Common rail injector for the diesel engines and different fuels

PETR STARY
Technical University of Liberec
Studentska 2, 461 17 Liberec
CZECH REPUBLIC

petr.stary2@tul.cz

Abstract: The paper deals with the problems of the injector for high pressure Common Rail fuel system. The test results on the experimental stand for the Common Rail injectors are discussed. The monitoring of the needle movement course is of great importance to the future research which will study the relationship between the movement of the solenoid lifting and dynamics of the input pressure.

Key-Words: Common Rail, Injector, Experimental Stand

Introduction

Thanks to relentless development of injection systems and application of turbochargers with intercoolers for air intake the diesel engines have been keeping pace with continuously higher and higher requirements for rated power, low fuel consumption and reduction of harmful emissions. The Common Rail fuel injection system adequately meets such requirements because it features high injection pressure ensuring accurate fuel metering and its efficient mixing with air.

The high-pressure part of the Common Rail system ensures generating the controlled fuel pressure in the high-pressure pump, maintaining the high pressure in the Rail and metering accurately the amount of the fuel by the injector.

The primary task of the Rail is to deliver the high-pressure injectors with fuel having the specified pressure. The fuel pressure is measured by a common rail sensor and its specified level is maintained by a pressure control valve located either on the rail or on the high-pressure pump. The fuel is delivered from the rail to the injector by a high-pressure fuel delivery pipe. Before entering the injector, the fuel flows through a flowlimiter whose safety function is to interrupt the fuel flow if the flow rate increases due to a common rail injector leak. The common rail injector nozzle leaks permanently and the amount of fuel exceeds the specified level. Moreover, the flowlimiter should absorb the amount of fuel delivered during the injection when the delivered fuel pressure drop occurs.

Solenoid operated injectors control the needle movement by means of changes in pressure applied to the needle body which are caused by the fuel flow back to the tank through a solenoid operated ball valve.

The values specifying in particular the nozzle opening start and velocity, the duration of opening and the nozzle closing velocity are specific for the needle movement curve pattern. The values affect the injected fuel amount pattern.

Table 1 Engine Specifications

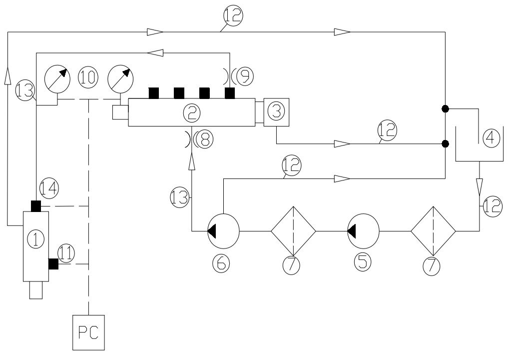
ESC Test Point	Engine Speed (rpm)	Rail Pressure (bar)	Torque (Nm)	Fuel Mass Flow Rate (g/cycle)	Peak Cylinder Pressure (bar)	Duration of Injection (Deg CA)
8	1900	1400	670	0.122	164	28
9	1900	1025	177	0.034	104	9

Measurement Description and Methods

For model testing at the experimental stand, initial parameters of two operating points (point 8 and point 9 of a 13-point ESC test, See Table 1) were defined which were based on extensive experiments conducted in the past on a Cummins ISBe4 engine with the Common Rail fuel system with injectors controlled by electromagnetic actuator [3] and [4]. The engine in question is a supercharged engine featuring the intake air intercooling and having an engine displacement of 4 dm^3 and rated power of 140 kW at 2400 rpm. The measurements were performed in accordance with the methodology of the 13-point stationary ESC test.

Fig. 2 Location of the piezoresistive pressure sensors at the test station

Fig. 3 Layout of pressure sensors at the test station



Injector, 2- Rail, 3- Pressure regulation, 4- Tank, 5- Low-pressure pump,6- High pressure pump, 7- Fuel filter, 8- Throttling the inlet to Rail, 9- Throttling the output from Rail, 10- Pressure sensors, 11- Needle lift sensor12- Low-pressure pipe, 13- High-pressure pipe.14- Lifting armature sensor

The experimental stand (See Fig. 2 and 3) contains the identical Common Rail fuel system elements as the internal combustion engine Cummins ISBe4 (a high-pressure pump, a Rail, a solenoid operated injector, a high-pressure pipe, piezoresistive sensors), it means the elements identical to the system used in the engine. Sensors Kistler 4618 A2 were used to measure the dynamic fuel pressure in the Rail and before the injector. The duration of the solenoid activation (the injected amount) was controlled by the ADCIS unit which enabled the realization of only one injection per cycle. The piezoresistive sensor signals were saved by means of our own software using the increment of 0.2°CA.

