GUANGYAO OUYANG | SHIJIE AN
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COMMON RAIL FUEL INJECTION TECHNOLOGY IN DIESEL ENGINES

国防工业出版社
National Defense Industry Press

WILEY

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This work is funded by B & R Book Program.

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Library of Congress Cataloging-in-Publication Data

Names: Ouyang, Guangyao, author. | An, Shijie, author.
Title: Common rail fuel injection technology in diesel engines / Guangyao Ouyang, Naval University of Engineering, Wuhan ; in collaboration with, Shijie An, Naval University of Engineering, Wuhan, Zhenming Liu, Naval University of Engineering Wuhan, Yuxue Li, Naval University of Engineering, Wuhan.
Description: Hoboken, NJ : Wiley, 2019. | Includes bibliographical references and index. |
Identifiers: LCCN 2018057453 (print) | LCCN 2018057853 (ebook) | ISBN 9781119107248 (AdobePDF) | ISBN 9781119107262 (ePub) | ISBN 9781119107231 (hardcover)
Subjects: LCSH: Diesel motor–Fuel injection systems. | Marine diesel motors.
Classification: LCC TJ797 (ebook) | LCC TJ797 .O985 2019 (print) | DDC 621.43/61–dc23
LC record available at https://lccn.loc.gov/2018057453

Cover image: © Aun Photographer/Shutterstock
Cover design by Wiley

Set in 10/12pt WarnockPro by SPi Global, Chennai, India

10 9 8 7 6 5 4 3 2 1

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Preface

Since the twenty-first century, the diesel engine is facing the challenge of two factors: energy and environmental protection; thus improving the efficiency and controlling the emissions has become an important problem facing today's diesel engine industry. The needs of society and economy of the diesel engine for future environmental protection put forward a higher request for better technology to enable a lift in demand for the diesel engine. The efficiency and lower emissions are closely related to the combustion process. The most feasible approach is to reform the diesel engine fuel system implementation to improve its performance. The electronically controlled fuel injection technology is an implementation of controlling the fuel injection quantity, injection timing, and fuel injection law, in order to realize the well-organized combustion process and optimize performance of economy, power, and emission under various working conditions.

Development of the electronic control fuel injection technology began in the 1970s, and the actual shipment of electronically controlled high-power diesel engines started to be commissioned in 1980. So far, the electronically controlled fuel injection system has passed through three stages of development: the initial development stage in 1970s, the production utility stage in the 1980s, and the stage of technological development in the 1990s. Currently, the most advanced electronic control fuel injection technology is the high-pressure common rail fuel injection technology.

The first generation of a common rail system was launched in the 1990s, with the second and third generations being rolled out after more than 10 years of research and improvement. The concept of a fourth generation of common rail system has been promoted in recent years. The latest mid-high speed and high-power diesel engines developed abroad, with no exception, adapted the common rail technology, so it is apparent that the common rail technology has become one of the important technical measures to respond to emissions and fuel economy.

Although common rail technology is one of the hot topics in the study of the modern diesel engine technology with abundant successful application examples, the system study is relatively rare, and it especially lacks a domestic research report. The author has been engaged in the research of this field for more than 10 years, involving research and development stages of demonstration, design, and key technology research. The author has reached a series of achievements with arduous effort and suffered from a deficiency of system data; thus he has developed the germination of summing up the research achievements systematically over the years, to offer some reference for

colleagues. It is his wish to provide a bit of inspiration and hopes that it might make a contribution to diesel engine technology development.

This book is based on the perspective of system analysis in order to provide a comprehensive introduction to common rail technology. The book is divided into seven chapters: the first chapter analyses the present situation of the common rail system; the second chapter introduces the common rail system modeling and simulation technology; the third and fourth chapters introduce the research of key technology and key parts of the common rail system; the fifth chapter introduces the ECU design technology; the sixth chapter introduces the machine assembling technology of the common rail system; and the seventh chapter introduces the research and development of a new type of common rail system.

The book is available for senior students in relevant colleges for graduate teaching and engineering and technical personnel. Due to a possible limited level of knowledge of the author, the book offers a preliminary view; if there are some inappropriate statements, please correct them.

The author gratefully acknowledges the help of Professor Jiang Deming at Xi'an Jiaotong University, Professor Gao Xiaohong at Wuhan University of Science and Technology, with the guidance and recommendation of Professor Wang Changyi and Professor Tang Kaiyuan at Naval Engineering University. Thanks also for the support of the National Defense Industry Press. Thanks also to colleagues and graduate students for 10 years of hard work, and it is their support that provided the author with the determination and confidence to realize the publication of this book.

