

Milestones in Common Rail Development

In 1997, Bosch launched the first diesel engine to use Common Rail technology. Ever since, the company has produced more than 50 million of these systems. And technologically speaking, today's Common Rail generation has come a long way from the first one.



Common Rail systems with piezo injectors and CP 4 high-pressure pumps are already available in series with a maximum injection pressure of 2,000 bar.

The basic idea behind the injection system that keeps the diesel running in the truest sense of the word is from none other than the father of the diesel engine himself – Rudolf Diesel – who described the principle in one of his books in 1912. It was as brilliant as it was simple: Generating pressure by continuously supplying diesel fuel by means of a rail system. In other words, here was a system that used high pressure to pump fuel to all cylinders. Be that as it may, it remained largely dormant until rediscovered by the Fiat Group in the early 1990s. Applying it to an initial prototype, however, involved major problems dealing with issues such as tolerance and durability. In 1993, Bosch acquired all relevant patents, refining the Common Rail system until it was ready for its market launch in late 1997.

It was then that this accumulator fuel-injection system really began to

bloom. In 2001 alone, no less than three million of these Bosch systems saw mass production. By 2002, Bosch produced a total of ten million Common Rail systems, delivering its 50-millionth system in 2008.

The Beginnings

The first Common Rail generation permitted a maximum injection pressure of 1,350 bar during its mass production use. Pressure comes from a high-pressure pump with three radial pistons arranged in a star-like position – the so-called CP1. A high-pressure control valve serves to monitor its continuous supply of maximum fuel. Individual high-pressure pumps of the CP1 series prevent excessive return heating by deactivating a certain pump element during low supply levels.

Control of the first-generation Common Rail (CRI 1) injectors comes from solenoid valves. This happens

by controlling the injection process increasing or decreasing pressure inside the valve control chamber. The valve control plunger then transfers the resulting hydraulic power to the injector nozzle, which then opens or closes in dependence thereof.

More Pressure

In 2001, Bosch launched its second Common Rail generation in series, characterising it by raising maximum injection pressure to 1,600 bar. That year also saw the introduction of a more advanced design of its high-pressure pump – the CP3. This pump works on the principle of suction-based fuel-delivery control using a metering unit. It involves a stage-independent solenoid valve, which is mounted within the supply line of the pump elements and which regulates the amount of fuel to be compressed as needed. Compressing only the amount of fuel actually needed

Solenoid valve injectors (left) yield top injection performance. Piezo injectors set the standard in sophisticated applications.



significantly increases the efficiency ratio of the overall system. This, however, does not necessarily render the rail system's pressure-control valve obsolete. It retains its function of rapidly decreasing pressure during load changes, for example. The pressure-control valve also maintains its function of controlling pressure during cold-running phases (just like in the first generation) in order to accelerate the fuel-heating process. Some second-generation applications also use not only the CP3 but also the CP1H. The latter stands out from the CP1 through its increased pressure as well as through the metering unit added by the CP3. Diverse detail improvements have

also been made to the injector solenoid valves of the second Common Rail generation (CRI 2). Among others, they are now leaner and faster, allowing as many as five individual injections for each combustion process.