Measuring and its Evaluation

The work focused on the experimental verification of how the dynamic changes in fuel pressure pattern before entering the injector affect the injector parameters when the controlling voltage setting and electromagnetic coil current values remain the same. Besides, the work examines if the armature movement can be sensed. The effect of a biocomponent in the fuel (in concentrations of B0, B30, B50 and B100) on the injector parameters (the nozzle opening duration, the course of armature lifting, fuel amount and the dynamic pressure patterns in the Rail and at the injector input) at the fuel temperature ranging from 38-40 °C was examined.

Fig. 4 The dynamic pressure pattern before the injector at 9°CA,1025 bar, 1900 rpm

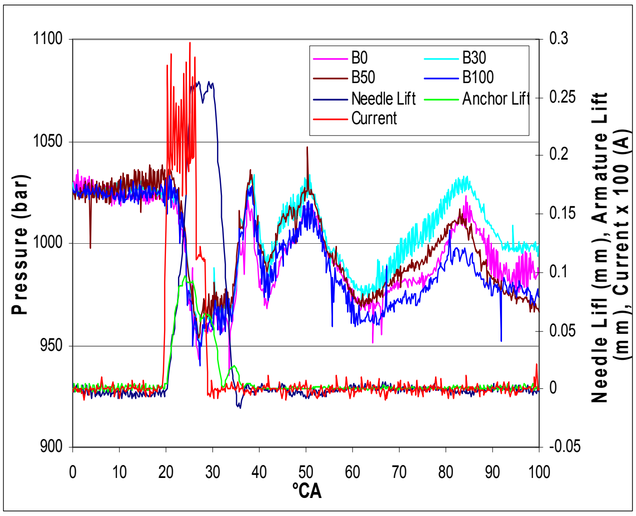
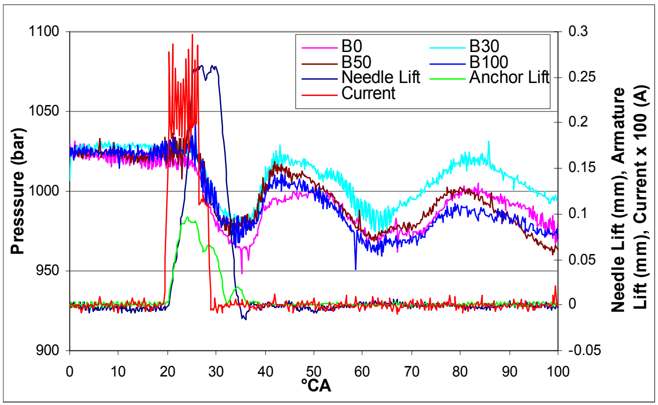


Fig. 4 illustrates the dynamic pressure patterns at the input to the high-pressure injector for the biocomponent concentrations from B0 to B100 and the needle lifting pattern, armature lifting pattern and electromagnetic coil activation current. The Figure 4 shows clearly the dramatic drop after opening the injector nozzle and the consequent pressure fluctuation. The nozzle opening duration is 9°CA at 1025 bars and 1900 rpm.

The following Figure (5) shows the fluctuation of pressures in the Rail for the identical injection parameter setting i.e. 9°CA, 1025 bars, 1900 rpm. The pressures will become stable, i.e. they will return to their initial values of 1025 bars after approximately 180 °CA.

Fig. 5 The dynamic pressure patterns in the Rail at 9°CA, 1025 bars, 1900 rpm



The full load of the engine at 1900 rpm was another mode which was examined within the 13-point test. This corresponds to the injector nozzle opening duration 28°CA and injection pressure of 1400 bars in the Rail. The following Figures show the dynamic pressure patterns and other measured quantities in the mode of full load for the biocomponent concentrations ranging from B0 to B100.