The author

Introduction

This book is the academic monograph about related technical aspects of the high-pressure common rail system of a diesel engine and summarizes the author's research achievements in the field of electronic injection and common rail technology in the past decade. This book systematically elaborates the following contents: the development history of high-pressure common rail technology, system simulation and optimization, key parts design and the optimization design of a new type of common rail technology, etc.

This book can be used as a reference book for Graduate teaching and is also available for engineering and technical personnel specializing in design, development, and manufacture of a common rail system of a diesel engine.

1

Introduction

Today, the diesel engine is being developed and perfected; with its advantages of high efficiency and a wide range of power, it has been widely used in industry, agriculture, national defense, and other fields. Predictably, the diesel engine will still occupy an important position in the field of engines for a long time in the future. With increasingly serious energy and environmental problems, people pay more and more attention to fuel economy and emissions of the diesel engine, especially putting emission issues at the top of considerations. Governments have developed increasingly stringent emission regulations since the 1970s, and internal combustion engine researchers and related companies have constantly committed to improve the performance of the diesel engine, in order to obtain better noise emissions and a more economic performance.

There are many factors that influence diesel engine exhaust emissions and fuel economy, which are quite complicated. The most important means of improving the emissions and economic performance of diesel engine performance is to improve its combustion performance. Therefore, transformation of the fuel injection system has become an object of primary concern since it has the greatest influence on the combustion performance. The parameters that impact the performance of the diesel fuel injection system mainly include injection pressure, injection quantity, fuel injection advance angle, etc. Traditional methods are not able to make these parameters in the diesel engine achieve optimal results in the broad scope of work carried out on the diesel engine, but the development of modern electronic technology has provided a broad space in which to improve the performance of the diesel engine.

The biggest impact of the diesel engine fuel injection system on combustion concerns three factors: injection timing, injection duration, and the fuel injection law. The main purpose of an electric controlled diesel engine fuel injection system is to realize the flexible adjustment of the above three factors, which ensure that the diesel engine is running in optimal working conditions.

The diesel engine electronic control injection system is usually composed of sensors, controllers, and actuators, as shown in Figure 1.1. The combustion process in the cylinder of the diesel engine is very complex, and is affected by many factors. The method of setting up a mathematical model, with the aid of all kinds of sensors, to realize the closed-loop control of the burning process is difficult. The basic method that most diesel engine electronic control fuel injection systems now adopt is: adopting engine speed and load as a basic signal reflecting the actual working conditions of the diesel engine; then referring to the fuel injection quantity obtained by experiment in the optimum working condition and the injection timing MAP graph in order to determine the basic

Common Rail Fuel Injection Technology in Diesel Engines, First Edition.
Guangyao Ouyang, Shijie An, Zhenming Liu and Yuxue Li.
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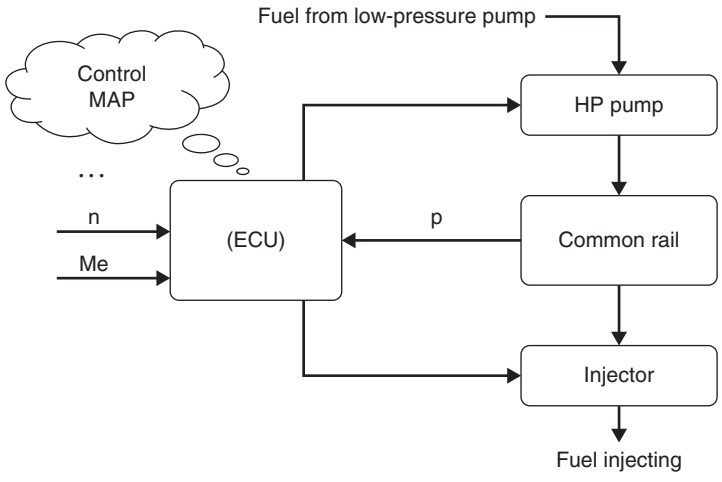

Figure 1.1 The basic compositions of the fuel injection system on an electronic controlled diesel engine.

fuel injection quantity and injection timing; then carrying on the various compensation schemes (such as engine speed, load, water temperature, oil temperature, atmospheric pressure, etc.) in order to determine the cycle fuel injection quantity and injection timing; and then taking the closed-loop feedback control to actuators in the process of working.

After the diesel engine fuel system adopts the electric control system, it has the following features:

(1) The degree of control freedom increases. The electronic control fuel injection system can optimize comprehensive control on the injection parameters in accordance with the different operating conditions.
(2) The control precision improves. For instance, the injection timing control accuracy (CA) is higher than 0.5° CA and the accuracy is four times higher than with mechanical control.
(3) Since the diesel engine fuel injection system has the characteristics of high voltage and high frequency and pulse, it will be able to achieve these objectives and will certainly bring about the complexity of actuator and control and strict requirements on reliability and duration of system that are required.

