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ANALYSIS OF THE PROCEDURE OF EVALUATION OF THE TECHNICAL CONDITION OF A HIGH-PRESSURE COMMON RAIL FUEL PUMP USING A TEST BED

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Abstract

Piston displacement pumps use in common rail fuel injection systems generates very high pressure, reaching even 300 MPa. Maintaining such a high pressure is possible thanks to very precise machining resulting in as little clearance between the piston-cylinder assemblies. Due to very high forces operating in the systems and relatively unfavourable lubrication conditions resulting from using fuel as lubricants, the pumps are subject to wear and consequently lose their operating parameters. The high cost of production of the pumps, resulting from their technological advancement, forced their manufacturers to introduce technologies for diagnosing and regenerating them. The diagnostics consists in removing the pump from the engine and having it verified using a test bed. The first stage consists of evaluating the pump's flow at null pressure; follow by evaluation of its maximal delivery for the pressure of 100 MPa. The obtained values are compared to the values achieved by a new pump. The effect of negative evaluation on a test bed is the disassembly of the pump, verification of the condition of its parts and replacement of the damaged elements. The authors examined new and used pumps on a tested, aiming to determine the characteristics of delivery of a pump for various pressures. The objective of the research was to identify the actual points in the pump's operation at which the delivery drops the most due to the wear. The highest difference in delivery was found to exist for the maximal compression pressure. The obtained results were analysed and the possibility of changing the pump diagnostics procedure with the use of a test bed was determined.

Keywords: *common rail, test bench, diagnostic*

1. Introduction

High-pressure common rail fuel injection systems are currently the most popular solution found in passenger car and truck engines. Given their very high precision of workmanship, connected to the necessity of achieving high injection pressure and the multiple division of the dose, the injection mechanism is costly to produce, which translates into the product's end price. It was therefore necessary to develop diagnostic procedures for the operated vehicles, which would allow testing injection system components along with the possibility of evaluating any damage and the justification of carrying out repairs, if necessary. A fuel pump, responsible for providing high, set pressure, is one of the most crucial and expensive elements of these systems. Fig. 1 shows how a pump is built, on the example of Bosch CP3, whose design is similar to the examined CP1H pump. The cam (1) placed on an eccentric shaft (3) is one of the pump's most important elements. This mechanism is set in reciprocating motion by a plunger (2) in the pump's section. A low-pressure gear pump (4) that sucks in the fuel from the tank and makes it possible to fill the pumping sections with it is located at the shaft's end. The pump's housing also incorporates a delivery adjustment valve (5) which allows the adjustment of the momentary delivery to the engine's current demand for fuel [1, 4].

