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ENGINE CLEANLINESS IN E85 POWERED FLEX-FUEL VEHICLES

Abstract

E85 is viewed as a potential alternative fuel to decrease fossil CO_2 emissions and dependence on crude oil. As for their conventional counterparts, engines powering flex-fuel vehicles deliver optimal performance when the sensitive areas in the intake system are kept clean and free of deposits. Since no standard tests are available for evaluating the tendency of fuels to form intake valve deposits in FFV engines fuelled with E85, interested parties such as fuel marketers or additive suppliers have to run in-house tests. This work focuses on experiments performed in a bench engine and vehicles operated on the road. The results demonstrate that additives based on polyisobuteneamine or polyetheramine are suitable to control the formation of intake valve deposits in this kind of engines.

Key words: flex-fuel engines, valves, deposit control additives

1. Introduction

E85 (a mixture based on 85 % ethanol and 15 % hydrocarbons) is viewed as a potential alternative fuel to decrease fossil CO_2 emissions and dependence on crude oil. Flex-fuel vehicles (FFV) are designed to be powered with low ethanol content gasoline and E85 (potentially also E100). As for their conventional counterparts, FFV engines deliver optimal performance when the sensitive areas in the intake system are kept clean and free of deposits. Since no standard tests are available for evaluating the tendency of fuels to form intake valve deposits (IVD) in FFV engines fuelled with E85, interested parties such as fuel marketers or additive suppliers have to run in-house tests. Previous work carried out in US flex-fuel vehicles indicates that deposit control additives (DCA) based on polyisobuteneamine (PIBA) or polyetheramine (PEA) are fit for purpose to prevent the formation of IVD [(1)]. More recent investigations suggest that a conventional DCA is not suitable for this application [(2)]. This paper focuses on the use of both PIBA and PEA as a DCA to prevent the formation of deposits in the intake system of FFV engines. Tests have been performed in a bench engine and vehicles operated on the road.

2. Test procedure

2.1 Fuel and additives

The fuel used in the test was an E85 blended from an E10 (DIN 51626-1) and a technical grade denaturated ethanol. Two commercially available DCA packages from BASF were used in this study, one based on PIBA, the other based on PEA. The package based on PIBA was used at a dosage of 60 mg per kg E85. This dosage reflects the situation where the hydrocarbon portion is first treated with the PIBA based package at a dosage common for this application and then blended with the ethanol containing no DCA at all. The package based on PEA was used at a dosage of 180 mg per kg E85. This corresponds to a situation where there was no DCA treatment of the hydrocarbon portion prior to the blending with ethanol and a where the final E85 fuel is additivated on purpose.

2.2 Bench engine tests

The bench engine was a naturally aspirated 1.8 L Duratec flex-fuel engine from Ford used in a previous study [3]. The same test cycle over 60 hours and the same reference oil were used as specified in the MB M111 test procedure (CEC F-20-98).

2.3 Vehicle tests

Three Ford Focus Flexifuel vehicles (model year 2011) were used. All had the same equipment and showed 0 km on the tachometer before the start of the test (SOT). One car was fuelled with a base E85 containing no DCA package (car A), whereas the two other cars were run with the same E85 treated with a DCA package (PIBA based package in car B and PEA based package in car C). The test was conducted over 20,000 km with the three cars. The driving cycle consisted in a combination of urban driving, country road and highway, the focus being on urban driving. To age the three cars in a similar way, the drivers changed the car every day and the lead car was changed from round to round. Both test distance and speed profile of each car were controlled via GPS sensors to achieve the same ageing.

Upon completion of the 20,000 km accumulation part, car A underwent twice an additional one-tank clean-up with the E85 fuel additivated with the PEA based package used in car C, however at a dosage of 1,000 mg/kg.

3. Test results and discussion

3.1 Bench engine tests

The system consisting of this bench engine, the selected base E85 and the CEC F20-98 test cycle turned out to be pretty mild since the fuel without DCA generated IVD of only 88 mg/V average (Table 1). On the other hand it showed a good response to both DCA packages. Even at a very low dosage of 60 mg/kg the PIBA based package could halve the quantity of IVD without impacting heavily the amount of combustion chamber deposits (TCD). The PEA based package used at 180 mg/kg performed even better with IVD of 25 mg/V and TCD at the same level as for the unadditivated fuel.

Table 1: IVD and TCD obtained in the bench engine tests

	IVD (mg/V)	TCD (mg/Cyl.)
E85 w/o DCA	**88**	**324**
E85 + PIBA based DCA	**46**	**415**
E85 + PEA based DCA	**25**	**331**

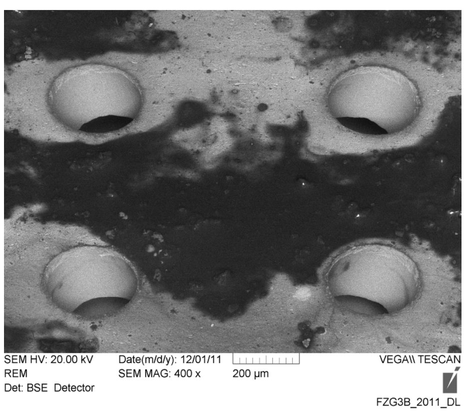
3.2 Vehicle tests

All three vehicles did not experience any problem in terms of drivability over the whole 20,000 km. While the car run with unadditivated fuel (car A) showed severe deposit formation (Table 2), the IVD control in both cars run with the additivated fuels was extremely good and in the same magnitude as in the bench engine: 55 mg/V for the PIBA based package in car B, 22 mg/V for the PEA based package in car C.