1.1 The Development of an Electronic Control Fuel Injection System

After decades of development, the diesel engine electronic control fuel injection system has experienced three progressive stages, namely, position type control, time control, and pressure time control.

Table 1.1 Typical representatives of a position type electronic control fuel injection system.

Form	System name	Control characteristics
S T	Pump Zexel (Japan) COPEC	High-speed solenoid valve control injection time, variable inductance displacement control fuel injection quantity
R A	BOSCH (Germany company) EDR	High-speed solenoid valve control gear lever displacement, adjustable CAM phase
I G	(American Caterpillar company) PEEC – ECD-P3	Brushless torque motor control gear lever displacement, linear potentiometer control injection time
H	(Japan Toyota) ECD-p	High-speed solenoid valve control injection time, adjustable CAM phase
T	BOSCH (Germany company) TICS	High-speed solenoid valve control plunger sleeve and gear lever position, the variable stroke
C	(Japan Toyota) ECD-p	High-speed solenoid valve control injection time, adjustable CAM phase
O	(British Lucas) EPIC	The phase of the CAM ring to control injection timing, control the distribution of rotor axial displacement control of oil
L U	(Stanadyne companies in the United States) PCF	Control CAM follower body axial displacement control of oil, the control of fuel injection advance unit control injection time
M N	BOSCH (Germany company) ECD – COVEC	Rotating magnet control sliding sleeve position, solenoid valve control injection time

1.1.1 Position Type Electronic Control Fuel Injection System

A position type electronic control fuel injection system retains the basic structure of a traditional injection system and only replaces the original mechanical control mechanism with electronic components. On the basis of the original mechanical control loop fuel injection quantity and injection timing, the electromagnetic actuator of linear displacement or angular displacement has been adapted to realize electrically controlled fuel injection timing and to improve control accuracy and the mechanical control response speed. Its products involve an array plunger pump electronic control system and a rotor pump distribution electric control system. Typical representative types are shown in Table 1.1.

A position type electronic control injection system adapts electronic control components to replace the original mechanical adjusting mechanism, while the use of electronic control mechanical actuators is to control the process of injection indirectly; thus the control accuracy, response time, is comparatively lower than in other electronic control systems. Since the basic structure of the injection system has not changed, the injection characteristics cannot be greatly changed and so the injection rate is not likely to achieve flexible control.

1.1.2 Time Type Electronic Control Fuel Injection System

As the performance of the diesel engine has further requirements on fuel injection process control, the first generation of fuel injection systems that installed an electronic control device with the original mechanical injector could not meet demand and thus the second generation of electronic control fuel injection system arises at the historic moment to use the electronic control unit (ECU) to control the injection starting point and end point directly. It has changed the traditional injection system of some mechanical structures, switching the original mechanical injector to a high-speed powerful solenoid valve injector, controlling the make and breaks of the electromagnetic valve through a pulse signal, and the action controls the opening and closing of the oil atomizer. The oil pump is completely separated from this mechanism and the control mechanism, and fuel metering is determined by the fuel valve open time length and the size of the injection pressure. Injection timing is controlled by the electromagnetic valve open time, in order to realize flexible control of the fuel injection quantity, injection timing, and the integration of control. It has changed the execution of the first generation of electronic control fuel injection systems, such as a slow response, low control frequency, and unstable control precision, and thus has much greater control of the degrees of freedom and a better control performance, which the first generation of the electric control system cannot reach. The electric control system can be divided into: an electric pump nozzle system, an electric distribution pump system, and an ECU pump or inline pump system. Typical representatives are shown in Table 1.2. Though the performance has improved greatly, it still has the following disadvantages: since the injection pressure is produced by a high-pressure oil pump directly, the injection pressure and fuel injection law is still under the control of the CAM (computer aided manufacture)-shaped line and cannot be adjusted freely.

1.1.3 Pressure–Time Controlled (Common Rail) Type Electronic Control Fuel Injection System

All the electronic control fuel injection systems described above directly adopt the traditional mechanical fuel pump pressure oil and fuel injection mechanism, with its basic principle based on fuel injection pump technology developed by Robert Bosch in 1926.

Table 1.2 Time control type electronic control fuel injection system.

