FEV EDE –
An approach to meet future CO₂-emission limits

Starting with the CO₂-emission limit of 130 g/km in 2012 a further limitation of currently 95 g/km has been planned for 2020 by the European Community. Since stratified lean burn engines, fully variable valve train and downsizing concepts are available on the market, there is a competition regarding the best solution for a SI powertrain which can meet this limit. Balancing the pros and cons of the different concepts, downsizing and boosting seem to be the most promising way.

The maximum downsizing potential is given by the combination of boosting and direct injection. However, also the part load efficiency needs to be further optimized – even with small displacement combustion engines and the resulting shift of operation point.

The new FEV EDE – Extreme Downsized Engine – is a turbocharged two-valve SOHC three-cylinder SI engine with 698 cm³ displacement and which is based on the ‘Smart Brabus’ engine. The original twin spark ignition is replaced by a single spark plug on the exhaust side with a high energy spark coil. The position of the replaced spark plug on the intake side is used as location for the direct injection. The spray pattern layout was done in accordance to FEV’s injector layout tool chain, which combines an early base geometry layout with the FEV-ILT (Injector Lay out & Targeting) tool towards reduced wall wetting and the FEV CMD process (Charge Motion Design). The specification of the fuel system is:

- Homogenous $\lambda = 1.0$ concept
- Multihole injector with solenoid actuation
- Asymmetric spray pattern with five spray cones
- Single piston high pressure fuel pump (200 bar)
- HP pump driven by additional cam on camshaft
- Cylinder head adaptation for different injector suppliers possible

The main focus for injector layout in small DISI engines is to prevent wall wetting ensuring low content of fuel in oil. With 66.5 mm, the bore diameter of the FEV EDE is smaller than all competitor engines currently in the market. The oil dilution measurement according to FEV’s standard procedure shows excellent results with an oil dilution in the lower range of current mass production engines with central mounted / piezo actuated injector.

![Oil Dilution Graph](image)
The following picture shows the integration of the injector and spark plug in the cylinder head.

In a second step the engine is adapted for a MAHLE CamInCam® camshaft. This system enables fully independent phasing of intake and exhaust cams on a SOHC valve train. The actuation is realized by a Hydraulik-Ring Dual-Stacked Vanecam® System. The phasing angle of the intake cam is 50 °CA and 40 °CA for the exhaust side.

This additional degree of freedom in valve timing is used for positive intake air scavenging during the valve overlap at full load operation and low engine speeds. A maximum increase in valve overlap of approximately 65 °CA is used compared to fixed valve timing of the base engine.

The higher exhaust gas mass flow through the turbine results in a significantly higher turbine speed and simultaneously higher boost pressure. An improvement of low end torque up to 50 % at 2000 rpm can be achieved with the same turbocharger – without a drawback on the specific power output of more than 100 kW/l.

The cooling effect of direct injection is combined with lower residual gas fraction due to scavenging of cooled charge air. The benefit of improved knock resistance can be used for an increased compression ratio.

The fuel efficiency at part load can be further improved using higher residual gas fraction – individual for each operation point. The adaptation of valve timing reduces the specific fuel consumption in the part load area which represents the NEDC driving cycle.

Additionally the combustion stability during idle operation can be improved by further reduction of valve overlap compared to the base engine with fixed valve timing.

Variable valve timing combined with split injection close to the spark timing enables further potential for low-emission cold start and catalyst heat-up strategies. The exhaust gas temperature upstream catalyst can be increased by more than 200 °C, resulting in higher heat flow combined with lower raw emission of unburned hydro carbons.

The scavenging effect resulting in higher low end torque contributes additional CO₂-emission reduction by 5 % in the NEDC with adapted gear ratios.

The FEV EDE engine concept can be matched to the specific Japanese regulations of K-Cars – by slight reduction of engine stroke – as well as a part of a hybrid powertrain. In such a configuration the engine can be used in vehicles up to the inertia weight class 1250 kg and can achieve a CO₂-emission lower than 100 g/km in the NEDC simultaneously with a good drivability.

The attraction of this small, powerful and efficient DISI engine will gain the development trend of downsizing and boosting to new limits in engine displacement.

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Status: 01.04.2010