HIGH PRESSURE HYDRAULICS IN DIESEL ENGINE FUEL SYSTEM

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DOI: 10.17973/MMSJ.2018_11_201847

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The use of high-pressure fuel injection with ultra-fast actuators provides an opportunity for flexible molding of injection parameters, not only for the corect size of the fuel batch, but also in terms of very precise timing. These are good preconditions for optimizing the combustion process and improving of engine performance parameters

KEYWORDS

fuel distribution, injection system, injector

1 INTRODUCTION

The diesel engine converts the chemical energy that is contained in diesel fuel first into heat, then into mechanical energy. For this process, it needs to provide both the flow source and the precise fuel distribution mechanism. Fuel delivery and distribution - that is, injection and rapid disintegration of fuel into small particles (droplets) - is subject to a number of parameters. The process is dependent on operating conditions, including load and angular speeds, but must be subject to stringent emission standards. It is not enough to ensure that the fuel mixture is ignited and burned up early. The process must be controlled during operation to achieve the required performance parameters with high efficiency and minimize negative environmental impacts as much as possible.

2 FUEL DISTRIBUTION

The flow source must overcome many resistors, including hydraulic resistors in the system, but also the pressure in the combustion chamber of the engine cylinder. However, this is not the main reason for which the fuel system is designed as high-pressure. Why, then, when the fluid mechanisms are high in load and therefore high pressure due to the problems not only of the strength but also bring other negatives - eg higher noise level of the mechanism, higher demands on sealing leaks etc.? For ignition and cultivation, accurate dosing with both time (position) and quantity is required. The dose volume of a few cubic millimeters, with a mass flow of a few milligrams, is necessary for transport to the combustion chamber at the right time and in a relatively short time interval. Increasing injection pressures is a response to higher demands - with an emphasis on efficiency and production of pollutants. The high pressure in the injection system will favorably influence both the demanding chronology of the delivery of injection - injection and the kinetics of the preparation of the mixture. Of great importance for the initiation and the actual course of combustion is the conversion of the continuous flow of fuel into the doses and the subsequent atomization - the fuel flow falls into a stream of droplets of very small diameter - in the order of micrometers. It will be appreciated that the total droplet area will be important for the rate of evaporation of the fuel, which increases with the number of elements and thus accelerates the chemical processes in the preparation of the flammable mixture. The so-called ignition delay is shortened and the dose burns faster. These are the prerequisites for the good performance of high-speed combustion engines that can achieve higher engine speeds in the past, while improving other parameters (especially reducing emissions of pollutants and noise levels).

3 FUEL DELIVERY SYSTEMS

The fuel flow is always provided by a hydrogenerator, yet high-pressure devices have a number of design variants. The basic arrangement is based on an external flow source - a high pressure generator - an injection pump. The pump is connected to a high-pressure line with the injection unit. Development has led to integration in one unit, the generator part of the associated injection unit was generally driven directly by the cam mechanism. The required injection control was provided for high-speed diesel engines via electromagnetic or piezoelectric actuators. But even this arrangement was not optimal. A somewhat different way of supplying fuel is accumulator systems with pressure accumulators (schematically shown in Figure 1). Such an arrangement is often referred to as Common Rail (CR). CR is a pressure accumulator that is continually refilled to provide high-pressure fuel availability. From there, the fuel is then distributed to the injectors to provide the required fuel dose setting. The injectors themselves are relatively complex and highly accurate electrically controlled valves. The advantage of such an arrangement of the hydraulic circuit with the CR is, in particular, during operation a constant supply of high pressure fuel as a source for operational injection control.

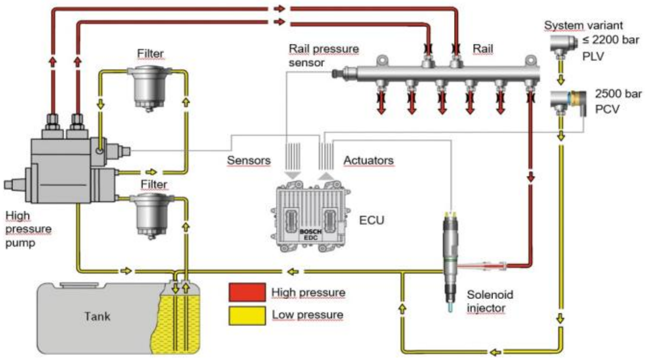

Figure 1. Hydraulic scheme of Common Rail system. from the fuel tank through the low- and high-pressure pump and the fuel tank through the hydraulic line to the injectors.