Form	System name	Control characteristics
Pump nozzle	Detroit Diesel Engine Company (DDEC)	Solenoid valve open and close control injection start and end
	British Lucas EUI	As above
	The University of Tokyo in Japan ACE	As above
Distribution pump	Zexel Japanese company ECD-V3	With oil spill control valve adjustment of oil pump
	DS (Stan dyne companies in the United States)	RS with high-speed solenoid valve control oil injection time and quantity
	Germany BOSCH company VP44	As above

In order to meet increasingly stringent needs of emission, noise regulations, and fuel consumption reduction, it must improve the control precision of the fuel injection quantity, injection timing, and fuel injection rate, in order to obtain fine control of each cylinder and adopt the high-pressure jet to get a better atomization effect. All these requirements prompted production of the third generation of electronic control fuel systems, that is, the emergence of the common rail electronically controlled fuel injection system.

The common rail system is characterized by: independent generation of the injection pressure and injection control and pressurization of the fuel in the common rail using a fuel supply pump in which the pressure can be maintained within the scope of 130–160 MPa, although some related research reports claim that it has reached 200 MPa. The opening and closing of the electromagnetic valve control the start and end of the fuel injection process. Thus, it can change the injection pressure according to the engine load and speed, with an operation condition in a wide range of 20–160 MPa, realizing the pilot injection, main injection, multistage spray, etc. It can also change the shape of the fuel injection rate in accordance with the demand, realize a high degree of freedom to control the fuel injection process, greatly improve the combustion efficiency of the diesel engine, and significantly improve emission performance.

The common rail fuel injection system formally entered the stage of practical application in the middle and later periods in the 1990s. This kind of electric control system can be divided into: an electronically controlled medium-pressure common rail fuel injection system (hereinafter referred to as the medium-pressure common rail system) and the electronically controlled high-pressure common rail fuel injection system (hereinafter referred to as the high-pressure common rail system).

1.1.3.1 Medium-Pressure Common Rail System

The fuel pressure in the fuel rail of a medium-pressure common rail system is 525 MPa. The fuel with medium pressure is sprayed into the combustion chamber using fuel injector booster piston pressurization with extremely high pressure. The typical representatives are the Servojet system by the BKM Company and the HEUI system by the Caterpillar Company.

The structure diagram of the HEUI system by the Caterpillar Company is shown in Figure 1.2.This system adapts a pressurization piston with the aid of machine oil pressure to increase the injection pressure and has two public oil ways. One is a high-pressure control oil way (the high-pressure control oil is machine oil), maintaining a certain degree of pressure to push a supercharging piston. Another is the low-pressure fuel oil supply, which provides fuel for the fuel injector. It controls the fuel injection pressure by adjusting the oil pressure in a high-pressure control oil circuit. Fuel injection quantity and injection timing are controlled by the solenoid valve open time length and opening moment.

The main characteristics of the system are as follows:

A. A very high injection pressure may be obtained by changing the proportion of pressure of the piston and plunger of the cross-section area.
B. High pressure only exists in the necessary part (booster amplifier, high-pressure tubing, etc.).
C. It does not need a high-pressure oil pump.

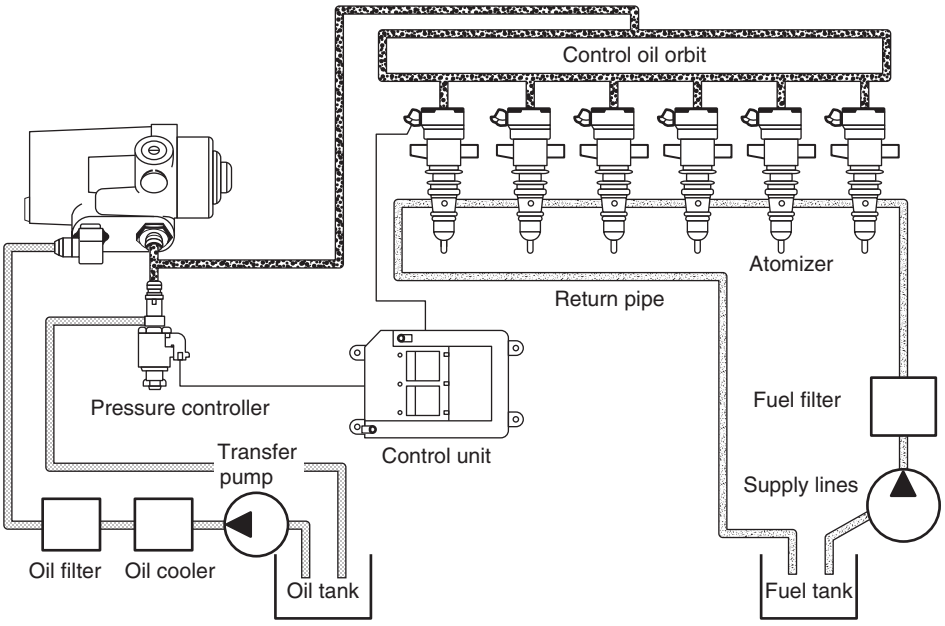

Figure 1.2 Schematic diagram of the liquid pressure type electronic control fuel injection system.