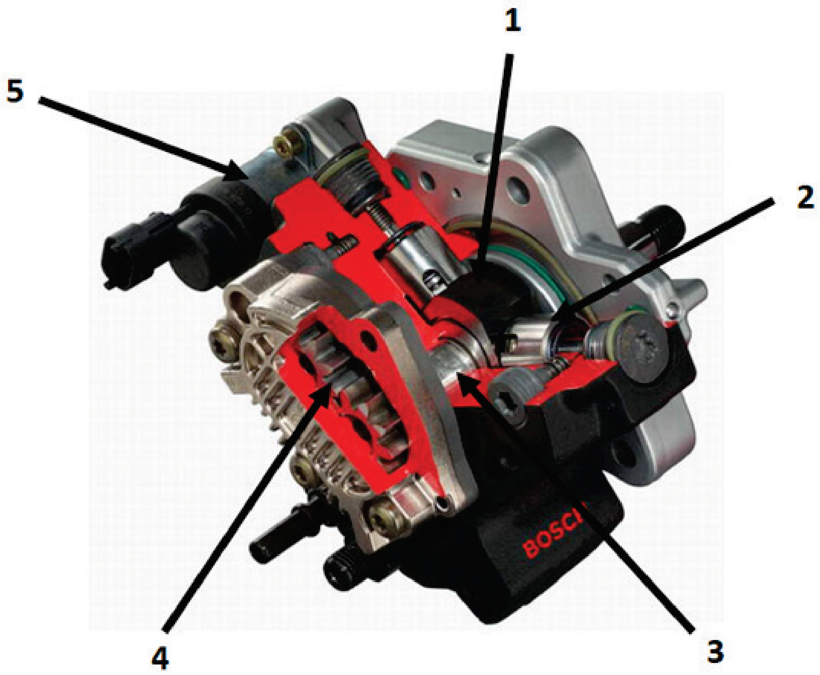

Fig. 1. Sectional view of the Bosch CP3 pump

The newest common rail pumps provide a very high fuel backpressure, up to 3,000 bars. The number of friction nodes is minimized in order to increase mechanical efficiency. It should be noted, however, that all pumps currently in production are radial piston pumps, feature one, two or three pumping sections and, depending on application, may have low-pressure pumps and delivery adjustment valves. Some pumps also incorporate a pressure adjustment valve. Still, this valve is found the fuel tank in most fuel systems. Given their common design features, similar problems appear during their operation, which reduce the flow or destroy pumps entirely [5].

Widely understood, poor quality of fuel and design errors are among the factors that most strongly affect the wear of pumps. Fuel quality should be understood as:

– the presence of abrasive micro particles or other impurities resulting from improper filtration of fuel or the wear of injection equipment,
– excessively low fuel lubricity,
– presence of water in fuel, which collects in the fuel tank and is not separated from fuel properly,

The damage effects may be different, depending on the factor contributing to the destruction, the duration of the destructive phenomena and the place of origin of the damage. Fig. 2 shows the examples of damage of common rail pumps. The low-pressure pump was damaged in the Continental pump. The impure fuel blocked the pump's blades making it impossible to supply enough fuel to the section. The operation with not enough fuel resulted in deteriorated lubrication within the section and the cam-plunger assembly, leading to their seizing. The damage in the Bosch CP4 pump was the result of a design flaw. The plunger, which has no guiding mechanism, rotated by 90 degrees in relation to the shaft, which replaced rolling friction with dry friction. This lead to very quick and intensive wear of the mating elements consequently leading to the creation of abrasive micro particles, which damaged the remaining fittings of the injection system. An improperly designed cam initiated the damage in Delphi DFP1. The generated high linear acceleration of the plunger, and hence the high force acting on it, combined with the cam's wrongly selected material results in its spalling. The spalling results in reduced cam lift, which translates into reduced maximal fuel dose, but also generates abrasive micro particles resulting, similarly to the case of Bosch CP4, in a very costly damage to the remaining elements of the injection system [2].

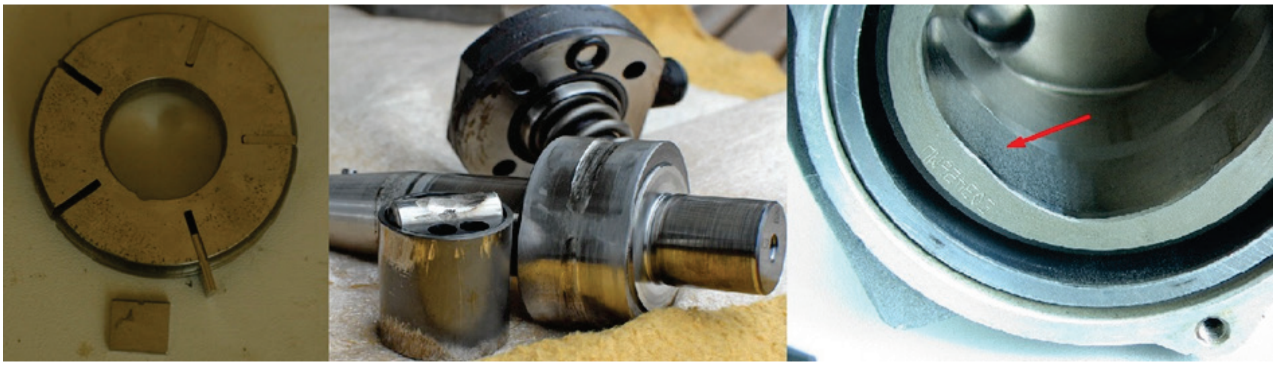

Fig. 2. Examples of damage of pumps by various producers, starting from left: Continental DHP, Bosch CP4 Delphi DFP1 [3]

