Diagnosis of the Unit Injection Pump's Elements

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Abstract. The paper presents the experimental and technical steps for diagnosis and optical investigation of the unit injection pump's elements for light and heavy diesel trucks, in order to establish the causes of malfunctioning and decision of replacing and/or repairing them. There will be presented some of the most usual damages and technical explanations and interpretation of the diagnosis tests.

Keywords: unit injection pump, diagnosis, fuel quality, light truck, heavy truck

1 Introduction

The day by day exploitation of the light and heavy trucks, equipped with diesel engines, encounters many problems, most of them being produced by fuel quality and incorrect repairing or maintenance technology. Few problems could be assigned to material's quality of the unit pump parts that comes from production or remanufacturing facility, but these are replaced, most of the time, through the warranty policy of the manufacturer or, in fewer cases, after an appropriate investigation, through assurance indemnification.

The most usual origin of the malfunctioning of the diesel engine is the contamination of the fuel with dust, rust, water and improper fuel, in the last case taking in consideration the higher percentage or quality of biodiesel in a blended fuel, with, more or less immediate deterioration of the working conditions of the engine, power reduction, heavy cold or hot starts and increasing of the pollutants.

The immediate diagnosis of the injection system must occur in order to avoid the imposed air quality regulations and exploitation costs due to the increasing fuel consumption and working regimes. Due to the high technology of the unit injection system's parts and high pressure of the injection cycle (more than 1800 – 2500 bar to full charge regime of the engine), the correct diagnosis and interpretation of these could be performed only on dedicated equipment and with proper devices.

In this paper will be presented the two situations and commonly damages that could be identified on the unit injection pumps (UIP), the first case being associate with the Bosch's UIP and in the second case being associate with the Delphi's UIP, these being the most usual injection systems on european/romanian diesel trucks fleets.

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2 Experimental Investigations

2.1 Testing Equipment

The testing of the injection equipment consists of a high technology, accurate and clean preparation and direct investigation of the parts, for each major component (injection pump, injection unit, nozzle, valve, spring etc.) being a dedicated device and/or a dedicated procedure.

Because there were tested injection pumps manufactured by Bosch and by Delphi, there were necessary both type generic testing equipment, and these equipment were [1,2,3]: Diesel testing device EPS 100 (Bosch), Diesel components test bench EPS 815 (Bosch), Diesel testing bench AVM2-PC-20hp (Hartridge), stereo microscope SZX 7 (Olympus), hypobaric niche, ordinary and special dynamometric wrenches and other specific tools (tools, diagnosis interfaces and software) and materials. During the tests was used the special calibration oil 4113 (Castrol) in order to fulfill the testing operation and condition demands.

2.2 Bosch UIP

The first analysis consists is focused on the six unit pumps that equipped the OM 502 LA-542 engine of an MB Actros 1840 LS truck (11946 ccm, 290 kW, Euro 2, 1998 year). The engine of the vehicle presents heavy start, either in cold or warm conditions and has altered performances (power, torque, speed stability). The suspicions lead to the injection systems, for instance also for the unit pumps and/or the injector's nozzles (Fig.1 and 2). The separately testing of the injectors, including nozzles, by visual observation under the microscopic procedure and on specific test bench, reveals that there are no obstructions or leaks and no abnormal geometry of the nozzle's holes and corresponding injection parameters (injection pressures, opening times, injection periods, a.o.), thus excluding the injector units as responsible of the malfunctioning of the engine.

Fig. 1. Bosch Unit Injection Pump (UIP)

Fig. 2. Delphi Electronic Unit Injector (EUI)

In these conditions, the whole attention was concentrate on the six unit pumps, as the most important part of the injection system that could generate working inaccuracies. In Fig.1 is presented one of the injection pump unit (UIP), which was tested for working parameters (injection pressure, pressure drop, leaks, flow, etc.). All the six UIP were tested individually, in order to precisely identify the whole problems of the injection system.

Fig. 3. Working parameters for flow measurements

Because the working condition refer also to the flow measurement, there were performed such tests on EPS 815 test bench and were followed up multiple parameters and demanding conditions requisites, for example fuel/conditioning oil temperature, pressure, flow on different conditions (start up point, warm up, clean run, conditioning, rated point, cooling). All these parameters were directly acquired and analyzed through specific interface of the test bench and some of this information, for rated point measurements, is presented in Fig.3.

