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EXPERIMENTAL RESEARCH OF A COMMON RAIL SYSTEM FOR DIESEL ENGINES

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Abstract: This paper describes the design and experimental results of a test rig for common rail system. The test bench is comprised of a fuel pump, filter, the high pressure pump, flow regulator, common rail, safety valve and four fuel injectors and the adequate measuring instruments. Using this test bench we can measure the fuel flow through the return pipes of the injectors, the steady flow through injection nozzle into the burning chamber and the control of fuel spray. The test unit can supervise and control the fuel injection parameters: fuel injection timing, delivery, flow rate, common rail pressure.

1. INTRODUCTION

Electronic fuel injectors of common rail system are very sensitive components of high performance Diesel engines (maximum power, low fuel consumption and low exhaust emissions required for engine certification).
For that reason, the injectors should be dismantled and checked in accordance with the manufacturer's guidelines (every 50,000 km.).
A regular check-up consist of the following measurements:

- fuel flow rate through the injector in the combustion chamber;
- injector fuel return flow rate;
- fuel injector spray pattern test;

It was our aim to design and realize a test bench, described in [1], which allows checking the function of Electromagnetic injectors.
The test bench allows following parameters to be modified:

- injector opening time can be varied between 0.1 to 0.6 ms;
- injector opening rate between 20 to 100 openings/min;
- pressure in high pressure circuit (0 to $1500 \cdot 10^5$ N/m^2);

The best way to keep the necessary working pressure in the common rail system is secure leak tightness which depends on the tightness of the injector fuel return hose and needle fuel seal.
The measurements were made by assembling the injectors on the test bench, considering the prescribed tightening torques recommended by the producers.

2. MAIN FUNCTION OF THE TEST BENCH

2.1. Measurement of real amount of injector fuel return (injector back leak test)

The amount of fuel return of an injector was determined by collecting the fuel in a volumetric flask through plastic flexible hoses.
The measurement of fuel return of an injector assign variable pressures, starting with a minimum value corresponding to the throttle down regime and reaching a maximum value at full throttle.
For start up procedure, the pressure was build up by the high pressure pump, without starting the injector controls, all injectors being in the closed state during the test.

We can modify the pressure in the high pressure circuit, at values as above mentioned, by controlling the fuel flow capacity at the inlet of the high pressure pump. The control is assisted by a pressure sensor (in figure 1 is presented the curves of calibration), monitoring the common rail pressure.

Measurements were made consecutively to all four injectors at variable pressure, from $260 \cdot 10^5$ N/m^2 to $1200 \cdot 10^5$ N/m^2, in a course of 30 s for every pressure step. The results of the tests are plotted on the following charts (figure 2 a-d):

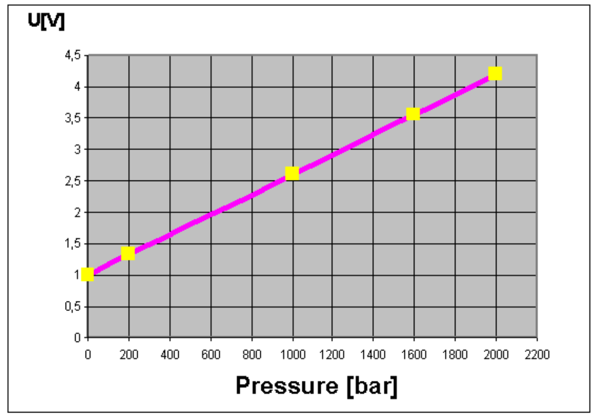

Figure 1: Pressure sensor calibration (output voltage of the pressure sensor vs. pressure in high pressure circuit).