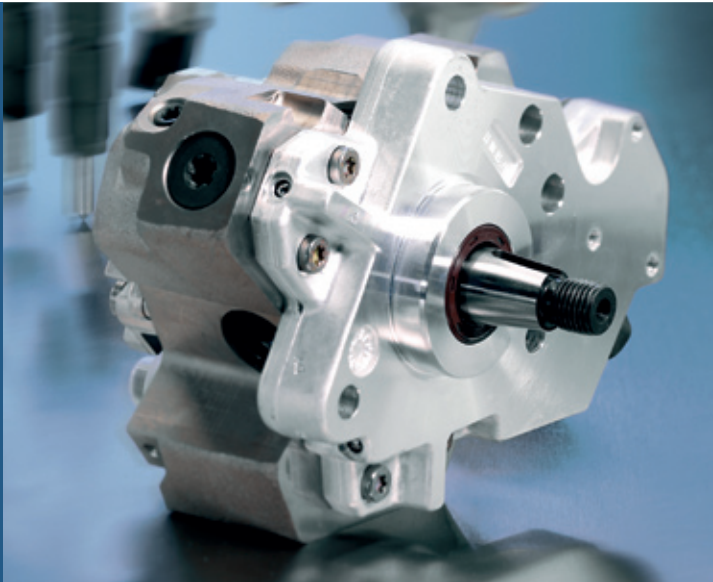
Shifting Gears Faster

In 2003, Bosch readied its third Common Rail generation for mass production. In doing so, Bosch engineers made a quantum leap in diesel injection technology. While leaving the fuel system itself unchanged for the most part, they managed to boost the initial injection pressure of 1,600 bar by adding a CP3 high-pressure pump and subsequently a CP 4

high-pressure pump. Designed as a radial-piston pump, the CP4 is leaner, simpler and more cost-efficient than the CP3, allowing pressures of 1,600 to more than 2,000 bar depending on the individual version (CP4.1 with one piston or CP 4.2 with two pistons). 2007 marked the series production of the first third-generation Common Rail system with a maximum injection pressure of 2,000 bar. The most important innovation for the third Common Rail generation was the piezo inline injector (CRI 3). Its advantages included reduced friction, instant reaction of the nozzle needle to activation of the actuator and increased shifting speed that resulted in shorter intervals between

The accumulator fuel-injection system "Common Rail", meanwhile, has evolved as the standard amongst diesel systems. Photos: Bosch





The CP 3 high-pressure pump works on the principle of suction-based fuel-delivery control using a metering unit.

two injection processes. The use of fewer mechanical components cut the amount of mass to be moved from 16 to 4 g. All this, along with a shift time of less than 0.1 ms, makes the piezo injector twice as fast as solenoid valve injectors. The new innovation also slashed the injector return by half, which served to reduce the power demand of the high-pressure pump by half, benefitting the overall efficiency ratio of the system.

Comeback of the Solenoid Valve Injector

Just a few years ago, Common Rail injectors appeared to herald the end of the solenoid valve. Piezo injectors just seemed better at everything: They were leaner, faster and capable of handling higher pressure. However, piezo injectors have one significant factor going against them. Compared to their solenoid valve siblings, they're relatively expensive. As a

result, increasing cost pressure from the automotive industry led Bosch to re-evaluate the use of solenoid valves in controlling Common Rail injectors. So Bosch commissioned its diesel engineers to design a solenoid valve injector whose injection performance would be on a par with of piezo injectors while costing less at the same time. The solution they came up with was the so-called pressure-compensated flow control valve. Compared to current ball valves, it boasts a larger opening cross-section independent of rail pressure with vastly reduced valve lift. It also comes with a solenoid armature consisting of a single component and a slotted control spindle. This solution would not have been possible without the cutting-edge production methods employed at Bosch's production site in Bamberg, Germany. Under its designation CRI2.2-M2, the first pressure-compensating solenoid valve injector

made its mass-production debut in late 2008 with a maximum injection pressure of 1,600 bar. Hence the decisive comeback of the solenoid valve injector. Meanwhile, its development continues as Bosch launches mass production of its CRI 2.5 this year. This is a pressure-compensating solenoid valve injector designed for a maximum injection pressure of up to 1,800 bar. For 2011, Bosch is planning mass production of its CRI 2.6, designed for system pressures of up to 2,000 bar. All the advantages of the new solenoid valve injectors notwithstanding, piezo injectors will continue to play their parts too – especially in large and extremely powerful engines. Development continues in this case too. The upcoming generation of piezo injectors (CRI 5) will be capable of handling a maximum injection pressure of up to 2,200 bar.