D. The injection shape is affected. It must adopt a large-flow electromagnetic valve (such as where the pressure ratio is 7 : 1 and the circulating oil quantity is more than seven times that of each injection volume). Since the response speed of the large-flow electromagnetic valve is comparatively slow, it is not easy to achieve advance injection when the injection time is very short.
E. Its installation size is comparatively large and it needs two sets of oil ways so that the oil duct size is also bigger.
F. It needs fuel valve plunger parts with high precision in order to ensure the separation of the high-pressure oil and jet fuel control.

1.1.3.2 High-Pressure Common Rail System

A high-pressure common rail system with an accumulator type injector and pressurization piston, and the public oil, the oil pressure directly controls at higher stress levels (the common rail pressure remains above 100 MPa), fuel injection quantity, and injection timing by electromagnetic control of a three-way valve or a two-way valve to adjust the use of a three-way valve or two-way valve control nozzle change of back pressure in order to change the fuel injection quantity and injection timing.

The main characteristics of the system are:

(1) There is freedom to adjust the injection pressure (common rail pressure). Using the pressure sensor, detect fuel pressure in the rail, so as to adjust for the oil pump, control the common rail pressure, and adjust the volume of injection.
(2) With engine speed and throttle opening information, etc., on the basis of optimal fuel injection quantity it is calculated using a computer by controlling the fuel injector solenoid valve moment of electric power and direct control of the fuel injection parameters.

(3) There is freedom to adjust the injection rate shapes. According to the needs of the engine, set and control the fuel injection rate shape after injection, multistage spray, etc.
(4) There is freedom to adjust the injection time. According to the parameters such as the engine speed and load, calculate the optimal injection time and control the open and close with the appropriate time, etc., so as to accurately control the fuel injection time.
(5) It requires a high-pressure fuel pump, as the system components for most of the work are under high pressure and thus may easily fail. Overall, a high-pressure common rail system can be realized in a traditional injection system that cannot otherwise achieve this function.

Its advantages are:

(1) Wide application fields (for cars and light trucks, each cylinder power can be up to 30 kW, while for heavy trucks and motorcycles and marine diesel engines, every cylinder power needs about 200 kW).
(2) A higher injection pressure; the current is currently up to 180 MPa and will soon be more than 200 MPa.
(3) Injection starting point, where the end point of injection can be easily changed.
(4) It can implement pilot injection and main injection, and after injection can be realized according to the discharge requirements, such as five to seven times that of a multistage injection.
(5) It has an injection pressure corresponding to the actual working condition. The establishment of the injection pressure is with no interdependent relationship between the fuel injection and the common rail pipe, and is always full of fuel injection at a certain pressure. The fuel injection quantity is determined by computer through calculation, but is less constrained by the other conditions.
(6) Injection timing and injection pressure are stored in the ECU (MAP) to calculate the characteristic curve of the spectrum; then the electromagnetic valve control is installed on each engine cylinder injector (injection units).

It is because of the advantages of using the high-pressure common rail system that several companies and research institutions at home and abroad are devoting a great effort to its study.

1.2 High-Pressure Common Rail System: Present Situation and Development

1.2.1 For a Common Rail System

In the 1980s research work on the high-pressure common rail system began and in the late 1990s the first generation of common rail system products were introduced.

A typical high-pressure common rail system is mainly composed of a high-pressure pump, electric control, common rail injector tube, current limiter, pressure limiting valve, rail pressure sensor, low pressure pump, filter and fuel tank, and sensors, as shown in Figure 1.3.

