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DI Engines as Flexible-Fuel Solution for the Brazil Market – Potentials and Challenges

The Brazil market has seen a steep increase in the production and sales of flexible-fuel vehicles since the introduction of the first model in 2003 as depicted in Fig. 1. Customers require the flexibility to fuel their vehicles based on economic considerations of the price difference between Gasohol (E20-E25) and E100. This difference varies significantly throughout the year depending on the harvest seasons of sugar cane which is used to produce ethanol.

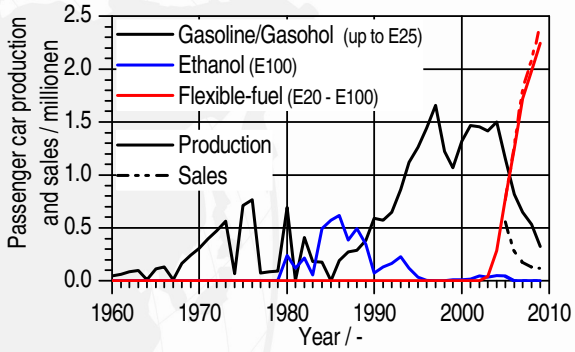

Fig. 1: Passenger car production and sales in Brazil

Main challenges and changes of ethanol fueled vehicles are:

- Cold start down to - 10 °C and cold drivability
- Fuel composition detection between E20 and E100
- Adaptation of hardware to 40 % increased fuel flow
- Optimized valve seat rings, spark plugs, plastic and rubber components
- Increased mechanical stress due to higher cylinder peak pressures and/or BMEP due to high RON of E100
- Oil dilution and sudden vaporization of fuel in oil
- Possible increased HC-emissions

So far only PFI flexible-fuel engines are offered in Brazil. However, development is progressing towards the market introduction of DI technology offering new potentials..

The biggest challenges can be attributed to the mixture formation and combustion of ethanol due to the critical combination of low vapour pressure, high enthalpy of vaporization and low stoichiometric air requirement. The hydrous E100 fuel in Brazil with a water content of 7 % makes startability even more difficult. With temperature records in Brazil as low as - 5 °C the customer expectations with regard to the start duration is different than for the European market where startability down to - 30 °C is required. Measures already used or in development to improve startability, driveability and emissions at low temperatures in PFI engines in Brazil are:

- Gasoline sub tank
- Fuel pre-heating in fuel rail
- Fuel pre-heating at injector tip (under development)

For DI engines injection strategy and the capability of stratification to a certain extend offer additional degrees of freedom allowing the injection phasing and strategy to be optimized in order to enable the formation of an ignitable mixture and achieve startability. Fig. 2 depicts the result of an E100 cold start calibration for - 10 °C developed for FEV's SGT engine with central injector, resulting in acceptable start durations below 2.5 s without any additional cold start device.

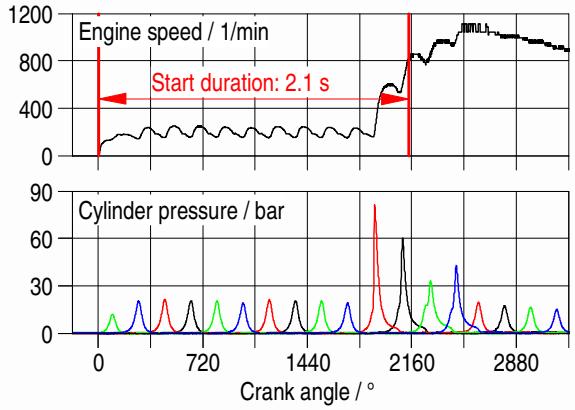

Fig. 2: E100 cold start calibration of FEV SGT engine for - 10 °C ambient temperature

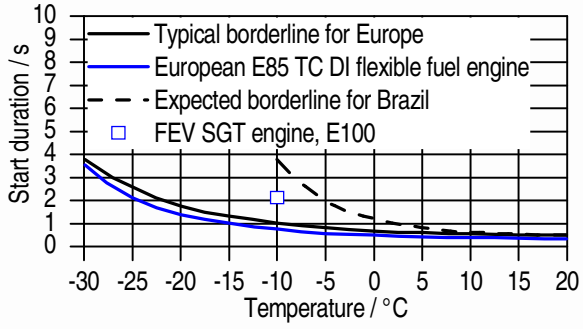

Fig. 3: Starting times for cold start

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E100 usage in turbocharged direct injection engines with sufficient peak pressure capability enables significant efficiency improvements at high engine loads. The high knock resistance and enthalpy of vaporization of E100 allow an optimal combustion phasing and reduced enrichment demand as shown in Fig. 4.

