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Bosch technology delivers dynamism and efficiency **Bosch gasoline direct injection reduces fuel consumption by up to 15 percent, enhances driving enjoyment, and is becoming standard worldwide**

March 2014

PI 8512 GS FF/af

- ▶ Direct injection is revolutionizing gasoline engines in the same way it transformed diesel engines a few years ago
- ▶ By 2016, it will feature in some 50 percent of all new gasoline engines in Europe
- ▶ “Gasoline direct injection and electrification complement each other perfectly”

With its common-rail technology, Bosch has already revolutionized one type of internal-combustion engine by means of direct injection. In the space of a decade, this technology became the undisputed standard for diesel engines. Today, it features in some 80 percent of new diesel vehicles worldwide. A similar transformation is currently taking place in connection with the downsizing trend for the gasoline engine. With Bosch gasoline direct injection, drivers benefit from higher torque at low speeds and therefore enhanced driving enjoyment. At the same time, the system reduces fuel consumption by up to 15 percent. “Gasoline direct injection is now heralding the same kind of revolution that we previously saw in diesel engines,” says Dr. Rolf Bulander, the member of the board of management of Robert Bosch GmbH responsible for powertrain technology. In Europe, the technology is already on the way to becoming standard, and Bosch components can be found in sporty compact cars, touring sedans, SUVs, and sports cars.

[Video](#)
[Gasoline direct injection](#)

Starting in 1951, Gutbrod was the first automaker to use Bosch gasoline direct injection in selected models of its Superior subcompact car. From 1954, Bosch made this technology available for large-scale series production in the Mercedes-Benz SL 300, the legendary “Gullwing.” The basic technical principle has remained the same over the years: the injectors

spray the fuel straight into the combustion chamber in such a finely atomized state that it is immediately combustible. The fact that the fuel vaporizes permits greater compression, because the combustion chamber is additionally cooled. Although the new combustion method saved a lot of fuel, it took a long time before the technology gained widespread acceptance. Over decades, the company further developed gasoline direct injection with innovations such as laser drilling for the injection holes, which enables particularly exact mixture formation and clean combustion. This innovation earned Bosch, Trumpf, and the University of Jena the German Future Prize in 2013.

Excellent sales in Europe today – with the U.S. and China soon to follow

At the start of the new millennium, tough emissions standards in Europe brought gasoline direct injection to the mass market. This pattern is repeating itself, because vehicles will be allowed to emit on average only 95 grams of CO₂ per kilometer by 2021. As a result, approximately half of new European vehicles with gasoline engines will have direct injection by as soon as 2016. “We are currently doing excellent business in Europe with gasoline direct injection. But in a few years, there will be lots of action in the U.S. and China too,” Bulander says. In these markets, the innovative injection systems are still largely restricted to imported vehicles. However, with automakers in China and the U.S. facing tough new emissions legislation in the future, they will increasingly adopt the new technology.

This will boost the fuel economy of U.S. pick-up trucks, European sedans, and medium-sized Asian cars in equal measure, saving motorists money at the pump. In addition, the economical systems make a valuable contribution to the environment. This effect is already measurable in Europe, the cradle of and lead market for the innovative technology. In 2013, some 40 percent of all new cars on the continent were equipped with gasoline direct injection. Bosch experts estimate that these new vehicles save a total of around 1.2 million metric tons of CO₂ a year, because they consume less fuel. “With innovative technology, Bosch is making powertrain systems energy-efficient, reducing emissions, and slashing the costs for every kilometer driven,” Bulander explains.

Ideal basis for electrifying the gasoline engine

Yet the potential of gasoline direct injection does not end with making internal-combustion engines more efficient: it is also the ideal basis for electrifying gasoline engines. Its optimum design for downsizing allows for compact engines with few cylinders, which can be supplemented by electrical components. In such cases, a highly efficient IC engine forms the

core of the powertrain and can be supported by electrical components during its less efficient running phases or even switched off altogether – such as in plug-in hybrids, which can drive up to 60 kilometers powered by electricity alone. “Gasoline direct injection and electrification complement each other perfectly,” Bulander says. Big reductions in CO₂ emissions can be achieved by a combination of electrical components and direct injection.

Bosch’s boost recuperation system is a good example of how this works. The 48-volt hybrid goes perfectly with downsized engines. A particularly strong generator supports the engine at low speeds or during acceleration by working as a motor. This electrification measure alone can reduce fuel consumption by up to 15 percent. In real driving conditions with the coasting function that shuts off the engine, additional reductions of 10 percent are possible. That makes for total fuel savings of up to twenty-five percent. The system can thus help to meet strict emissions standards in the compact class.