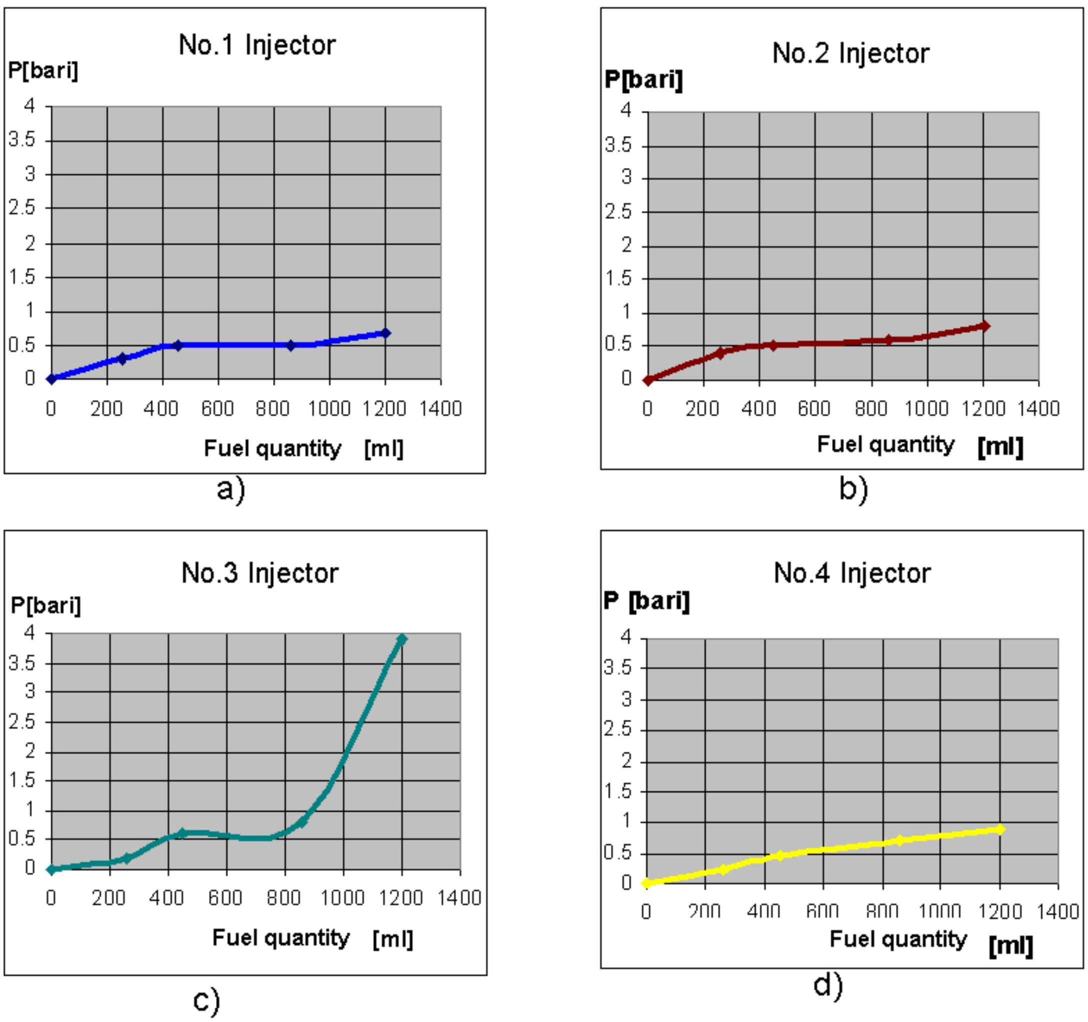

Figure 2: Amount of injector fuel return (injector back leak test)

Analyzing the charts in Figure 2, one can observe that injector No. 3 works correctly at low pressure but at high pressure, over $1000 \cdot 10^5$ N/m^2, it may show symptoms of considerable leak-off on the fuel return circuit. This means a considerable decrease of pressure in the

high pressure circuit. The pressure sensor appraises this leak-off and sends an electric signal to the fuel injection computer.
At it's turn, the fuel injection computer receives the sudden dramatic lowering of pressure in the high pressure circuit.
Considerable fuel leak is normally associated with a cracked pipe that means decrease in fuel supply at the high pressure pump.
This decrease can continue to emergency operation, working pressure can reach maximum $400 \cdot 10^5$ N/m^2, limiting engine power.

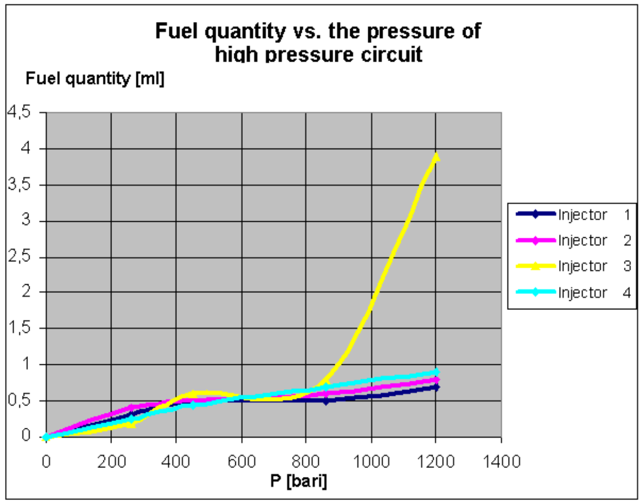

Figure 3: Amount of injector fuel return (superimposed plot for all 4 injectors)