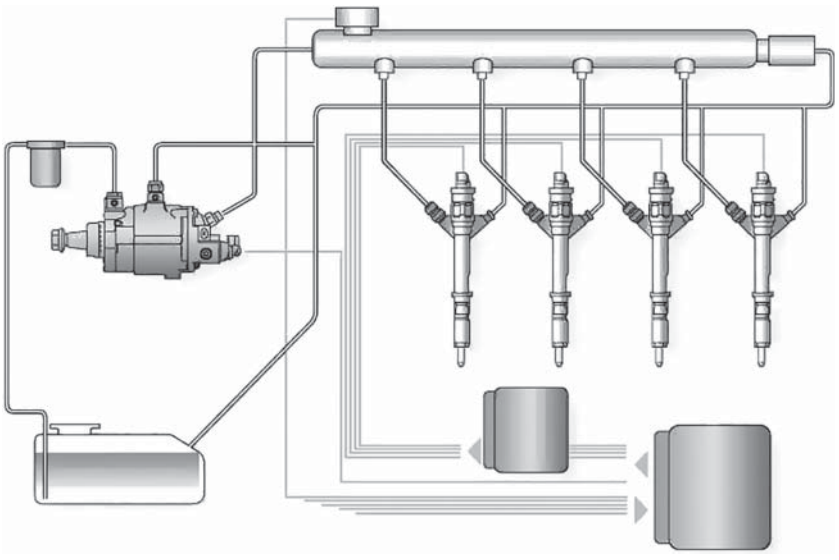

Figure 1.3 The typical schematic of the high-pressure common rail system.

Fuel from the tank passes through at a low pressure to the high-pressure oil pump and then to the radial piston pump, which has three functions: fuel will flow into the high-pressure oil rail, a part of this fuel oil will pass through the injector and is sprayed into the combustion chamber, and a small part will control the injector needle valve after the flow back into the tank. On the high-pressure oil rail there is a pressure sensor; the system will measure the fuel rail pressure compared with the preset value in the ECU, and if the measured value and book value are not consistent, the high-pressure oil rail pressure regulator on the overflow valve will open or close, allowing the fuel back to the fuel tank. Fuel injection timing and fuel quantity control, according to the measured results of each sensor, allow the ECU control high-speed solenoid valve to open and close. The system of the high-pressure oil pump for the three parts of the rotary piston pump has a control input control solenoid valve, when the engine load is low, by closing a feed to reduce the power consumption of the high-pressure oil pump. Fuel injection timing uses the function in the electronic control injector solenoid valve to control the pulse time and the fuel injection quantity uses the function in the electronic control injector solenoid valve to control the pulse width.

Due to the superiority of the high-pressure common rail system, many companies at home and abroad have studied its development and used the characteristics of the common rail system.

1.2.1.1 Germany BOSCH Company of the High-Pressure Common Rail System

So far, BOSCH Company is planning and designing four generations of the high-pressure common rail system. The first-generation batch was on the market in 1997 and with an injection pressure of 135 MPa was mainly used in cars. The second generation of mass production started in 2000, raising the maximum system pressure to 160 MPa, and started using the fuel control function of the high-pressure pump and solenoid valve injector, and improved the injection cycle by pre-injection, main

injection, and many multistage jet injections; it is mainly suitable for engine power under 55 kW/l.

In May 2003, BOSCH Company began to produce innovative piezo inline technology of the third generation of the common rail system. In the first two generations of the common rail system, BOSCH Company mainly paid attention to improve the injection pressure, while the third generation of the common rail system's center of gravity shifted to technical complexity and precision, temporarily to keep the pressure at 160 MPa. The special feature of the third generation of the common rail system is that it uses a fast switch compact piezo inline injector. A piezoelectric actuator is built into the fuel injector on the shaft and is very close to the injector nozzle needle valve. The new fuel injector reduces about 75% of the moving parts and quality. An electromagnetic valve actuator compared the injector of the common rail system, its advantage being: a more accurate supply fuel and injection of the fuel in the combustion chamber, as well as better atomization and mixing. A fuel injector higher switching speed means that the time interval between the two jets is reduced, so the injection process has a more flexible control. The result is that the diesel engine is quieter and the fuel burn is cleaner, more efficient, and gives more engine power. From 2003 to 2008, five years, BOSCH injection pressure of the third generation of the common rail system of the company had two versions in order to achieve the 200 MPa high-pressure jet.

BOSCH Company developed heavy commercial vehicles in the fourth generation of the common rail system. The system configuration of the new type of injector had a pressure conversion device and a pressure transducer that could be triggered independently. Figure 1.4 is a BOSCH fourth-generation N4 interchange type automobile engine high-pressure common rail system. This system has the following characteristics: the system uses two levels of pressurization; in the second level within the fuel injector pressure amplifier, the injection pressure can reach 230–250 MPa; it can realize multiple