More information
[Boost Recuperation System](#)

For larger vehicle classes, a plug-in hybrid with gasoline direct injection can help achieve these targets. Here, greater electrification combined with more efficient direct injection results in a greater potential for savings than the boost recuperation system. The following rough calculation shows the advantage for drivers with an annual mileage of 15,000 kilometers: a person who commutes 20 kilometers to and from work every day in pure electric mode would end up driving about 10,000 kilometers a year – or two-thirds of their annual mileage – without using gasoline. For the remaining 5,000 kilometers, they would profit from the efficient gasoline direct injection. In total, the fuel savings enabled by the plug-in hybrid’s electrical components and gasoline direct injection would exceed 70 percent.

Press photos: 1-GS-19999, 1-GS-20000, 1-GS-20001, 1-GS-20002, 2-GS-12399, 1-UBK-19634

Additional links

Online dossier on gasoline direct injection

<http://bit.ly/1m3NM5W>

Online dossier on German Future Prize 2013

<http://bit.ly/1iJ4UxF>

Online dossier on Boost Recuperation System

<http://bit.ly/1ilpRf8>

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Automotive Technology is the largest Bosch Group business sector. According to preliminary figures, its 2013 sales came to 30.7 billion euros, or 66 percent of total group sales. This makes the Bosch Group one of the leading automotive suppliers (note: due to a change in the legal rules governing consolidation, the 2013 figures can only be compared to a limited extent with the 2012 figures). Automotive Technology largely operates in the following areas: injection technology for internal-combustion engines, alternative powertrain concepts, efficient and networked powertrain peripherals, systems for active and passive driving safety, assistance and comfort functions, technology for user-friendly infotainment as well as car-to-car and Car2X communication, and concepts, technology, and service for the automotive aftermarket. Bosch has been responsible for important automotive innovations, such as electronic engine management, the ESP® anti-skid system, and common-rail diesel technology.

The Bosch Group is a leading global supplier of technology and services. According to preliminary figures, its roughly 281,000 associates generated sales of 46.4 billion euros in 2013 (Note: due to a change in the legal rules governing consolidation, the 2013 figures can only be compared to a limited extent with the 2012 figures). Its operations are divided into four business sectors: Automotive Technology, Industrial Technology, Consumer Goods, and Energy and Building Technology. The Bosch Group comprises Robert Bosch GmbH and its more than 360 subsidiaries and regional companies in some 50 countries. If its sales and service partners are included, then Bosch is represented in roughly 150 countries. This worldwide development, manufacturing, and sales network is the foundation for further growth. In 2013, Bosch applied for some 5,000 patents worldwide. The Bosch Group's products and services are designed to fascinate, and to improve the quality of life by providing solutions which are both innovative and beneficial. In this way, the company offers technology worldwide that is "Invented for life."

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8 questions, 8 answers from the Bosch CEO

Dr. Volkmar Denner

December 4, 2013:

PI 8321 RB Rs/Na

“Manufacturing technology is a driver of product innovation”

Ultrashort laser pulses as a prime example

- ▶ Long tradition at Bosch
- ▶ Extreme precision, mass production
- ▶ Connectivity is growing in importance

1. How important is manufacturing technology for Bosch?

Denner: “Manufacturing technology is one of Bosch’s main strengths. It puts us in a position to manufacture machinery, production lines, and products that we cannot procure ourselves in the market. Especially when it comes to premium products, this allows us to achieve USPs in terms of cost, function, and quality. To name just one of many examples, we use ultrashort laser pulses in the manufacture of the valves for our gasoline direct injection systems. Or again, there is the process we use to manufacture micromechanical sensors, which are the ‘sensory organs’ of today’s automotive and consumer electronics. Using a process developed in-house, now known as the ‘Bosch process,’ we have become one of the leading suppliers of these sensors. This long manufacturing tradition began as early as the first magneto ignition device, when Robert Bosch found that the market was unable to supply the high-precision components he needed for this device. As a result, he started to construct his own manufacturing machinery and to acquire the necessary technological expertise. This is a principle we at Bosch have followed since then, and will continue to follow.”

2. How does manufacturing contribute to new products?

Denner: “Many of our components would not be possible without precision engineering. Manufacturing diesel direct injection components involves assembling parts machined to an accuracy measured in thousandths of a millimeter. Moreover, manufacturing technology often inspires developmental leaps on the product plane. Using ultrashort pulse technology, for example, we can now drill the tiniest holes in the injection valve – even holes with different diameters. This was previously not possible. One of these holes has roughly the same diameter as a human hair. Its walls are extremely smooth. This allows our customers to control the distribution of fuel in the combustion chamber even better, and to adapt it to each individual type of engine. In this way, manufacturing technology makes an essential contribution to reducing emissions and fuel consumption.”

