Development of the measuring system on multi-stage injection rate and quantity for diesel injection pump

Akio Takamura (ONO SOKKI Co., Ltd.)
Masamichi ONO (ONO SOKKI Co., Ltd.)
Yukimitsu Omori (ONO SOKKI Co., Ltd.)
Susumu Fukushima (ONO SOKKI Co., Ltd.)
Satoshi Ishikawa (ONO SOKKI Co., Ltd.)

1. Outline

Although the high thermal efficiency of a diesel engine is attractive to avoid global warming, reduction of exhaust gas emissions and combustion noise are subjects to be solved. Multi-stage injection using a piezo electric common-rail fuel injection system is effective to solve the subjects and has been coming into wide use. On the other hand, there had been only classical methods for the measurement of injection rate and quantity, however, they could not measure these individual values at each injection stage in multi-stage injection. We developed a new technology, which realized to develop new equipment for measuring injection rate and quantity of multi-stage injection, as a result of our R&D activities that have been continued for many years. The equipment with the constant volume method, a high-speed discharge mechanism and a new data processing method was added to the product line-up. It enables to measure the injection timing and duration with a high accuracy at each injection stage. An internal calibration device can automatically measure a change in bulk modulus of the fuel due to changes in back pressure and/or its temperature, and correct necessary data in taking its influence into account. The equipment is also applicable to the DME (Di-methyl Ether) and bio-fuels. The equipment has been introduced into not only overseas makers that have led the de facto standard for the measurement of injection quantity, but also main domestic and overseas manufactures of injection systems and diesel engines and plays an active part as the mother machine for inspecting products and has internationally obtained the acknowledgement as the new de facto standard. This new technology has significantly contributed to improve the quality of multi-stage injection system with piezo electric injector.

2. Technical overview

In the case of the volume measuring method using a cylinder and a piston, it is difficult to measure injection rate and/or quantity under high-pressure, high-speed or small-injection-quantity conditions. Hence, we started a research on a device of detecting injection rate in considering that it is possible to improve time-resolution and volume-resolution functions on the constant volume method, which measures injection quantity from the change in the pressure in a high-pressure, constant-volume chamber,

and developed the injection rate detection device FJ-6000. In 2004 we have it progress to FJ-7000 that can precisely measure 12-stage injection.

Figure 1 shows scheme of this system. The main problems to be solved, at the measurement of injection rate and quantity with a data processing applied to pressure waveforms in the high-pressure chamber when fuel is injected into it, are as follows:

(1) Elimination of pressure noise in the high-pressure chamber;

(2) High-speed discharge of injected fuel;

(3) In-situ calibration of bulk modulus of the fuel in the high-pressure chamber.

To minimize the pressure noise due to high-speed, high-pressure injection, several parameters, such as the design geometry of the chamber, the type and mounting position of the sensor, the mounting method of the injector on the chamber, back pressure, etc. were optimized. The resonant frequency of the chamber was designed over the frequency of the multi-stage injection (10 kHz) and digital filtering technique was applied to eliminate high-frequency noise over 10 kHz with FFT digital filtering.

To realize high-speed fuel discharge we designed and developed a new air-cooled electromagnet valve. To comply with high injection pump speed of 4,000 min^{-1}, high-speed response was necessary; furthermore, to prevent the change in the chamber volume, we completed a special electromagnetic valve that made no leakage with metal touch sealing.

Two different methods were adopted to calibrate the bulk modulus of the fuel. The first one is to automatically correct the bulk modulus with the updated value all the time in comparing with the accumulated fuel quantity measured by the precise flow meter set in the discharge line of this detector with the integrated injection quantity. The second one is to perform an in-situ precise calibration by measuring bulk modulus with the device, when the cam and piston, which are installed in the chamber, generate small and constant volume fluctuation amplitude, and by comparing it to the known value. A precise measurement can be kept by automatically performing the first method all the time and performing the second one at inevitable timing.

3. Summary

We started the research on the equipment based on the constant-volume method since 1988. This was 7 years before1975, when the common rail system firstly launched in the market. After this, the equipment has been widely spread because of increased requirements for measuring the multi-stage injection; resulting in sales of the equipment to 18 domestic and overseas companies. The equipment has been introduced into not only overseas makers that have led the de facto standard for the measurement of injection quantity, but also main domestic and overseas manufactures of injection systems and diesel engines and has internationally obtained the acknowledgement as the new de facto standard.

