Development of Diesel Engine using New Fuel Injection System
-Direct Monitoring of Fuel Injection Pressure using Injector with Built-in Sensor, and its Applications -

Takeshi Miyaura, Atsushi Morikawa, Yoshiyasu Ito (TOYOTA MOTOR CORPORATION)
Koji Ishizuka, Toyomori Tsuiki (DENSO CORPORATION)

1. Overview

Recently, diesel engine has been improving its environmental performance. However, it is still difficult for the diesel engine to adopt the strengthening of emission regulation and various kinds of diesel fuels simultaneously. Thus, we have developed on injection system to automatically compensate over the course of its lifetime, which is called i-ART (Intelligent Accuracy Refinement Technology), and adopted IMV (Innovative International Multi-purpose Vehicle) diesel engine (KD model) for Brazil. This engine equipped with the i-ART has successfully passed a new emission regulation and is compatible with the various kinds of diesel fuels used in Brazil.

2. Technology details

A conventional injection system could only detect an injection quantity based on indirect methods such as combustion or an engine rotation fluctuation, whereas the i-ART enables a direct detection of the injection quantity. There is a unique point of the i-ART, for which each injector is equipped with a built-in fuel pressure sensor to directly measure injection pressure inside the injector. As shown in Figure.1, based on the information from the built-in pressure sensor, the Engine Control Unit (ECU) reads fuel pressure values for each injection rapidly, and calculates an actual injection quantity and timing by a rapid waveform processing. The learning value for the injection quantity and timing calculated with the i-ART is applied to subsequent injections through its lifetime.

Figure.2 (upper) shows the actual pressure waveform by the i-ART pressure sensor. The i-ART performs a pre-processing by compensation to the no injection pressure waveform to estimate the injection quantity and timing correctly, and calculates the injection rate based on the processed pressure waveform optimized by filtering. The injection rate can be expressed by five parameters of a trapezoid shape. Calculating the area of the trapezoid, the injection quantity is obtained. (Figure.2 bottom)

Learning with the i-ART starts immediately after the injector is installed in the engine. The i-ART learns the injection quantity and timing constantly while the engine is in operation. It has two advantages by using this characteristic. The first advantage is an adoption of the triple pilot injection with high accuracy of injection quantity. The triple pilot injection allowed a lower a compression ratio to 15.0 (previous model was 17.9) . It also allowed to maintain an enough preheating effect so that a deterioration of fuel ignitability with the lower compression ratio due to the lower cylinder temperature can be avoided, thus it reduces both NOx and PM. Since the injection accuracy was improved with the i-ART, the second advantage is an adoption of a cetane number detection. The cetane number detection logic is to estimate the difference of the engine speed fluctuations by fuel characteristic, allowed a stable combustion and minimized combustion noise change regardless of the various cetane number fuels in the market.

3. Summary

The i-ART system was adapted to the IMV for Brazilian market with the needs of the compatibility to the stringent emission regulation and various kinds of fuels. With the high accuracy by the i-ART, the combustion improvement by the lower compression ratio, substantial reductions in both NOx and PM, and the adoption of the cetane number detection covered various kinds of fuels were achieved. CO2 was improved by 5% from the previous model with the lower compression ratio, the accuracy improvement of injection quantity and timing, and the engine calibration improvement, although this was a combined effect.

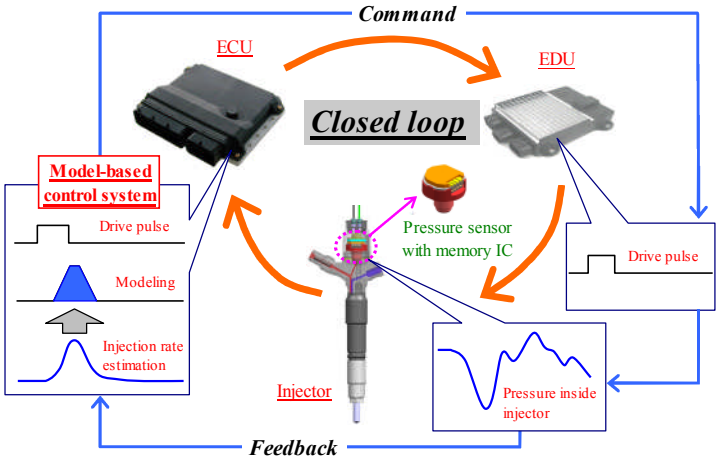

Fig.1 i-ART injector and overall structure

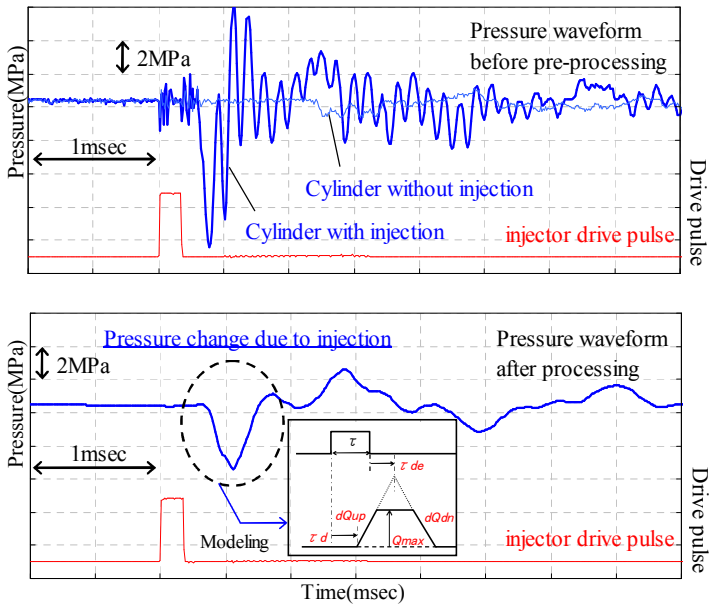

Fig.2 Pressure waveform in injector
(upper: before process, bottom: after process)

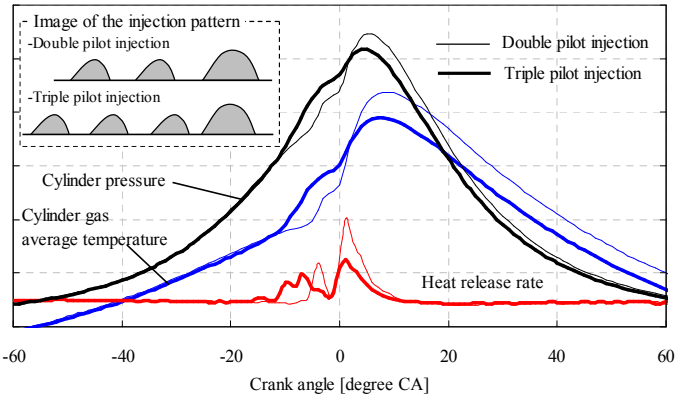

Fig.3 Comparison of the rate of heat release
(double and triple pilot injection)