3. Why does Bosch believe it is important to manufacture key components in its own plants?

Denner: “We have set ourselves the goal of supplying large volumes of top-quality precision-engineered parts. Customers expect this from us, and will continue to do so in the future. To achieve this, we need sophisticated production and process engineering. Only if we can understand and master this down to the last detail will we be truly able to offer the quality customers expect. This is why we have our own separate unit for the construction of assembly lines and special-purpose machinery, as well as the test and process engineering to go with it. This unit designs many of the Bosch Group’s complex production lines for core technologies.”

4. What are the issues that will be important for Bosch in the future?

Denner: “Manufacturing technology for electromobility will gain in significance in the years ahead. Currently, volumes here are so small that manufacturing is almost artisanal compared with the huge mass of components we manufacture for injection systems. We are now only at the beginning of the development toward a cost-effective mass product. Among other things, this applies to power electronics, electric motors, and battery systems. For all our products, resource efficiency in product design and manufacturing will continue to grow in significance. More and more, software and connectivity will determine

not only our products and services, but also our manufacturing processes. The key word here is Industry 4.0. This will be a crucial driver for increasing productivity along the product creation process, and beyond company boundaries.”

5. When it comes to improving production processes, how important is collaboration between industry and universities?

Denner: “Very important. Again and again, we have seen how interdisciplinary working groups often achieve better results. Closely cooperating with universities gives us the chance to give research a practical direction. In this way, we can more quickly use the results of research in the development of our manufacturing processes. In return, we provide stimuli for new research subjects. It’s a win-win situation.

In many areas, the abundance of information and knowledge is already so huge that one individual can no longer have everything at their fingertips. This makes it important to be part of a scientific and industrial network. In such networks, specialists can achieve more in a joint effort than on their own. This collaboration generates synergies, often in the form of new, improved solutions. This is not only true for Bosch. Collaboration among experts is one of the reasons for Germany’s success. One outstanding example of this is the way Bosch worked with TRUMPF, the University of Jena, and the Fraunhofer Institute to refine the use of ultrashort laser pulses in materials processing.”

6. How can publicly funded projects – such as those supported by the German Federal Ministry of Education and Research – help drive innovations?

Denner: “Through publicly funded projects, the government creates a major platform for applied research. In research networks, universities, research institutes, manufacturers of systems and components, and users work together intensively in a competition-free atmosphere. Whenever experts from different faculties and backgrounds come together, a new, critical mass is created. And this can set free the next wave of innovations in a certain area. Such networks frequently cover the entire value-added process, and allow the results of research to rapidly find their way into products. This not only spurs individual companies on to new innovations, but also secures the innovative strength of Germany as an industrial location.

The PRIMUS and PROMPTUS networks, supported by the German Federal Ministry of Education and Research, are a good example of how innovative manufacturing technology can be developed. Thanks to the close collaboration of universities, manufacturers of laser and systems technologies, and users, the use of ultrashort laser pulses for materials processing has been transferred from the research laboratory to the raw reality of industrial production. The business success this has now generated benefits Germany as an industrial location, both with respect to jobs and to tax revenues. In addition, research networks are a driving force in education. When basic research collaborates with industry-based research, young researchers can not only contribute their knowledge, but also use opportunities such as company-sponsored PhD programs to further their education. Bosch makes extensive use of such opportunities.”

7. Does Bosch also collaborate with suppliers?

Denner: “Collaboration with suppliers is absolutely necessary and important. Many suppliers have a wealth of expertise in their specialty areas. If we need special solutions, we work with them to develop these. This goes for both products and manufacturing machinery. It takes a lot of know-how to apply the results of basic research to a machine for continuous operation that will work without a hitch 24/7. For this, you need competent process plant engineers. Examples of such effective collaboration such as these can be found in Germany, where they are a strategic advantage for this high-wage country. They also ensure that products and the manufacturing processes that go with them are developed hand in hand, right from the start. Only in this way can we create excellent products.”

8. How long has Bosch been using lasers in manufacturing?

Denner: “We’ve been using them to make products for more than 36 years now. They were once used to adjust the resistors used in automotive electronics. And laser welding is used in the production of sensors and injection components. Despite this experience, it took a lot of work to transfer micro-processing with ultrashort pulse lasers from university laboratories to the shop floor. This is why Bosch does a lot of industrial research. It starts from scientists’ findings, and uses its own

know-how and staying power to help make them ready for industrial use. Materials processing using ultrashort laser pulses is a good example of this. Our research and development department worked ten years on this subject.”

