TEC INFO

FEV GmbH
Neuenhofstraße 181
52078 Aachen · Germany

Phone +49 241 5689-0
Fax +49 241 5689-119
marketing@fev.com
www.fev.com

VCR
Variable Compression Ratio (fully variable)

Variable compression ratio is the key to realize a higher degree of downsizing by turbo-charging. The variability allows high compression ratios in part load with improved efficiency and low compression ratios at high loads avoiding knocking and high peak pressures. Starting from a naturally aspirated 4-Cyl.-1.6 l (56 kW/l) engine the CO_2 reduction potential by downsizing to a direct injected 3-Cyl.-1.0l engine (90 kW/l) with turbocharger, variable cam phasing (intake and exhaust) and cooled exhaust manifold is approximately 12 %. Variable compression ratio in combination with continuously variable valve lift can improve CO_2 emission in the NEDC cycle by additional 9 %, resulting in a total CO_2 reduction of 20 % compared to the base engine. Ethanol E85 fuel is especially adequate for downsizing in combination with high compression ratios due to its higher octane number of approx. 110 RON and a strong cooling effect through three times higher vaporization energy. The conversion to E85 improves the medium part and high load and thus achieves a better fuel consumption in emission test relevant area and in practical driving. A further 2.5 % CO_2 saving is possible by the conversion of the engine to Flex Fuel E85 with adapted compression ratios.

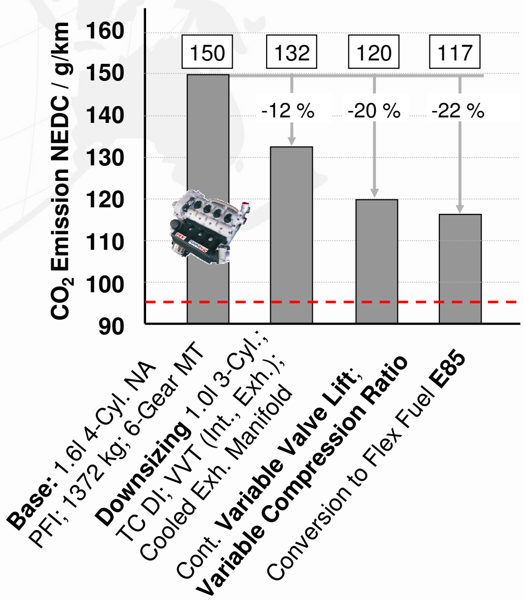

Fig. 1: Example scenario of CO_2 saving potential of VCR in combination with downsizing

For the realization of a fully variable compression ratio, FEV has developed a system fitted with an eccentrically supported crankshaft, the so called "crankshaft shift" system. Standard main bearing shells are mounted in eccentrics. To achieve the required alignment of the bearing tunnel these eccentrics are connected to become a torsionally rigid unit which can be rotated in the crankcase main tunnel. With respect to low manufacturing costs a welded design made out of sheet metal is a favourable solution for mass production. Due to the steel eccentrics the undesired thermally induced increase in main bearing clearance can be avoided. Thus, by comparison with a crankshaft bearing of an aluminium crankcase, the oil flow rate at the main bearing is reduced. The additional leakage at the oil delivery point from the crankcase to the eccentrics can be kept very low through the use of suitable sealing elements, which, in sum, results in a reduced oil flow rate in the area of the crankshaft bearing. In addition, the formation of an oil film between the eccentrics and the bearing tunnel has the positive side effect of a (partial) decoupling from structure-borne noise. This kind of eccentric crankshaft suspension can be applied to all kind of crankcase design approaches such as deep skirt with individual MB caps, short skirt with bedplate, ladder frame designs etc.

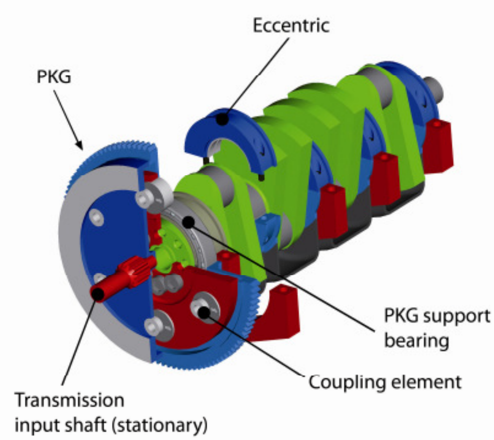

Fig. 2: Design of the VCR system

In order to bridge the shaft offset between the crankshaft and the stationary transmission input shaft, a variety of approaches are available. In terms of robustness, installation space requirements and cost efficiency, a so-called "Parallelkurbelgetriebe" (PKG) offers a well balanced solution. The PKG consists on two discs while one of these discs is

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bolted to the crankshaft flange and the other disc is stationary suspended and is aligned to the transmission input shaft by means of a support bearing. The torque transmission from the moved to the stationary disc is realized by multiple coupling elements (eccentrics) equally spaced on a circle. One of the main development goals is to reduce the frictional losses induced by the PKG and to achieve durability targets at the same time. By means of intensive component testing, it was possible to identify the major sources of friction losses, and an optimization of the PKG with regard to friction behaviour was successfully performed.

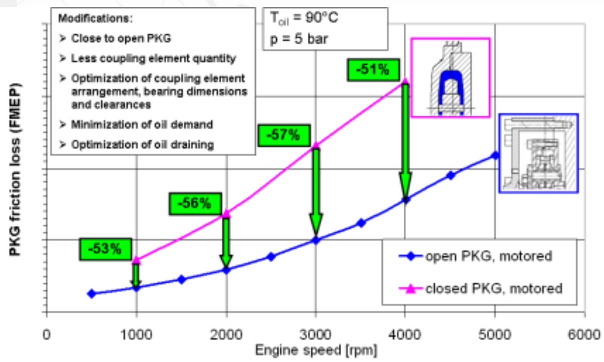

Fig. 3: Progress in PKG friction reduction

As a result the thermodynamic savings are reduced by only 1 % (example upper class vehicle in the NEDC) due to the remaining PKG friction. By means of a 500 h durability run under full load condition the robustness of the latest friction optimized PKG design was confirmed successfully w/o facing any abnormal wear or fatigue problems.

To realize a power take-off for the timing drive, the oil pump, the accessory drive and eventually a mass balance drive FEV has developed a variety of solutions such as a small PKG at the front end, a combined power take-off with the main PKG or a variable chain drive which is capable to handle a moving crankshaft position. The right concept depends on the given or intended engine architecture with its individual needs and constraints to be considered.

For the actuation also different layouts were investigated. While in early prototype stages a support of the eccentric moment was realized by a pinion shaft being engaged with each eccentric, latest designs consist on a worm gear stage which is engaged only at one cylinder. Due to the self locking character of the worm gear stage no electric energy is needed to keep the position. The generation of the required actuation torque is realized by an electric DC-Motor with a reduction gear set.

FEV has applied this VCR system to many different engine architectures of its customers within the last years. All the individual design solutions were confirmed by intensive CAE and testing activities. As a result this VCR system has reached a high level of maturity up to now and can be considered as a reliable basis for a series application.

Contact: Dr.-Ing. Karsten Wittek
FEV GmbH
Neuenhofstraße 181
52078 Aachen, Germany
Phone: +49 241 5689-9984
Fax: +49 241 5689-9950
I-Fax: +49 241 5689-7-9984
E-Mail: wittek@fev.com
Internet: http://www.fev.com

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