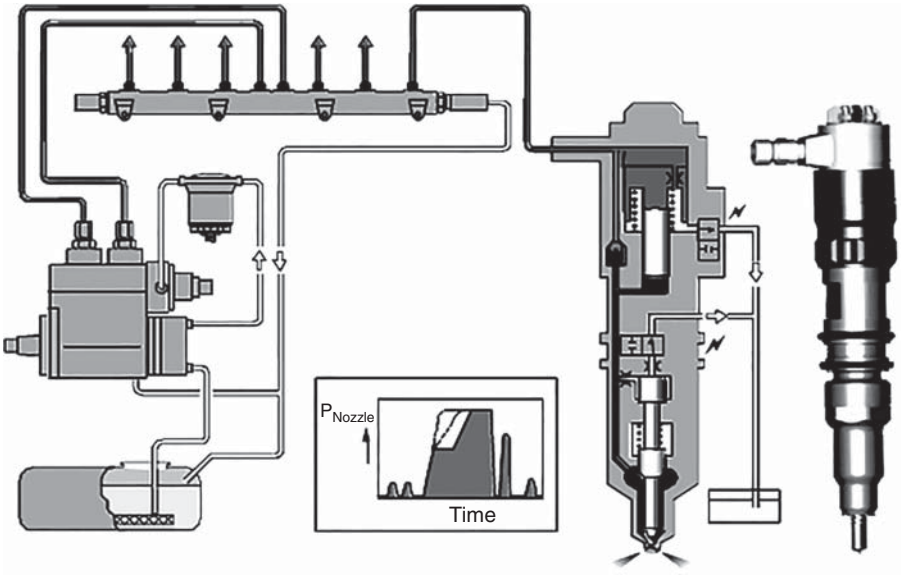

Figure 1.4 BOSCH N4 common rail injector.

injections; the injector with a two-solenoid valve can be used to control the fuel injection rate shape; it is a highly flexible control; and it can make each operation condition point of emission a minimum.

1.2.1.2 The Delphi DCR System of the Company

Delphi is the most representative of the advanced Multec DCR diesel common rail injection systems. The main components of the Multec DCR diesel common rail injection system are a common high-pressure oil rail, high-pressure fuel pressure regulator, ECU for a high-pressure fuel pump, fuel injector, and fuel filter and sensor, etc.

The Multec DCR diesel common rail injection system of injection pressure also has nothing to do with the engine speed and load, for even in low-speed running, the system can still maintain enough pressure for the high-pressure fuel injection. The system can produce injection many times and can meet the requirements of the EU emission regulations although the fuel injector design is unique. Multec DCR mainly adopted a balance control and feedback control strategy of an electric solenoid valve structure of fuel injector, which can provide extremely fast response actions and can accurately measure the fuel flow rate. The quick response, compact structure, small. and exquisite injector solenoid valve control only needs a conventional 12 V car battery drive to work normally. Compared with the world's production of any kind of diesel common rail injection system this system is energy saving, which greatly reduces the production cost of the automobile electronic design system and complexity. The whole system uses a modular design that is easy to apply in different forms and different kinds of engine.

In 2004, a new generation of diesel engine driven directly by the Delphi Company common rail fuel injection system (direct acting diesel common rail (DADCR) system) was introduced into the market. Because the new fuel injector system used piezoelectric actuators, the high-pressure pipe line was not required, which greatly saved the energy waste caused by the high-pressure oil return.

1.2.1.3 Denso High-Pressure Common Rail Injection System of the Company

Denso Co. Ltd. is one of the earliest research and development companies to produce a common rail system, and in 1995 took the lead in the world production of commercial vehicles using the common rail system, the first generation of which entered mass production in 1998. Their product was used in Japan's big four commercial vehicle manufacturing companies. Shortly thereafter, a passenger car using the common rail system began in cooperation and development with Toyota, and in June 1999, production commenced for export of cars to the European market. From that development and experience of the first generation common rail system, the system was further developed to produce the second generation system, with a practical application appearing in June 2002.

The second generation of the common rail system included a fuel injection device where the high-pressure injection was introduced many times with a burning cycle and high-precision injection quantity control, which is critical technology for the development of the second generation of common rail systems focusing on the following two aspects: one is a highest injection pressure of 180 MPa and the second is a high-precision multiple injection capacity.

1.2.2 High-Power Marine Diesel Common Rail System

Relative to the automotive diesel common rail system, the marine diesel common rail system includes new features, mainly including:

(1) A loop supply of a large amount of oil. Under the condition of a small cycle fuel injection quantity, using the electromagnetic valve can realize accurate control of the fuel injection process. Under the condition of a larger circulation of oil, how can control of the fuel injection process ensure the stability of the system pressure; this needs careful study.
(2) A large marine diesel engine power requires high system security. If the diesel engine fuel system fails there will be serious consequences, so the system should include very effective safety protection measures.
(3) As opposed to a relatively stationary diesel engine, in a marine diesel engine the electronic control system electromagnetic interference is stronger, creating a very bad working environment. The narrow space, dampness, corrosive gases such as those produced by environmental conditions of the common rail system signal acquisition, signal processing, electromagnetic compatibility of ECU, etc., make higher requirements necessary.
(4) The vehicle diesel engine has a vehicle load characteristic and its operation with is by a throttle control. In comparison the load characteristics of the marine diesel engine run as a power plant or as the propulsion characteristics of the host, completely by the ECU control strategy during operation control of the diesel engine speed.
(5) As used in a marine diesel engine, the fuel quality is worse than for an automotive machine, so the requirements to ensure the fuel system can run reliably an inferior fuel is used under high pressure.

