from BASF SE. The PIBA based formulation has a composition typical for a package widely used in the US market and was tested at dosages corresponding to LAC, TT, 3 times TT, 5 times TT and 7 times TT in both E0 and E10 fuels. The GPP with PEA was evaluated only in the E0 gasoline at dosages resulting in unwashed gum (UWG) levels equivalent to the PIBA based package used at 3 and 7 times TT (medium and high dosages). LAC is the lowest allowable concentration at which the GPP can be used in order to comply with US legislation. TT stands for the TOP TIER™ Detergent Gasoline initiative that promotes a higher cleanliness standard than required by US law. Two parameters were monitored during the operation of the engine: the injection time (TI) and the particle number emissions (PN). The extent of deposit formation was evaluated by capturing images of the injector tips with a scanning electron microscope at the end of the test.

A good repeatability of the measurement of both injector cleanliness and particulate emissions could be achieved with this test method based on the VW EA 111 engine. With regards to injector cleanliness, it appears that the E0 fuel was far more severe than the E10 gasoline, an observation that confirms past results. While an additivation with the PIBA based GPP at LAC level was not effective in fulfilling the tentative upper limit of 5 % injector fouling defined by the CEC test development group F-113, a TT dosage was borderline. Higher additivation dosages of 3 times TT and more led to an excellent prevention of deposit formation. Contrary to the findings published by a 3rd party, a negative instantaneous impact of GPP on particulate emissions could not be observed at the tested dosages. Surprisingly, LAC led to a higher increase of particulate emissions during the test than with base fuel, although the level of injector fouling was lower. High dosages in the range 3 to 7 times TT allowed to keep the emissions at the starting level as a consequence of the ability to avoid the formation of injector deposits. Although PEA was less efficient than PIBA, its use at a high dosage also enabled the avoidance of injector fouling and therefore ensured an excellent control of particulate emissions.

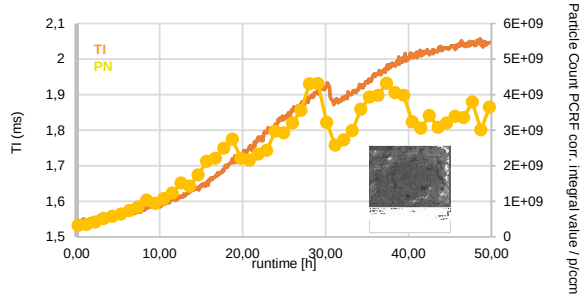

Fig. 1 Change of injection time (TI) and particulate emissions (PN) with unadditivated E0 fuel

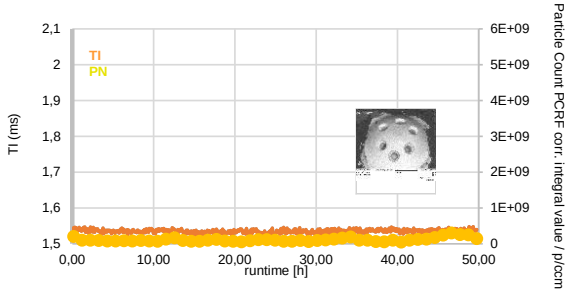

Fig. 2 Change of injection time (TI) and particulate emissions (PN) with additivated E0 fuel (7xTT)