Fig. 6 The dynamic pressure pattern before the injector at 28°CA,1400 bars, 1900 rpm

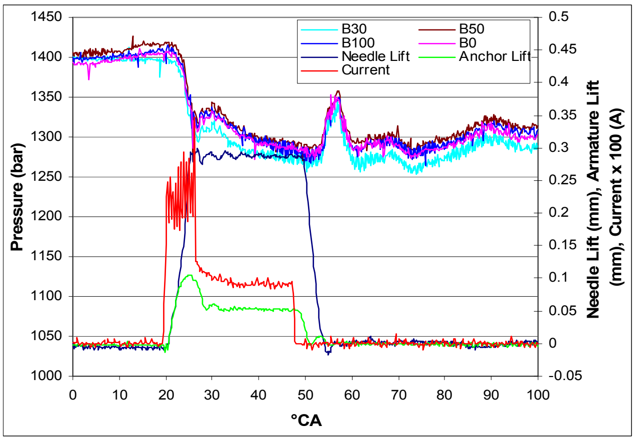
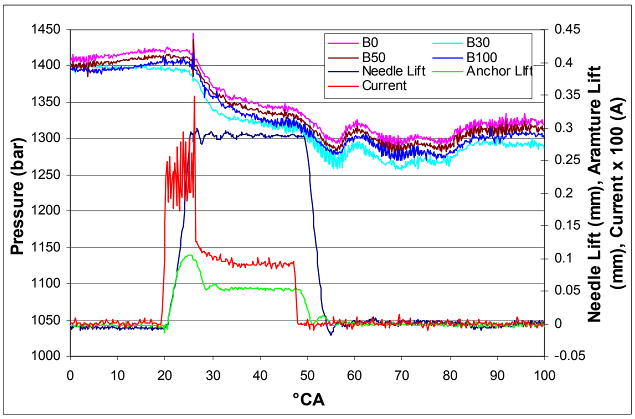


Fig. 7 The dynamic pressure pattern in the Rail at 28°CA,1400 bars, 1900 rpm



Figures 6 and 7 illustrate behaviour of the dynamic pressures in the Rail and before the injector for the set injector nozzle duration, 28°KH and pressure of 1400 bars. The setting shows clearly the time delay between the current supply start to the electromagnet coil and the subsequent response of the armature, which corresponds roughly to 1°CA. The time delay between the armature response and the injector nozzle needle is almost insignificant.

Effect of the Biocomponent on the Fuel Amount per Cycle

Other examined parameters were the fuel amount per cycle and the waste quantity of the high-pressure injector. The amount of fuel which flowed through the injector nozzle and the solenoid valve ball is measured gravimetrically. The measurement can help us assess the condition of the injector from the view point of stability of supplied amount of fuel per cycle as well as express the overal injector efficiency and characteristics.The ratio between pure diesel (B0) and pure biocomponent (B100) was used for comparison. The following two graphs show the amount of fuel supplied through the nozzle per cycle (Fig.) and waste fuel quantity which flowed through electromagnetic coil valve back to the fuel system waste pipe (Fig.9).

Fig. 8 Comparison between B0 and B100 amounts per cycle

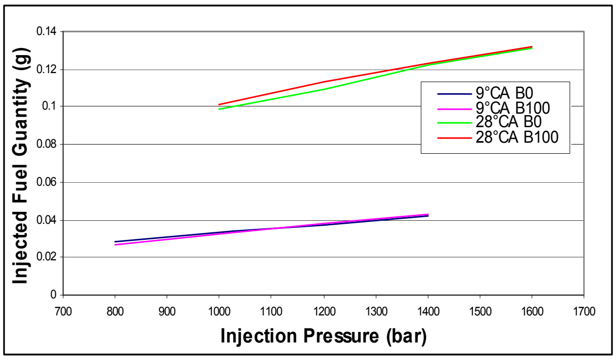
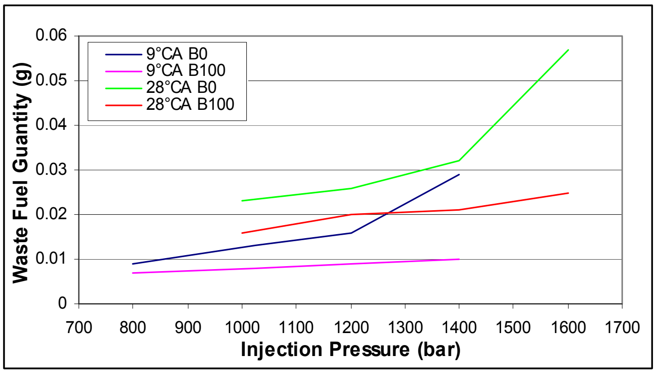