Because the marine diesel engine has the characteristics above, in order to improve system security, common rail pressure fluctuation should be reduced and the characteristics of the marine common rail system need to be adapted with some significant differences made from that of the common rail system.

1.2.2.1 System Structure

A typical marine common rail system is that of L'Orange for the MTU Company MTU8000 series diesel engine production of the common rail system and that of Wartsila Company for Sulzer RTA – flex marine diesel engine production of the common rail system. Figure 1.5 gives the Wartsila ship common rail system schematic diagram (the system can be applied to the 4–18 marine diesel engine cylinder). The whole system consists of a high-pressure oil pump, high-pressure oil rail, accumulator, electronically controlled injector, control oil, electric control system unit, and the composition of the high-pressure oil pipe. The high-pressure oil pump is used to press the fuel into the high-pressure oil rail connecting each accumulator to each other by high-pressure tubing to offer jet fuel to two injectors. Electronically controlled injector fuel is injected and controlled by an electromagnetic valve oil circuit control. L'Orange for MTU Company MTU8000 series diesel engine production of the common rail system and structure of the Wartsila common rail systems are similar, in that in the system each accumulator is only responsible for providing a fuel injector, jet fuel, and fuel injector directly controlled by an electromagnetic valve, without the need of setting

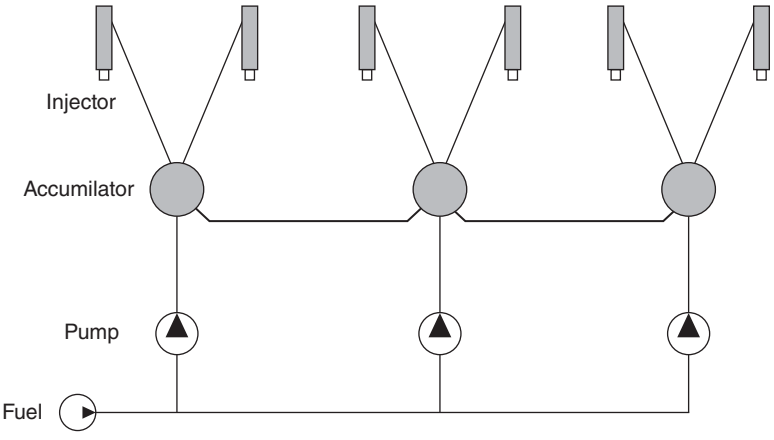

Figure 1.5 Schematic diagram of the Wartsila common rail system.

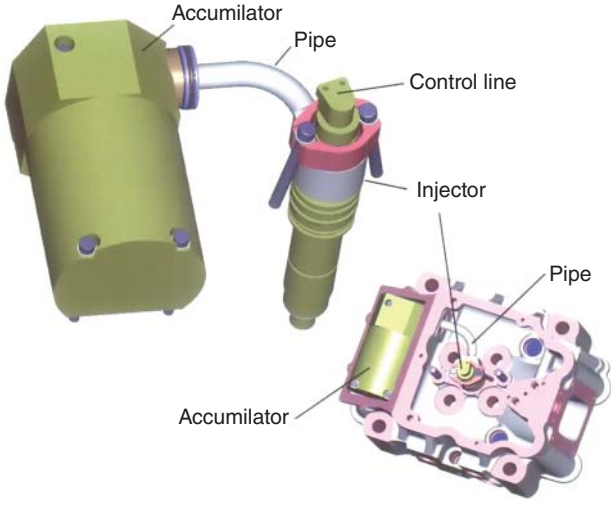

Figure 1.6 MTU8000 injector and accumulator.

up a control hydraulic system to control it. Figure 1.6 shows the accumulator and injector arrangement.

1.2.2.2 High-Pressure Oil Pump

Because the system does not require only high-pressure fuel in the fuel injection stage to be provided, the high-pressure oil pump adopts multiple bumps on the oil supply CAM method, which can effectively reduce the peak torque and improve the high-pressure oil pump volume efficiency. To control the amount of fuel into the accumulator, a high-pressure oil pump inlet is equipped with a rotary solenoid valve to control the oil. Because of the high-pressure oil pump, the oil valve quality has a great influence on the system, so the high-pressure oil pump is used for monitoring the oil valve status of the thermocouple.