2. CR pump diagnostics

Given the high cost of production of fuel pumps, diagnostic and regeneration procedures have been developed. Most manufacturers produce spare parts, making it possible to regenerate their pumps by replacing the damages elements. It should be noted that the previous chapter described mechanical damage leading to the destruction of the entire pump. In practice, the wear may be of a completely different nature and the reason behind fault operation of the pump may be the achievement of threshold dimensions values for the pump's individual elements, such as the plunger-cylinder or cam-roller assemblies. Increasing the clearance (space) within the plunger and cylinder area, may result in reduced delivery of the pump, which in turn may lead to the pump's increased temperature (delivery adjustment valve setting must be changed) and the reduction of the car engine's power, especially in the high RPM range of the crankshaft. Proper diagnostic procedures were determined for this purpose, allowing examining the efficiency of the pump removed from a car, on a test bed. The pumps' flow is checked, when the fuel pressure is zero. The pump's shaft is rotating at 1,000 RPM for one minute and the flow is measured for one minute. Next, with identical operating conditions, the pump's delivery is checked at the pressure of 1,000 bars. If the determined delivery and flow values differ substantially from their nominal values, the examined pump undergoes regeneration or is replaced.

The article's authors conducted examinations aiming to determine the limitations and inaccuracies resulting from the application of the method of evaluating the pump's delivery at one, constant fuel pressure value. It was stated in the research hypothesis that there exists a connection between the increase of fuel pressure and more prominent leaks in the pump's pumping section. CP1H pumps (Fig. 3) designated as CR/CP1H3/R70/10-7182S were used in the examination. Half of the examined sample was new pumps, while the other half were pumps removed from cars with mileage of 150,000-300,000 km. Three pumps were used in each of the group and the obtained results were averaged.

Delivery characteristics in fuel pressure function were plotted for each of the examined pumps. The minimal pressure value was 20 MPa, with 180 MPa being the maximum, which is the rated value for the examined pumps. Delivery in specific thermal conditions (pump warmed up, fuel temperature 40ºC) was determined for all examined objects, with 10 MPa pitch. A STPiW-3 test bed, made by Autoelektronika Kędzia (Fig. 4) was used for this purpose. The delivery measurement was made after achieving stabilization in a given point, with the use of a DHGF-2 flow meter made by Meister, with 2% accuracy of the measured value.

The setting of the delivery adjustment valve was fixed at 50%, corresponding to the pump's full delivery. The pressure adjustment valve was controlled using the fuel pump tester – common rail, with signal frequency of 25 Hz, to maintain the set pressure in the container. The valve's setting was also read during the measurements, but given the negligible differences, the results of these measurements were omitted. Tab. 1 shows the results of the examinations.

