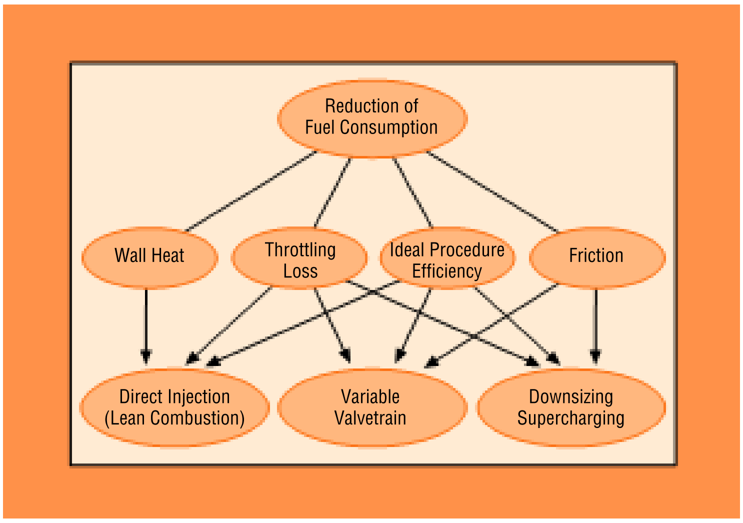
Acoustic Behavior of New Gasoline Engine Concepts

New technologies, such as direct injection and mechanical fully variable valvetrains are state-of-the-art in gasoline engines. Additional concepts currently under development include the use of variable compression, high-pressure supercharging and electro-mechanical valvetrains. The paramount goal of all these new developments is a reduction in fuel consumption.

One of the papers FEV will introduce at the 25. Vienna Motor Symposium 2004 details how these new concepts affect noise excitation. In addition, it evaluates the concepts, with vehicle interior noise being the main criterion. Measures that can be taken to optimize these designs are also discussed.

Customer expectations regarding passenger cars mainly concern performance, fuel consumption, purchase price and noise. Depending on the vehicle classification, the individual criterion needs to be weighted differently. Moreover, reducing fuel consumption is currently the main development target, due to the need to compensate for the fuel consumption disadvantage gasoline engines have, compared to diesel engines. A second requirement is to improve fleet fuel consumption.

Gasoline Engine Concepts for the Reduction of Fuel Consumption



Gasoline engine concepts that can be utilized for the reduction of fuel consumption are illustrated in Figure 1. Direct injection with lean combustion causes minimal wall heat losses. Partial and fully variable valvetrains reduce pumping losses through dethrottling. Freely selectable timing helps to optimize the efficiency of the procedure. Turbocharging or mechanical supercharging an engine, when combined with variable compression or high-speed design for downsizing reduces pumping losses and engine friction.

The potential to reduce fuel consumption is about 20%. However, disadvantages may exist in the form of higher production costs as well as increased HC and CO emissions. Noise and vibration issues need to be considered as well, especially with regard to interior noise. This includes combustion excitation (e.g. controlled self-ignition), actuators and pressure wave clearance at the orifices (e.g. if a fully variable valvetrain is used) as well as vibrations (e.g. cylinder deactivation).

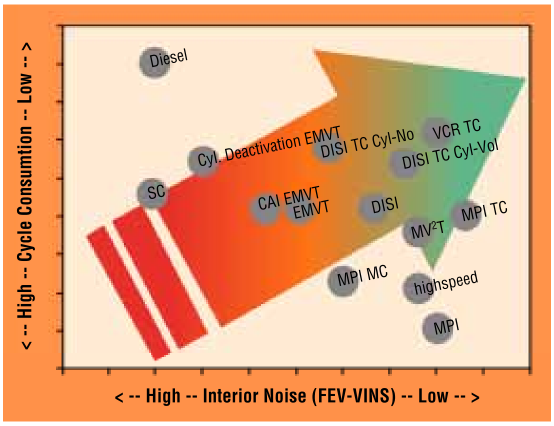
FEV has developed a simulation method called FEV VINS (Vehicle Interior Noise Simulation), to evaluate the impacts on interior noise and vibration behavior. The evaluation is based on data obtained by predictions using FEV's CSL (Combustion Sound Level) method as well as noise measurements on the engine test bench. The following concepts have been examined:

Conventional Gasoline Engine (Multi-Point Injection)	(MPI)
Direct Injection Spark Ignition (DISI)	
Direct Injection with Turbocharging (Downsizing Cylinder Number)	(DISI TC Cyl. No.)
Direct Injection with Turbocharging (Downsizing Cylinder Volume)	(DISI TC Cyl. Vol.)
Mechanical Fully Variable Valvetrain	(MV^2T)
Turbo (Turbocharged)	(MPI TC)
Mechanical Roots Supercharger	(MPI MC)
Turbo with Mechanical Supplementary Charging (Roots Supercharger)	(SC)
Electro-Mechanical Valvetrain (Intake Side)	(EMVT)
Electro-Mechanical Valvetrain with Cylinder Deactivation	(Cyl. Deactivation EMVT)
Controlled Auto-Ignition with EMVT	(CAI EMVT)
Variable Compression Ratio with Turbocharging	(VCR TC)
High-Speed Engine	(Highspeed)

Criteria considered in the evaluation are interior noise, fuel consumption and cost. The target value is situated in the upper right corner of Figure 2. The corner points that show a positive score mark the conventional gasoline engine (excellent interior noise) and the diesel engine (low consumption).

Engines that use electro-mechanical valvetrains with cylinder deactivation as well as high-speed mechanical engines with additional charging have a less than favorable acoustic behavior. Variable compression, when combined with turbocharging, appears to be a good compromise. Downsizing the engine with a smaller cylinder volume results in good acoustic behavior and decreasing the number of cylinders reduces fuel consumption.

Noise/Cycle Consumption



Based on an evaluation of interior noise levels and production costs, conventional gasoline engines are most efficient. Modern diesel engines with common rail injection are the most expensive. All gasoline engine concepts prove to be less cost intensive.

An evaluation of the different gasoline engine concepts does not produce a clear winner. Variable compression or electro-mechanical fully variable valvetrains as well as certain direct injection concepts are relatively expensive. However, they offer a high potential for fuel consumption reduction. Variable compression turbocharged engines as well as direct injection turbocharged engines with reduced cylinder volume result in good acoustic behavior with low fuel consumption.

Engines that utilize the gasoline pumping loss and combustion procedure concepts that have been described are bound to appear on the market in the near future. Depending on the manufacturer and the line of production, the engine's cost, fuel consumption and acoustic behavior aspects need to be weighted differently.

Our attempt at evaluating cost, fuel consumption and noise and vibration behavior of new gasoline engines concepts is based on a quick review of several, specific examples. A more thorough evaluation of each concept may produce considerably better or worse results.

We hope that this article will encourage further in-depth discussions and we would be pleased to hear your opinion on this matter.

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Truck Engine Design

Yuchai F-6113 Engine Upgrade with a New Cylinder Liner Concept for HD Diesel Engines

The Yuchai F-6113 is an inline 6-cylinder heavy-duty diesel engine and is mainly utilized for truck applications. The engine has a displacement of 8.4 L and a rated power of 258 kW. It was derived from the F-6108 model that has a displacement of 7.3 L. The engine was designed and developed in a joint effort by YMC (Yuchai Machinery Co., China) and FEV. The concept design and layout, using various simulation tools, was performed by FEV. YMC was responsible for the detail design. YMC and FEV agreed to divide work regarding procurement, prototyping and testing.

The YMC F-6113 with UPS

A major target was to carry over as many features as possible from the F6108, in order to minimize the investment required for production facilities. The existing machining line for the crankcase defined the bore spacing for the new engine.

The new design features electronically controlled unit injection pumps. The pumps are mounted in a separate housing, with the potential alternative of using an inline injection pump. The two 2-valve cylinder heads, covering three (3) cylinders each, were replaced by a 4-valve one-piece cylinder head. The engine structure was laid out based on the high specific output and the peak cylinder pressure requirements for compliance with Euro III standards. The engine was placed among the top performers of state-of-the-art European and North American truck engines, with a specific power of 30.6 kW/L and a maximum BMEP of 20.9 bar.