Fig. 9 Waste fuel quantity comparison (for B0 and B100)



Figures 8 and 9 indicated that there is a minumum effect of the biocomponent on the fuel amount per cycle, both for the injector nozzle opening duuration of 9°CA and 28°CA within the whole range of measured pressures from 800 to 1600 bars. More significant differences relate to the waste fuel quantity, for the same setting of pressures and injector nozzle opening duration. Considering that no time difference for individual pressures was recorded from the detailed measurements of the armature lifting and needle lifting patterns, the small flow rate through the electromagnetic coil ball cannot be attached to a different position of the armature and injector nozzle needle closing. A potential explanation can be connected with different density for B0 and B100. When the ball valve is opening, the flow rate is massively throttled by the input cataract which, in the ratio of areas considered, is significantly smaller than the whole area of the injector nozzle outlet orifice. This could cause redistribution of flows between the nozzle and the ball valve so that the higher percentage of the total input fuel amount flowing to the injector can flow through the injector nozzle orifices. These effects will be examined in detail.

Conclusion

The work focused on verification of how the FAME biocomponent in diesel fuel in concentrations of B0,B30,B50 and B100 affects the high-pressure injector behaviour. The measured data indicate that the biocomponent content neither affects the time setting of the Common Rail high-pressure injector nor has an effect on characteristic dynamic pressure patterns corresponding to diesel fuel. The measurement of the monitored quantities was carried out at the fuel temperature ranging from 38 to 40°C and therefore it cannot be expected that any higher temperatures would significantly change the system behaviour from the viewpoint of the dynamic pressure patterns and injector timing setting. Another goal of the work was to verify how sensing of the electromagnetic coil armature movement can be made and consequently, how the delays of the individual parts of the injector could be specified both in the course of the solenoid activation itself and the high-pressure injector nozzle closing. The measurement did not demonstrate any difference in characteristics between the pure diesel fuel and any biocomponent concentration which had been used. However, some partial design shortcomings related to the sensor installation were seen. These can be noticed from the armature lifting pattern itself. In particular, at the beginning and at the end of the armature movement the pattern is accompanied by plate bouncing from the armature itself in limit positions. This happens because of inertial masses of the plate and insufficient thrust between the sensor plate and the electromagnet armature. Consequently, as far as the measured values are concerned, only the beginning of the armature movement and its velocity (slope) can be taken into account. The other values cannot be considered as accurate. To measure a real armature lifting pattern, a fixed attachment between the sensor plate and the electromagnetic coil armature is a must. This will necessitate new design solutions for the needle movement sensor installation.

Acknowledgement

This paper was prepared with financial support from the Student Grant Competition TUL with the internal number 21009/115 under the specific university research.

References:

[1] Scholz C, Starý P, Experimental Stand for Research of Common-Rail Injectors, In: XLI. International Scientific Conference of Czech and Slovak Universities Departments and Institutions Dealing with the Research of Combustion Engines, Liberec, 2010, pp. 277-287. ISBN 978-80-7372-632-4.

[2] Scholz C, Starý P, Common Rail Injector Leak Testing. In: Journal of Middle European Construction and Design of Cars- MECCA, Number 03, volume XI, Praha, 2013, pp.22-28. ISSN 1214-0821, ISSN 1804-9338.

[3] Scholz C, Dynamic Analysis of Common Rail System. In: Research Report Nr. SM 633/2010, Technical University of Liberec, pp. 96.

[4] Scholz C, Starý P, Experimental Study of Common Rail Injection Diesel Engine Fuelled with RME and Diesel Fuel. In: XLII. International Scientific Conference of Czech and Slovak Universities Departments and Institutions Dealing with the Research of Combustion Engines, Zilina, 2011, pp. 277-287. ISSN 1337-8996.