4 INJECTION CONTROL

Achieving high efficiency but also controlling emissions, in particular noise, vibration and pollutant emissions, is subject to strict timing of individual parts of the fuel batch. It consists of a sequence of parameters dependent on injections. The first group consists of a very small pilot dose - a pre-injection (or several pre-injections) that is initiated before the end of the piston compression stroke, ie several angular degrees before top dead center (TDC). The main injection represents a substantial fuel supply of several angular degrees behind TDC. Another additional injection (or late injection - usually two post-injection) of a small amount of fuel affects the reduction of pollutants. Injection units have been of great importance in the past. Their quality influenced both performance parameters and operational reliability. The current trend of strict limitations on consumption and other negative phenomena poses extraordinary pressure on the design and operation of the fuel system. Injection units are now relatively complex electrically controlled elements and play a dominant role in high-pressure CR systems. It has to meet the main fuel distribution requirements. These are in particular controlled dosing sequences, which must comply with current operating parameters. That is, accurately determining the dose size, start and duration, with precision to the angular degrees of crankshaft rotation. On the timeline, the interval is very short (in fractions of milliseconds). The speed of such actuators is therefore extraordinary and the accuracy requirements are high. The response of actuators to the control signal is not entirely proportional, so signal modulation is the subject of development - the following figure (Figure 2) shows an example of a control signal modification. The characteristic in the figure shows the difference in timing and shortening the reaction time - the green characteristic shows a new (shorter) time interval for the series of injections. From the difference in the size of the areas under the curves it is possible to consider differences in the fuel supply - the adjusted signal corresponds to a higher fuel supply, even in a shorter time interval.

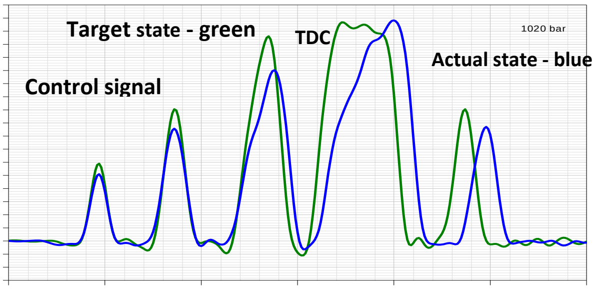

Figure 2. The timing of the control signal. Time

The main representatives of current injectors are electromagnetically operated injection units (solenoids) and piezo injectors (Figure 3). The latest in-market injectors include an electromagnetic injector with a so-called multiplier. The advantage of piezo injectors is that the individual injections are more accurate and faster due to the almost instantaneous reaction of the piezoelectric element to the change in the supply voltage. They work under difficult conditions. In addition to quasi-static loads (they work at pressures above 200 MPa), they have to face the dynamic phenomena that complicated and fast injection mode is.

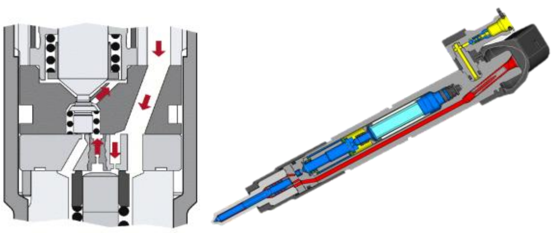

Figure 3. Injection unit with piezo-actuator. The stroke of the needle is controlled by a piezoelectric element. In the left part of the figure, the initialization process is indicated. The almost instantaneous reaction of the piezoelectric element to the change in the supply voltage guarantees fast and very accurate timing of each injection.

The demanding operating mode of the combustion engine, on the one hand, and the high demands on impeccable functionality, force designers to continuously upgrade the fuel system and its components. An example of such a modification is shown in Figure 4. The original arrangement in which the pressure force from the high-pressure circuit was used to activate the piezo-actuator was replaced by another solution. The power source for the initiation is derived from the low-pressure circuit (low-pressure - waste hydraulic branch). The load of the control mechanism can be significantly lower, which brings many advantages. These include a lower wear rate, but also a faster response.

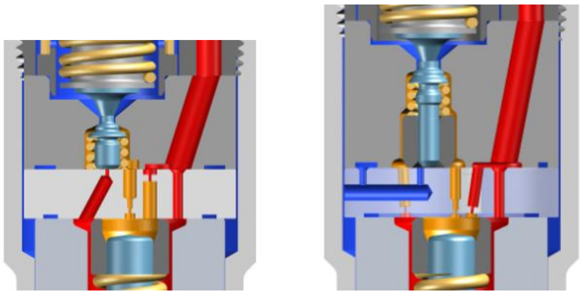

Figure 4. Piezo-valve innovation. The figure on the left represents the original version (the control force is derived from the pressure in the high-pressure branch), on the right is a different design with connection to the low-pressure - waste hydraulic branch (with a pressure of approximately 1MPa).

5 CONCLUSIONS

Although strong pressure on the development of so-called electromobility could be a precursor to the end of a drive train with a traditional combustion engine, it is precisely thanks to the development and application of progressive systems that the required performance parameters are achieved, with significant reductions in negative environmental impacts. The diesel engine fuel system hydraulic circuit is still a major challenge for designers. By exploiting the benefits of a combination of mechanics, hydraulics and electronics, the parameters of the internal combustion engine can continue to improve.

The paper shows the trend of the development of diesel engine injection systems and points to some concrete examples (only selected examples with respect to the protection of property rights).

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