2.2. Measurement of the amount of fuel injected in the combustion chamber

The cyclic injected fuel amount depends on the opening time of the injector and the tightness of the injection needle. The tightness is ensured by the holding spring and the correct laying of the needle on the injection nozzle seat.
The measurements were made using volumetric flasks, every flask having caps with holes, punched at the diameter of the injection nozzle.
The flask caps avoid fuel fine drops to dissipate in the atmosphere contributing to measurements accuracy and protecting the operator.
As in above mentioned practical example, the pressure varied from $260 \cdot 10^5$ N/m^2 to $1200 \cdot 10^5$ N/m^2.
Opening time of 0,1, 0,3 and 0,6 ms was imposed for every pressure. The measuring time was 30 s for every pressure and opening time.
For an opening time of 0,1 ms, the amounts of injected fuel are plotted in figure 4.
Exhaustive results of fuel amounts injected by every injector are presented in figure 5 (a-d).

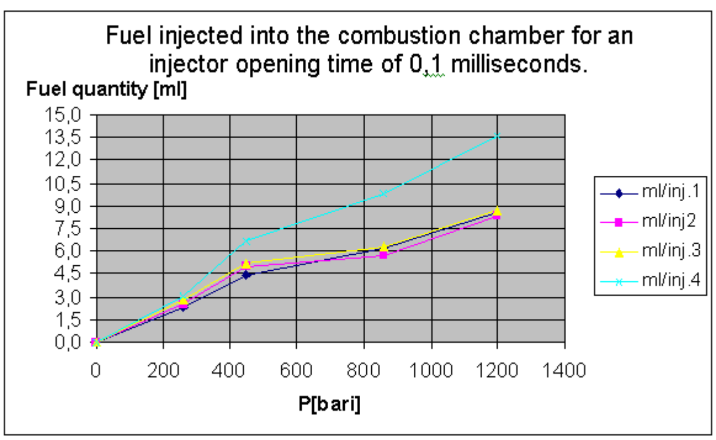

Figure 4: Amount of injected fuel in the combustion chamber for all 4 injectors

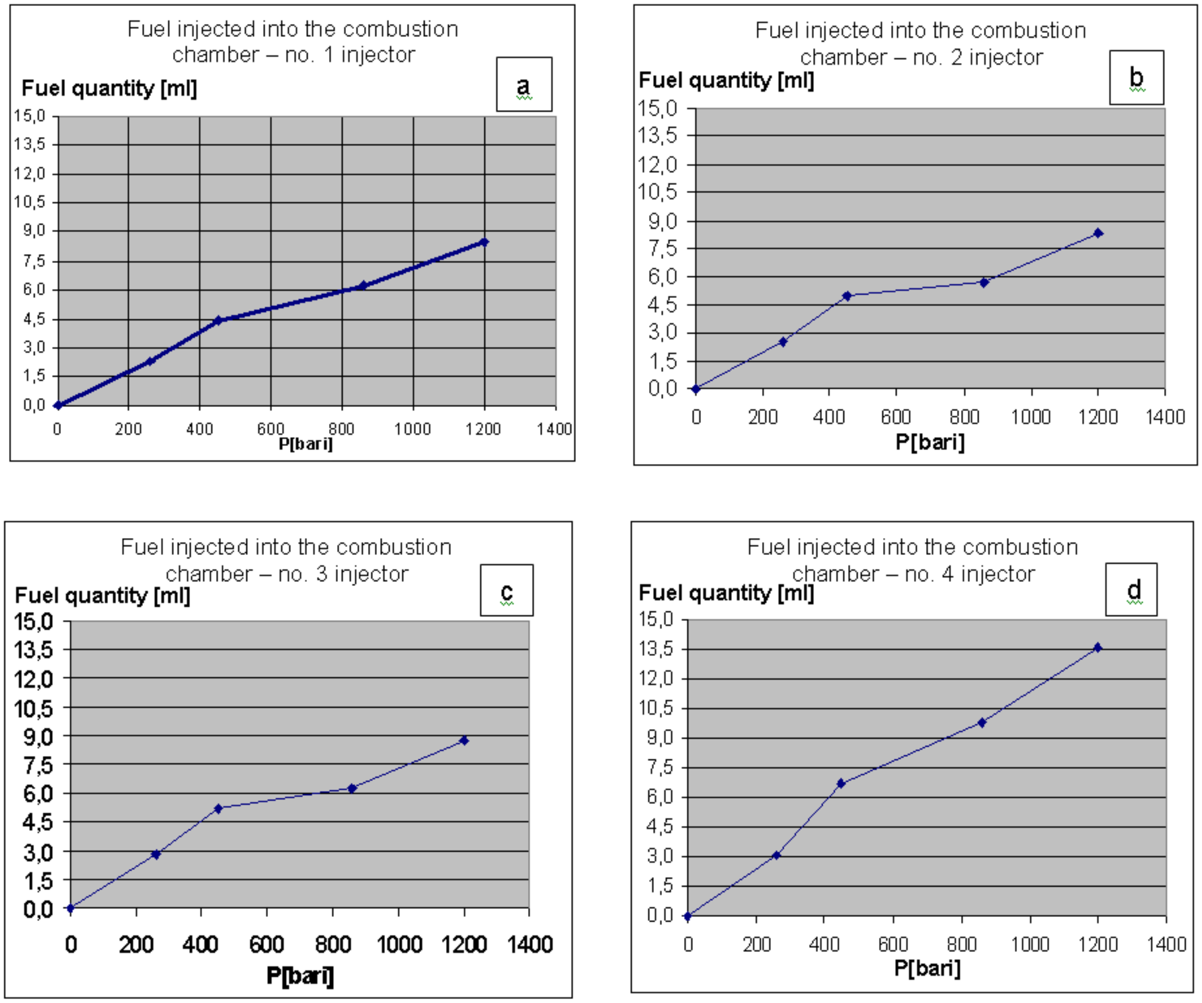

Figure 5: Amounts of fuel injected by every injector
a – No. 1 injector , b – No. 2 injector, c - No. 3 injector, d - No. 4 injector

Results of fuel amount injected in the combustion chamber at an opening time of 0,3 s are plotted in figure 6.

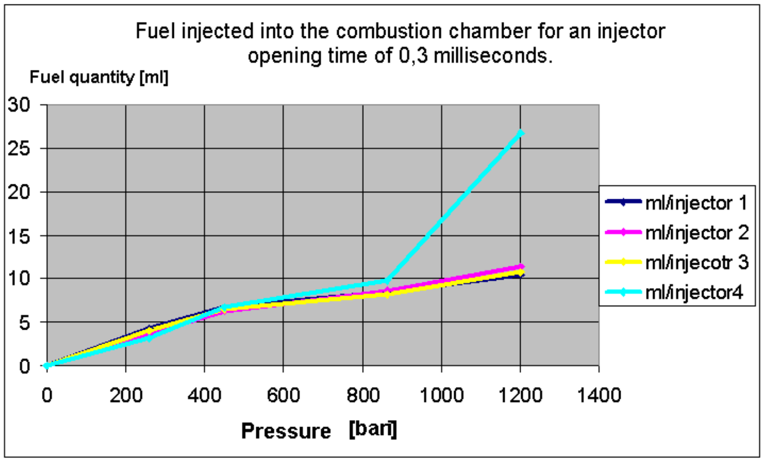

Figure 6: Superimposed plot of fuel amounts injected by all four injectors at an opening time of 0,3 ms

For pressure larger than $850 \cdot 10^5$ N/m^2, one can observe that injector No.4 supplies more fuel, irregularity of filling process, increase of specific fuel consumption, increase of exhaust emissions per cycle. Detailed results for every injector and test conditions are plotted in figure 7.