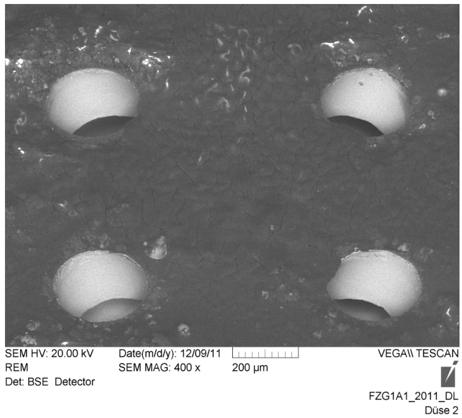
Table 2: IVD obtained in the vehicle tests

	IVD (mg/V)
E85 w/o DCA	**229**
E85 + PIBA based DCA	**55**
E85 + PEA based DCA	**22**

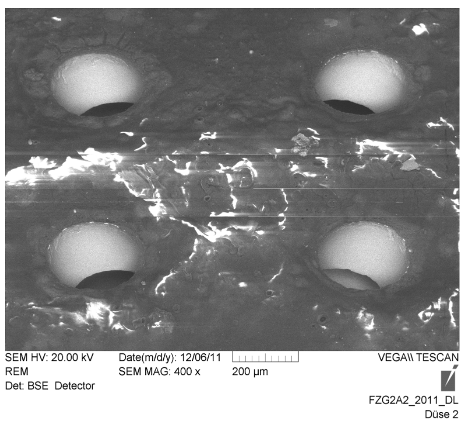
The appearance of the injector tips after 20,000 km was also examined with a scanning electron microscope (Figure 1). The result was that no deposits could be observed in the upper part of the injector orifices, neither for the vehicle run with unadditivated E85, nor for the two vehicles operated with additivated fuels. This absence of deposits in the injector orifices is the main explanation why no drivability issues were faced during the accumulation phase over 20,000 km.



E85 w/o DCA



E85 + PIBA based DCA



E85 + PEA based DCA

Figure 1: Appearance of the injector orifices after 20,000 km

Following the assessment of the IVD level obtained after the 20,000 km trial, the valves of car A were re-assembled in the engine and the vehicle underwent two subsequent “one-tank clean-up” (OTCU) treatments. The fuel used for this task was E85 additivated with the same PEA based package as in the keep-clean run in car C. The treat rate was 1,000 mg/kg, which represents a typical dosage for this kind of application. The reason why the PEA based package was chosen for this exercise instead of the PIBA based package is because of the better miscibility of PEA in E85 at high concentrations above 500 mg/kg. Although the distance travelled to empty the tank was only around 500 km, it was sufficient to reduce the IVD from 229 mg/V at the start of the test (SOT) to 60 mg/V at the end of the first OTCU, hence leading to an excellent IVD clean-up of 74 % (Table 3). The valves were then re-built into the vehicle prior to starting the second OTCU, which was performed under the same conditions as the first one. This additional cleaning step resulted in IVD of 26 mg/V, which translates into a CU of 89 % based on the deposits present after the 20,000 km accumulation test.

Table 3: IVD “one-tank clean-up” treatments in car A with the PEA based package

IVD start of test (mg/V)	229
IVD end of test OTCU #1 (mg/V)	60
OTCU #1 based on start of test (%)	**74**
IVD end of test OTCU #2 (mg/V)	26
OTCU #2 based on start of test (%)	**89**

4. Conclusion

Following conclusions can be drawn from this study:

● No drivability issues could be reported from a 20,000 km durability test in the field with flex-fuel vehicles run with E85.

● PIBA and PEA are very effective additives to control intake valve deposit formation in flex-fuel engines.

● A similar level of intake valve deposit control could be achieved in both a bench engine operated over 60 hours and vehicles run over 20,000 km on the road.

● A substantial clean-up of dirty intake valves could be achieved with a high dosage of a PEA based DCA package in only one tankful.

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ČISTOĆA MOTORA KOD "FLEX-FUEL" VOZILA POGONJENIH GORIVOM E85

Sažetak

E85 se smatra mogućim alternativnim gorivom radi smanjenja emisije CO_2 iz fosilnih goriva, kao i smanjenja ovisnosti o sirovoj nafti. Kao i kod konvencionalnih vozila, motori "flex-fuel" vozila (FFV) ostvaruju optimalan učinak kada se osjetljiva područja u usisnom sustavu održavaju čistima i bez taloga. Budući da nema razvijenih standardnih testova za ocjenjivanje sklonosti goriva prema stvaranju taloga u usisnim ventilima u FFV motorima pogonjenih E85 gorivom, zainteresirane strane, kao što su trgovci gorivima ili proizvođači aditiva, moraju raditi interna (ne)standardizirana ispitivanja.

Ovaj rad se temelji na pokusima provedenim na ispitnom motoru i vozilima na cesti. Rezultati pokazuju da su aditivi na osnovi poliizobutenamina ili polieteramina prikladni za kontrolu stvaranja taloga na usisnim ventilima za ovu vrstu motora.

Ključne riječi: "flex-fuel" motori, ventili, aditivi za kontrolu nastajanja taloga

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