Fig. 4. Valve seat erosion

Fig. 5. Valve erosion

Fig. 6. Valve pin erosion

The faults identified on the valve-seat assembly of the six UIP, through microscope visualization, were similar and consist of many erosion marks caused, most probably, to the impurities in the fuel and compromising of the fuel filter, due to long time exploitation between changes. Thus are presented images captured on valve seat, Fig.4, valve, Fig.5, and valve pin, Fig.6, respectively, with the erosion spread marks on the jointed surfaces (in these pictures the parts were separated, after dismounted, for direct investigation).

2.3 Delphi UIP

The tested D12D diesel engine of the Volvo FH 42 truck (12.130 ccm, 309 kW, Euro 3, 2005 year) was equipped with six Delphi E3 Electronic Unit Injectors (EUI), Fig.2, and the symptoms claim by the owner consists of impossible normal start (only with additional volatile substances injected/sprayed in intake pipe), variable idle speed and poor performances (power/torque). The injection system works at high pressure (maximum around 2500 bar) and the “mechanical” parts are controlled through an electronic control unit (ECU) of the diesel management structure. As a whole assembly, consisting either of high pressure pump but also with the valve-nozzle injector unit, the possible damages that distort the working parameters must be separated, and each part must be distinctly diagnosed.

Following technical specification of the EUI manufacturer (Delphi), the units were tested for:

T1. Nozzle Opening Pressure – NOP, that must be around 250 – 300 bar. The precise value is recorded only in the technical documentation of each specific type of nozzle/injector, and is not directly presented in this article;

T2. Seat Tightness – ST, presume the direct observation of possible leak of fuel/calibration oil that could occur on the nozzle hole’s surface, when the pressure inside the injector are maintained at least 10 s, at a pressure with 15 bar less than the pressure prescribed for NOP;

T3. Back Leakage – BL, that reveal the period of maintaining the drop of pressure between 170 to 140 bars, inside the nozzle. Optimum period of the pressure drop must be in 3 – 30 s range;

T4. Testing of the EUI in the Hartdrige AVM 2 – PC – 20hp test bench.

Fig. 7. Pressure drop test

Fig. 8. EUI body

Fig. 9. Hartdrige test bench

Fig.7 presents the testing device for pressure drop measurement of the nozzle, Fig. 8 presents the special unmounting/mounting device of the EUI and an EUI body (consisting of hydraulic body, valve, electric coil, a.o.) and Fig. 9 presents the Hartdrige AVM 2 – PC -20hp test bench, prepared for EUI test.

Table 1 presents the values obtained for the T1 – T3 test items, applied to all six EUIs, and also some comments abot the status of each injector/part when was unmounted.

Table 1. Results of the tests on the Delphi EUI

EUI	T1 [bar]	T2 [10 s]	T3 [s]	Valve Figure	Observations
1	335	yes	10.5	Fig.10	stuck nozzle
2	342	yes	5.2	Fig.11	stuck valve
3	341	yes	1.3	Fig.12	unidentified small part
4	339	yes	1.35	Fig.13	
5	342	yes	2.5	Fig.14	
6	339	yes	1.7	Fig.15	

Fig. 10. Valve EUI 1

Fig. 11. Valve EUI 2

Fig. 12. Valve EUI 3

Fig. 13. Valve EUI 4

Fig. 14. Valve EUI 5

Fig. 15. Valve EUI 6

2.4 Results and Discussions

According to Table 1 results it can be observed that all the EUI's nozzles present proper values for the NOP and only the first two EUIs (1 and 2) present appropriate values for the BL test. Because only these two/three types (T1 – T3) of results are not enough for validate the testing operation of the EUIs, all the units will be tested also on the Hartridge AVM 2 – PC -20hp test bench. After the complete tests of the EUIs on the test bench, also the EUI 1 and 2 were rejected ("Out of Limits" results, see Fig.16 and 17), because internal testing procedure consisting on "Peak Pressure" – line 9, "Rated Delivery" – line 10 and "Peak Torque Delivery" – line 11, were not passed.

Fig. 16. Rejection of EUI 1

Fig. 17. Rejection of EUI 2

Thus it was necessary supplementary investigation on the internal damages of the hydraulic assembly of the EUI that were performed on the stereo microscope. The visualization of the corresponding joint surfaces reveals pronounced erosion marks (micro grooves, Fig.18 and micro abrasive marks Fig.19) on the high pressure valve linens and pins, all of these as consequences of the impurities in the fuel or compromising of the fuel filtration. Were excluded the inappropriate material quality because on these surfaces were not identified point-size regions where pitting occurs and also there was no thermal hardening or chemical treatment of these surfaces applied.