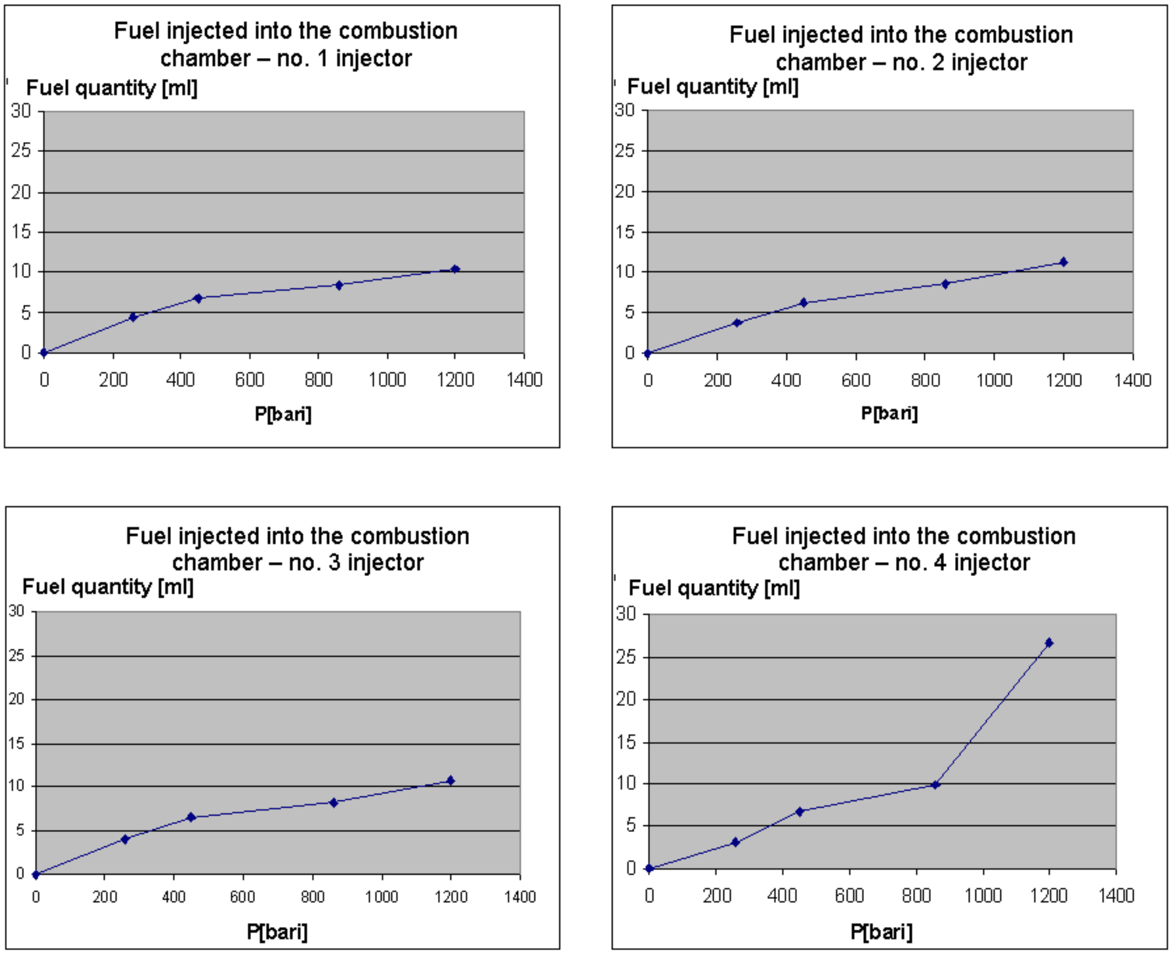

Figure 7: Fuel amounts injected by each injector at an opening time of 0,3 ms

Last experimental results were obtained by measuring the amount of fuel injected in the combustion chamber at an opening time of 0,6 ms.

Comparatively amounts of fuel delivered by all injectors are plotted in Figure 8.

The amounts of fuel injected by every injector are plotted in figure 9.

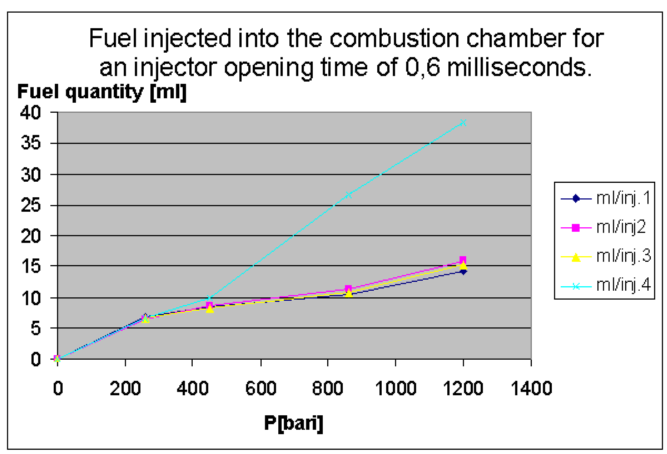

Figure 8: Superimposed plot of fuel amounts injected by all four injectors at an opening time of