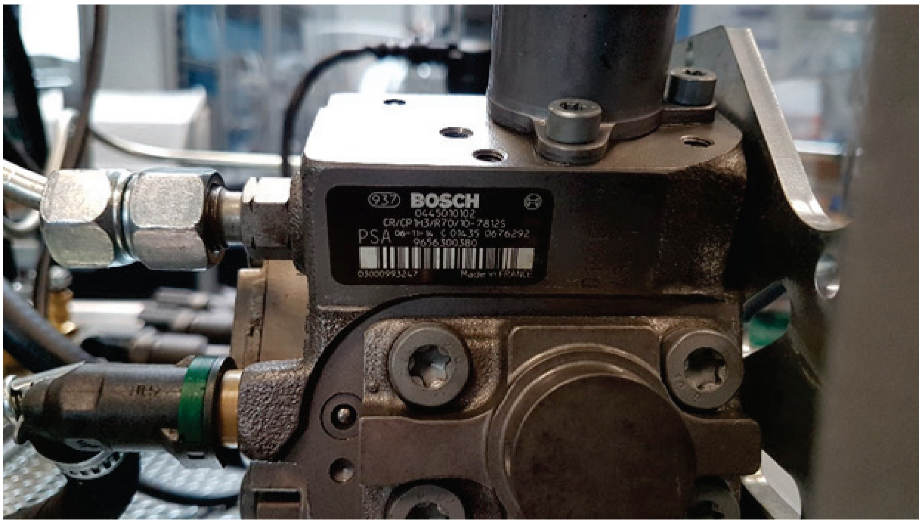

Fig. 3. The examined CP1H pumps

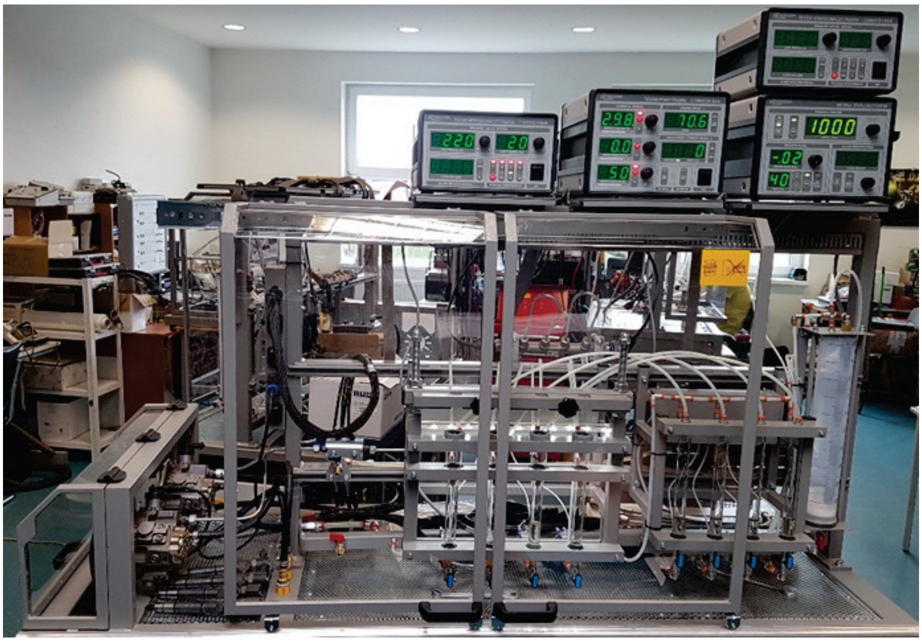

Fig. 4. The STPiW-3 test bed made by Autoelektronika Kędzia with measuring and setting devices and with the installed CP1H pumps

3. Conclusions

An observation was made during the examination that each of the examined pumps features similar characteristics within small and medium pressures, while significant differences were noted within the rated pressure area (Fig. 5). In practice, such parameters are used within the engine's maximal power area, at high RPM. The decreased delivery in this range may lead to pressure reduction at maximal delivery of injectors, resulting in reduced engine power.

The pump's wear, leading to its complete destruction, results in a serious drop in fuel delivery. In case of normal wear processes, resulting from the completed fuel backpressure cycles, the gap between the sliding surfaces of the cylinder and pump's plunge grows systematically. Due to the high pressure generated by common rail pumps, the gap must be sufficiently small to limit any leaks that may contribute to the drop in the pressure. Consequently, the identified difference in fuel delivery is particularly visible for high-pressure values, when the highest amount of energy is applied to the pressurized fluid and in turn when the forces exerted by the fuel on the elements making up the compression chamber are the highest. Within the plastic range, they allow the plunger's surface to grow slightly, thereby improving the sealing of the chamber, but when threshold dimensions are reached or exceeded, the value of plastic deformation is too low, and the chamber cannot be additionally sealed using the plastic phenomena within the plunger's crown area.