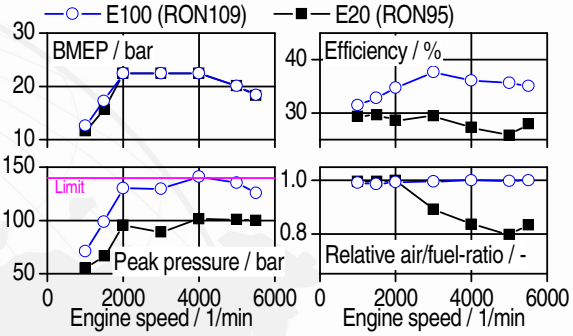

Fig. 4: Full load of FEV SGT engine with E100 and E20

Depending on the combustion system and calibration the usage of high ethanol content fuel can lead to a broad spectrum of resulting oil dilution. Within various engine concepts FEV has measured oil dilution levels ranging from low oil dilution comparable to gasoline fuel up to a three times increased dilution. A higher dilution with water, caused by the increased water content of the exhaust gases has to be handled in every case. Ethanol will also degas significantly faster from the lube oil once the oil reaches the boiling temperature of ethanol at 78 °C. This requires additional ECU functionalities to prevent engine stall by enrichment and a careful layout of the blow-by system in order to ensure a sufficient equal distribution of the blow-by gas over all cylinders and to avoid icing.

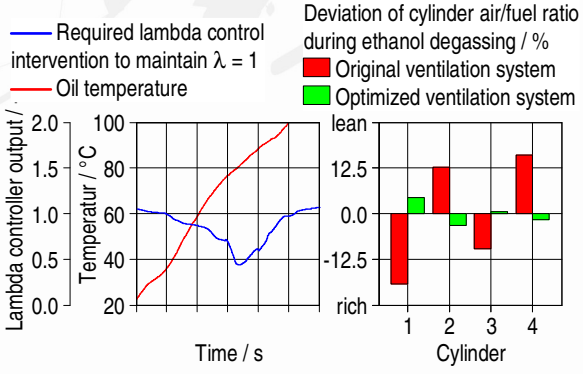

Fig. 5: Degassing of ethanol from lube oil during engine warm-up after repeated cold starts and blow-by system optimization

Fig. 5 shows an example of the required enleanment during E100 degassing from the oil and results of a blow-by system redesign intended to improve the blow-by gas distribution.

For 2014 new vehicle models for Brazil have to be certified according to the Proconve L6 emission standard which has tightened limits for CO and NO_X emissions. This emission limit can be met by good engine calibration especially for DI engines without any cold start assistant devices.

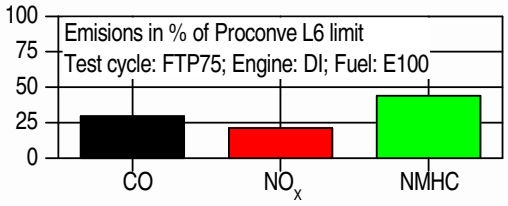

Fig. 6: Emissions of the SGT DI engine in the FTP75 test cycle using E100

E22, the other available fuel in Brazil, can also pose significant challenges. Abnormal combustion phenomena can emerge using this fuel with a RON of just 93 despite the high ethanol content. Furthermore severe fouling problems can occur using the un-additived E22 in PFI engines. The impact on DI engines is still under investigation.

DI engines as flexible-fuel solution for Brazil

- Startability down to -10°C without cold start devices possible for good DI combustion systems
- Careful layout of crankcase ventilation system required
- Brazil emission limit can be met
- Increased full load performance especially on TC engines with E100
- Know-how in E100 and flex-fuel engine layout, software requirements, calibration, fouling cycle development and testing available at FEV

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