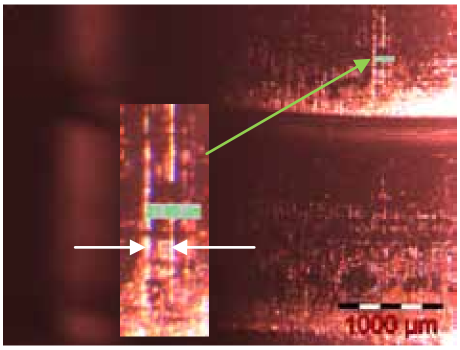

Fig. 18. Valve pin micro groove

Fig. 19. Valve pin erosion

The micro groove presented in Fig.18 reveal the action of some abrasive particles (the dimension of the groove is 21.96 µm, see details in Fig.17) which generate axial wear on material and Fig.19 present the spreading of the wear surface to up to 35 – 45% of the lateral surface of the sealing/joint surface of the valve, that generate the inappropriate working conditions of the whole EUI. Due to these advanced erosion of the valve linen – valve pin joint, for all the EUIs, the high pressure “sealing” are compromised, the leaks and pressure drop are high and the EUI were rejected by the Hartdrige testing equipment, and the only possibility too fix the claims of the malfunctioning of the engine is to replace all these EUIs.

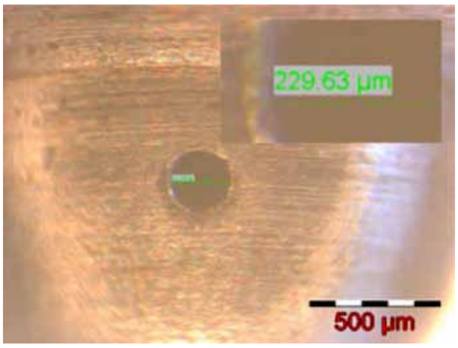

Fig. 20. Measured nozzle's hole

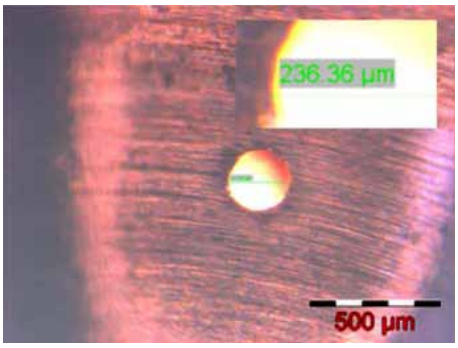

Fig. 21. Nozzle's hole with internal light source

In the same time, for all the six injectors visual analysis was performed, on the stereo microscope, to identify possible alteration of the nozzle's holes. For each of the fifth holes of each nozzle the optical measured dimensions, using an internal light source (see Fig.21) were in the 220 – 240 µm range, Fig. 20 and 21. According to this visual inspection were observed compromising of the nozzle's surface and was established that these defects occur as consequences of the steel-brush cleaning of the injectors, in order to remove the soot and unburned hydrocarbons deposits on EUI.

3 Conclusions

The diagnosis of the injection system of a Diesel engine is a high technology operation due to the high level of the testing equipment demands. Thus, only in specialized laboratories or facilities, on dedicated devices and following specific and coded information (not open/explicit values), these tests applied on injection system parts, for validating their performances, could be applied. The testing equipment manufacturer could offer the possibility to test not only the same brand/manufacturer parts but also to test some other parts from other manufacturer, but, in most of the cases, the validation and coding of the injector assembly, in order to be installed on the Diesel engine, could be performed exclusively on some dedicated equipment.

The tests made on the Bosch's injection pump units that were claimed for malfunctioning on an Euro 2 heavy truck 12 liters engine, reveals the erosion marks and grooves on the valve assembly (valve seat and joint surfaces), these damages being produced as consequences of fuel impurities and fuel filtration alteration. In this case the injector assembly performed on specific parameters and only the injection pump units are responsible for engine's malfunctioning.

For the Euro 3, 12.1 liters tested Diesel engine, that were equipped with Delphi's Electronic Unit Injectors (EUI), only the whole diagnosis, on separate parts and for the whole assembly of each EUI, reveals all the troubles of these equipment. Because the general leaks and pressure drops are considered only as guided information, there were necessary direct testing of each EUI, performed on the special test bench, and all of the tested EUIs were rejected, in direct accordance with the technical specification of the manufacturer. Supplementary investigations performed on the hydraulic assembly identified also massive erosion marks and grooves, produced by the same fuel contamination and fuel filtering discredit.

References

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