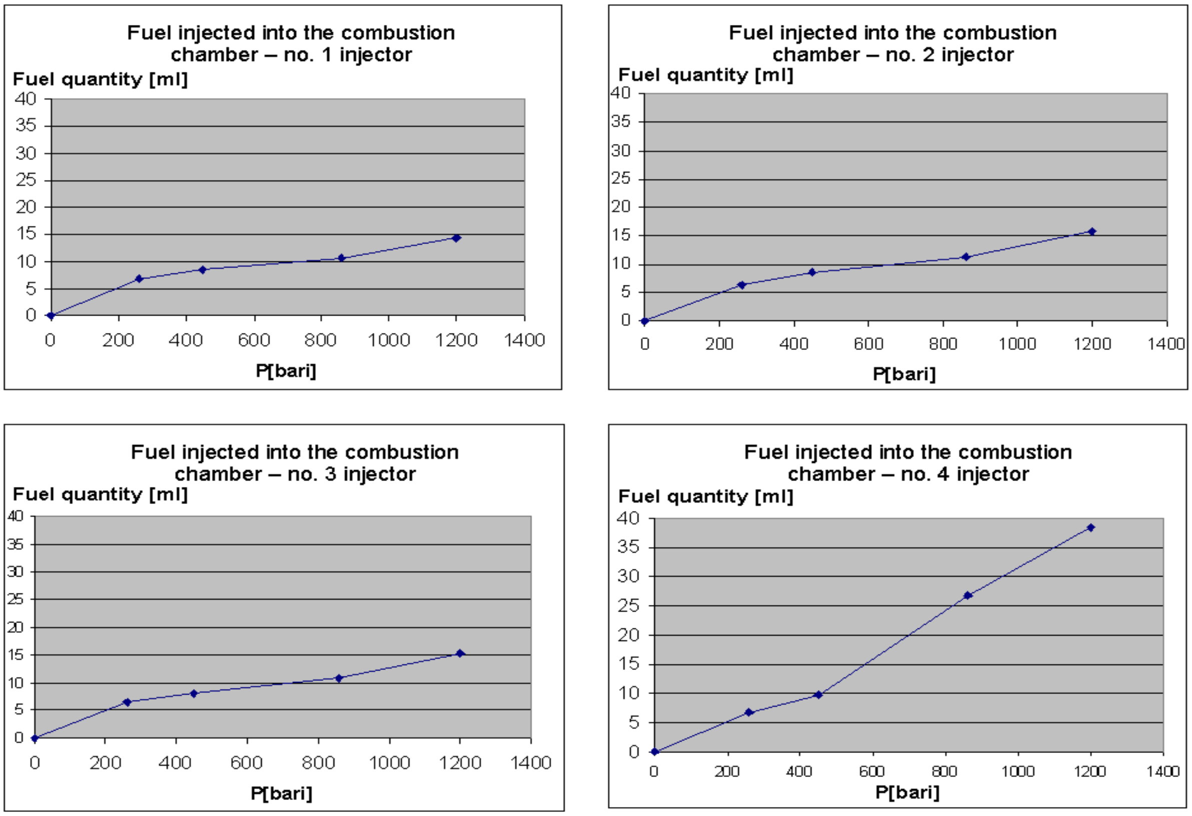

Figure 9: Amount of fuel injected into the combustion chamber for all injectors at opening time of 0,6 milliseconds.

3. CONCLUSIONS

Using this common rail injection tester we made a series of measurements to diagnose efficiently and accurately fuel injection equipment and injectors. In the first phase, we plotted the calibration plot (output voltage of the pressure sensor vs. pressure in high pressure circuit). After that we made the injectors back leak test. Studying the experimental results, we find out a disturbance of function at No.3 injector. Verifying the amount of fuel injected in the combustion chamber by No.4 injector, we find out that at medium pressure it is working properly. At high pressure and heavy work regime, fuel loss is double beside the average of the other injectors. This normally denotes a malfunction of the injector. One particular cause can be the risk of clogging of the needle completely or partially by very small solid particles in the fuel. Another cause can be the injector nozzles pressure spring. This spring can weaken or even break. The test bench allows a visual control over the appearance of the spray (figure 10) in every injector nozzle. This can be made by varying the opening time of the injector, frequency of opening and injection pressure. A detailed analysis of spray pattern can be made by high-speed shooting techniques.

Figure 10: Fuel injection spray

References:

[1.] **NCT-1500 Common Rail Tester Quick Manual,** www.nex-tek.com/.../NCT-1500%20MANUAL.pdf;

[2.] **F. Payri, J. M. Lujan, C. Guardiola, G. Rizzoni,** Injection diagnosis through common-rail pressure measurement, Proceedings of the Institution of Mechanical Engineers, Journal of Automobile Engineering, Volume 220, Number 3 / 2006.