Tab. 1. Pump delivery examination results

Pressure [MPa]	Fuel volume [cm^3/min]	
	New pumps	Used pumps
20	709	699
30	698	690
40	692	686
50	689	676
60	690	675
70	684	674
80	677	668
90	668	659
100	655	645
110	645	634
120	639	614
130	619	594
140	607	568
150	589	548
160	566	516
170	547	492
180	518	457

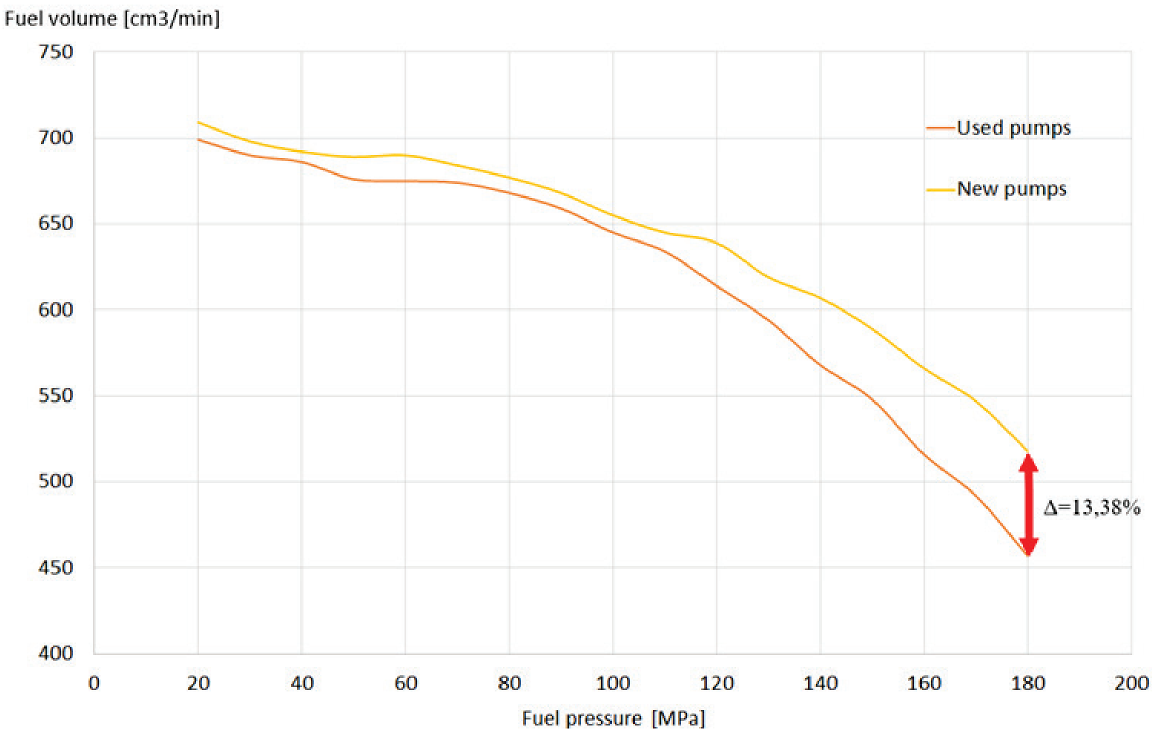

Fig. 5. Characteristics on new and used up pumps showing the difference in delivery for high fuel pressures

The performed examination allowed proving that introducing a diagnostic procedure that facilitates the evaluation of the pump's delivery across numerous operating points, with particular focus on the rated pressure value, is justified. Results falling within the range of measurement error were obtained, at pressures lower than or equal to 100 MPa, for new and used pumps, whereas the delivery different for high pressures was significant, exceeding 13%. It would therefore be advisable to expand the diagnostic procedures by at least two measuring points, namely for the minimal and maximal value of system pressure for a given pump.

References

[1] Zbierski, K., *Układy wtryskowe Common Rail*, Wydawnictwo Politechniki Łódzkiej, pp. 18-54, Łódź 2001.

[2] Karpiuk, W., Borowczyk, T., Bieliński, M., *Problemy eksploatacyjne układów wtryskowych typu common rail*, Logistyka – Nauka, Radom 2014.

[3] Training materials by CMS Autoelektronika Kędzia.

[4] Idzior, M., *Problemy doboru wtryskiwaczy silników o zapłonie samoczynnym zasilanych paliwami alternatywnymi*, Biblioteka Problemów Eksploatacji, pp. 34-65, Radom 2012.

[5] Gunther, H., *Układy wtryskowe Common Rail w praktyce warsztatowej*, WKiŁ, pp. 59-72, Warszawa 2010.

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