Press photos: 1-RB-18494, 1-RB-19606, 1-RB-19603

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The Bosch Group is a leading global supplier of technology and services. In fiscal 2012, its roughly 306,000 associates generated sales of 52.5 billion euros. Since the beginning of 2013, its operations have been divided into four business sectors: Automotive Technology, Industrial Technology, Consumer Goods, and Energy and Building Technology. The Bosch Group comprises Robert Bosch GmbH and its roughly 360 subsidiaries and regional companies in some 50 countries. If its sales and service partners are included, then Bosch is represented in roughly 150 countries. This worldwide development, manufacturing, and sales network is the foundation for further growth. Bosch spent some 4.8 billion euros for research and development in 2012, and applied for nearly 4,800 patents worldwide. The Bosch Group’s products and services are designed to fascinate, and to improve the quality of life by providing solutions which are both innovative and beneficial. In this way, the company offers technology worldwide that is “Invented for life.”

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5 questions, 5 answers from the Bosch CEO
Dr. Volkmar Denner

December 4, 2013

PI 8320 RB Rs/Na

“Education, innovation, and creativity are the safeguards of our future”

Using ultrashort laser pulses in manufacturing is a prime example

- ▶ Innovation is the answer to a stagnating economy
- ▶ New techniques for new products in mature markets
- ▶ Schools, universities, and businesses must encourage creativity

1. Bosch can use short laser pulses to drill the tiniest of holes into solid metal. Why is this innovation so important?

Denner: “Bosch uses ultrashort laser pulses to manufacture products in a way that just wasn’t possible before. Gasoline direct injection is a good example: the holes in the nozzles are so minute that a human hair only just fits. Thanks to the use of laser pulses in manufacturing, the edge of the hole is precisely formed and the inside of each hole is exceedingly smooth. As a result, the fuel in the combustion chamber is extremely finely atomized – and the gasoline is delivered to precisely the desired location. This makes the combustion process particularly efficient, contributing to fuel savings and reductions in emissions. All this is to the advantage of automakers and car drivers, and the result of the highly precise manufacturing process that ultrashort laser pulses make possible.

What I have just described constitutes a technological advance. The other side to it is that these innovative products help us to increase our market share in mature yet relatively wealthy markets such as Europe and the United States. By the end of 2013 Bosch will have supplied customers with around 30 million components manufactured using this laser technology. Aside from injection nozzles for gasoline direct

injection, this also includes lambda sensors, diesel injectors, and injection valves for oil-fired central-heating boilers. What's more, this figure is set to rise significantly: it all goes to show that innovative products are the correct response, particularly in tough economic times."

2. How is Bosch reacting to the prospect of a protracted period of economic stagnation?

Denner: "Many experts reckon that Asia's share of global economic output will grow to the detriment of Europe. Were this to be the case, job creation would naturally center predominantly on these growth regions. In Germany and in Europe as a whole we must prepare ourselves for a protracted period of stagnation that could last several years. These muted prospects must be brought out into the open and into constructive public debate, both in Germany and in Europe. Faced with such a situation, the question we must ask is: how can we offer attractive products – and so create jobs – in a stagnating marketplace? For me, one of the answers is to come up with creative product ideas for mature yet relatively wealthy markets such as Europe and the United States. That will be a challenge – for all companies. The good news is that we have all the tools we need at our disposal, whether it's highly trained associates or the numerous networks we maintain with research institutions and universities."

3. How fierce is the competition we have seen emerge in Asia?

Denner: "For many years, countries such as China or India were merely extended production facilities for the West. These were the places where other engineers' ideas were made to order. This pattern is now undergoing a fundamental change. No longer do these countries compete on price alone, but increasingly in terms of innovation, too. China doesn't want to be the world's factory forever and is changing its focus dramatically – targeting innovation as well as research and development. In many areas, the era when China would simply imitate products is long gone. Wages and salaries in China have soared, and the country is reacting by placing more and more emphasis on research and development activities, thereby putting its faith in innovation.

To give a few examples, China is already developing high-speed trains and airplanes. In 2002, in the region of 80,000 patent applications were submitted in China; by 2012, this had risen to some 650,000. In China

alone, around six million people graduate from university each year – more than two million of them in an engineering discipline. In Germany, only around 50,000 first engineering degrees are currently awarded in a year. We can't compete with the sheer volume of graduates. That's why we have to be significantly better than they are."

