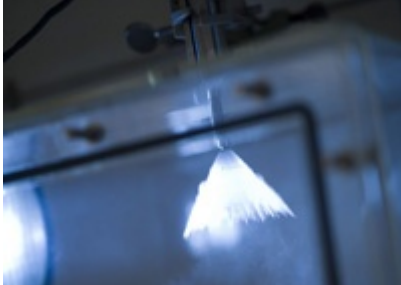


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Piezo-actuators in fuel injection systems

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Prize-winning piezo

From as early as the beginning of the 1980s, Bosch and Siemens have been pursuing research into the applications of piezo-technology. This program has led to considerably more than 100 patents. But only now has this decade-long development work come to the attention of a broader public. Federal President Horst Köhler awarded the German Future Prize 2005 to researchers Friedrich Boecking of Robert Bosch, Dr. Klaus Egger of Siemens VDO Automotive and Prof. Hans Meixner from the Corporate Technology department of Siemens for a project entitled Piezo injectors: A

new technology for clean and low-consumption diesel and gasoline engines. The award carries a prize of €250,000; this was the first time that researchers and developers from two competing companies have been honored as a team.



Winners of the German Future Prize 2005: Dr. Klaus Egger, Siemens VDO Automotive, Friedrich Boecking, Robert Bosch GmbH, and Prof. Hans Meixner, Siemens AG Corporate Technology

Reduced fuel consumption

The core of the prizewinning injectors are piezo-actuators from EPCOS. "In the meantime many automobile manufacturers and suppliers worldwide use this technology," explains Prof. Hans Meixner. So far EPCOS is the only manufacturer who can produce piezo-actuators in volume quantities. The greatest advantage of these components: they allow the fuel consumption of diesel and gas engines to be reduced by up to 15 percent.

Modern diesel engines operate on the principle of direct fuel injection. This technology is now being used increasingly in gas engines too. A fuel injection system consists – in simplified form – of a pump that brings the fuel up to a high pressure level of up to 2000 bar and a nozzle that injects finely dosed quantities of fuel into the engine cylinder with the aid of a valve. "The higher the pressure and the more accurate the dosing and time of injection the more efficient and less polluting the combustion. So the injection nozzle has a crucial impact on engine quality," explains Bosch's R&D

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man, Friedrich Boecking.

Optimized injection system

Two injection variants are dominant today: common rail and pump injectors. In the first of these, the fuel is fed by a separate pump to the injection nozzles via a common rail and injected via a valve. In the second variant, the injection pump and nozzle are integrated in a single module. The camshaft of the engine drives the pump cylinder of the injection element via a roller rocker arm. A needle in the valve doses the injected quantity. The valve needles in both systems are activated by either electromagnetic or piezoelectric means.

Siemens VDO and Volkswagen have already developed a pump injector system with an injection pressure of more than 2000 bar for ultra-clean combustion. But as the injection pressure increases, the diesel engine tends to become louder (knocking). This can be avoided by piezo-actuators. The engine is then not only quieter but also more economical. For this purpose, the injection pressure during idling is reduced by hydraulic support of the valve spring to below 200 bar, thus reducing the knocking. Another drill-hole between fuel feed and spring chamber makes this possible. The fuel, that flows in at high pressure in any case, strengthens the spring force.

“As the valve is actuated more quickly with piezo-actuators, very precise intervals are possible between pre- and main injection, which significantly reduces the emissions. Developments so far mean that peak pressures of up to 2500 bar can certainly be implemented,” observes Dr. Klaus Egger, management board member of Siemens VDO Automotive.

“The basis for the success of piezo-technology was the reduction of the required drive voltage to a range of below 200 volts,” adds Dr. Reinhard Gabl, Head of Piezo-Technology Product Development at EPCOS. This can be done because the piezo-actuator – like a ceramic multilayer capacitor – is built up of many individual ceramic and electrode layers. A modern actuator for diesel injection consists of around 350 active piezo layers. At a length of 30 millimeters, it can produce a stroke of 40 micrometers. Forces of up to 2500 N are then released. “That is sufficient to open the valve needle against a future pressure of up to 2000 bar,” he continues. It should be added that whereas the stroke was fixed in the previous electromagnetic injection systems, piezo-actuators allow it to be varied by the magnitude of the applied voltage.

Second generation of direct gasoline injection

The gas engine still also has great potential for fuel savings. BMW already presented a jet-controlled direct piezo-injector in its X3 Efficient Dynamics concept study at IAA 2005. This technology promises fuel consumption savings of around 20% compared with conventional gasoline engines with injection via intake manifolds, depending on the car and driving style. The new generation of piezo injectors also has fuel consumption advantages over the latest generation of solenoid injection systems, according to Siemens VDO.

The jet injector no longer needs a controlled flow in the combustion chamber to mix the fuel and air. They are mixed directly by a tapered injection jet in the combustion chamber. The piezo-injector is positioned centrally between the valves and the centrally placed spark plug. Piezo technology enables a stable combustion process in lean stratified injection operation, an extended operational state of the motor that enables the greatest fuel savings.



THE PATH TO CLEANER MOTORS

The reduction of fuel consumption and thus of emissions is a major goal of the automobile industry. This can be realized over the short term by further optimization of internal combustion engines (diesel and gas) as well as in conjunction with electrical drives (hybrid vehicles). In contrast, surveys by the Association of the German Automobile Industry (VDA) suggest that fuels from regenerative sources with a superior CO₂ balance will not gain importance until after about 2010.

Diesel engines have a higher efficiency than gas engines and use fuel up to 30 percent more efficiently. That is a convincing argument for increasing numbers of car buyers. A survey by the European Association of Automobile Manufacturers (ACEA) showed that 50% of all new vehicles purchased were powered by diesel. The future Euro 5 standard will also mean a further reduction of the NO_x (nitrogen oxide) limits after the year 2010. The 250 mg/km limit set by Euro 4 has already been reached by internal improvements to the engine. As no exhaust post-treatment for further NO_x reduction is currently at the series stage, internal engine solutions will be at the forefront for the foreseeable future.

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FUEL INJECTION WITH PIEZO INJECTORS



Cutaway injector which is driven by a piezo actuator (left). Shown on the right is the piezo stack with copper contacts from EPCOS.

Author:

Achim Scharf, freelance technology writer