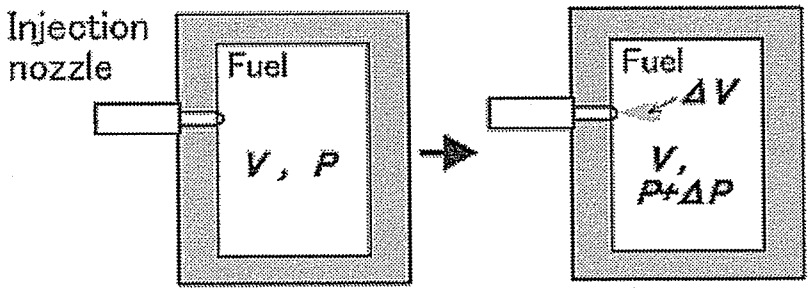

Fig.1 Scheme of the constant volume method.

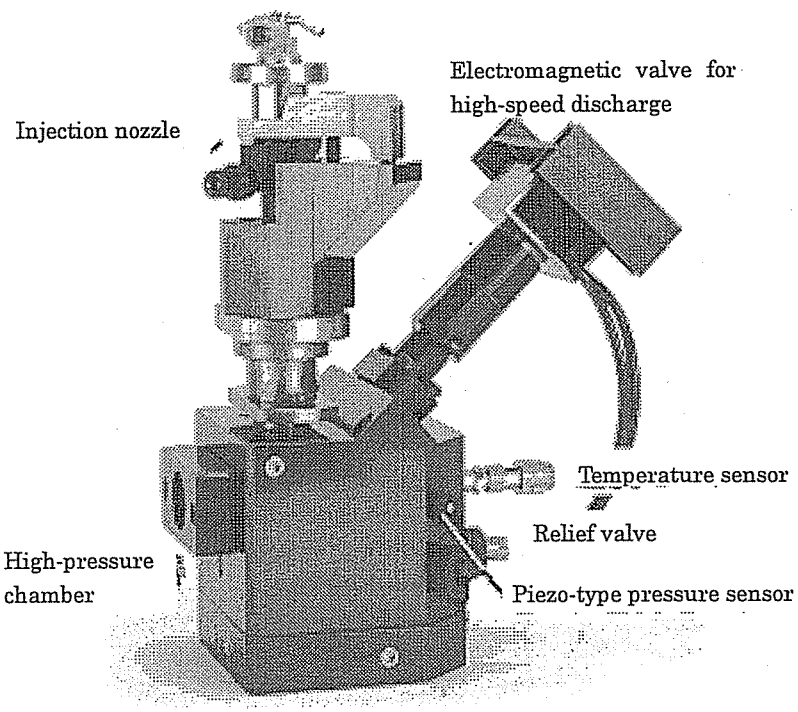

Fig. 2 Photograph of detecting apparatus.

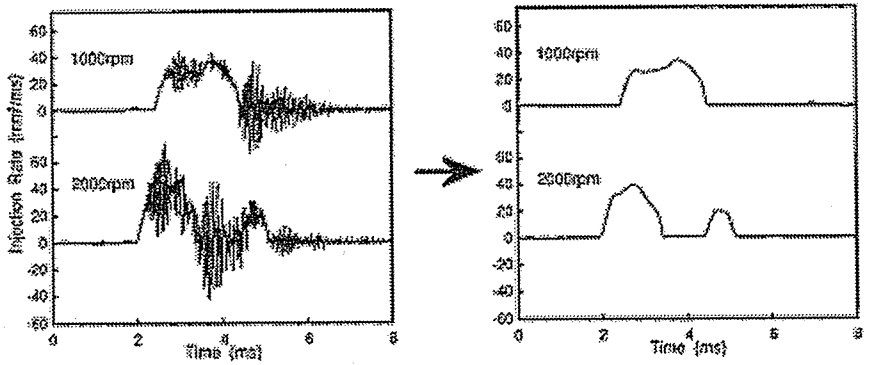

Fig. 3 Pressure noise elimination by FFT digital filtering.