4. How can Germany and Europe react to these trends?

Denner: "Germany's key resources are the knowledge and creativity of its people. In Asia, on the other hand, the education system is often characterized by repetitive learning techniques. This is an area where Germany still has a competitive advantage. In Germany, the creativity of the individual and their individual skills lie at the heart of what we do. We ought to safeguard and encourage this creativity in schools, in training, and in our universities. After all, creativity helps when you are trying to think systematically and to understand complex systems. These are precisely the sorts of skills we need across all levels if we are to stand up to international competition. Accordingly, these strengths should be developed further.

Yet instead of putting creativity at the center, we in Germany have introduced some measures that are clearly misdirected. This includes the way the switch to eight years of high school has been handled and the tendency to make university more and more like school. If you overload school pupils and students with an overfull syllabus, how are they meant to develop creativity and find their own approaches to solving problems? Instead, we need to encourage learning based on curiosity and research."

5. How can we encourage creativity within companies?

Denner: "Above all, creativity calls for breathing space and the ability to link disparate things. It can be planned only to a certain degree. However, we can create the best possible working atmosphere to promote creativity, for instance by building our new research center in Renningen near Stuttgart. Here we are investing 310 million euros in some 1,300 jobs. We are investing these sums because we believe that there is still significant room for improvement in our research and advance engineering work. That's why Renningen is being established as a sort of campus with a university feel, where information can flow freely and associates can work together in new, cutting-edge ways.

New ideas often emerge from connecting up the knowledge we already have. This is why it is so important that the right specialists come together and form new overlaps. What's more, we need an attitude, a spirit, that allows creative minds to engage with innovative topics – even at the risk that they might lead nowhere. Germany's prevalent culture of error avoidance stifles many creative ideas, and that is a competitive disadvantage.”

Press photos: 1-RB-18494, 1-RB-19613

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Background

What is a laser?

Focused light with many uses

December 4, 2013

PI 8326 RB Rs/Na

Stuttgart – Lasers are artificial sources of light that emit a very focused, and therefore very energy-rich, light. The technology has been around for more than 50 years. In a laser device, a crystal, for example, is charged with very powerful flashes of light. Physicists call this stimulation. The atoms in the crystal are then made to emit the absorbed energy in exactly equal “portions” of energy. This involves reflecting the light back and forth between two mirrors. This brings more and more energy “portions” together, until finally a part of the light escapes the laser device in the form of a beam. Unlike sunlight or other light sources, laser light has only one color, which varies according to the type of laser. In addition, the beams emitted by the laser run almost parallel to each other. The word laser is an acronym of “**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.”

Many applications

Since the 1960s, many different lasers have been developed with various colors (i.e. wavelengths) and therefore for various applications. These range from working on the lenses of eyes to correct poor vision to cutting thick sheets of steel to build huge ships. Satellites use lasers to exchange data over long distances, in DVD players they are used to read films or music, and tradesmen use them to measure houses.

One special application involves drilling minuscule holes or other structures into hard metal or other materials. In this case, it is not enough to simply aim the concentrated energy at the correct area and wait, since this would result in the metal getting hot and eventually melting. Such a process does produce holes, but with edges that are not clean, and therefore cannot be used. This is far from good enough for precise applications. To get round these problems, laser light has to be used in the form of incredibly short but extremely powerful pulses.

Ultrashort pulses

At Bosch, this is currently up to 800,000 light pulses per second. Each one of these heats a tiny area of metal to approximately 6,000 degrees Celsius (hotter than the temperature on the surface of the sun) so quickly that it evaporates immediately. In other words, the material hit by the laser beam simply doesn't have time to melt. Controlled by a special system of mirrors, the next pulse follows, hitting the area of metal immediately next to the first – and so on. In this way, hundreds of thousands of light pulses, each hitting a precisely defined position and having slightly different properties, create the tiny hole required, But of course, all this depends on know-how when it comes to controlling the laser perfectly – and Bosch has this know-how. This is a process that requires ultrashort laser pulses in the realms of

picoseconds (0.000000000001 seconds) or even
femtoseconds (0.00000000000001 seconds).

Internet

- Information on lasers from the Deutsche Physikalische Gesellschaft:
<http://bit.ly/15QrOgE>
- The inventors of the laser received the Nobel Prize for Physics in 1964, here is the address for the award: <http://bit.ly/15iLg37>
- A film by the Berthold Leibinger Stiftung provides a good, comprehensive description of lasers: <http://bit.ly/17pbrES>

Press photos: 1-RB-19566, 1-RB-19567

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