TESTING
AND DIDACTIC EQUIPMENT

Cause and effect analysis of the degradation of the piston and cylindrical bushing in the engine supplied with diesel oil in the platform operated in the company vehicle fleet

KRZYSZTOF GARBBALA [1], PIOTR CIBULKO [2]
[1]INSTITUTE OF LASER ENGINEERING, WHITE AND WHITE,
[2]AC S.A. RESEARCH AND DEVELOPMENT CENTER, BIAŁYSTOK

Keywords: engine, motor vehicle, piston damage, cylinder damage

ABSTRACT:

The operation shows the cause and effect mechanism of a malformed cylinder bushing of the combustion engine of a motor vehicle. Details of the damage caused to the individual parts of this drive unit are shown. The direction of action of forces on individual damaged parts is discussed.

Analiza przyczynowo-skutkowa degradacji tłoka i tulei cylindrowej w silniku zasilanym olejem napędowym w aucie eksploatowanym we flocie pojazdów firmowych

Słowa kluczowe: silnik, pojazd samochodowy, uszkodzenie tłoka, uszkodzenie cylindra

STRESZCZENIE:

W pracy przedstawiono mechanizm przyczynowo-skutkowy wadliwie zamontowanej tulei cylindrowej silnika spalinowego pojazdu samochodowego. Pokazano szczegółowo powstałe uszkodzenia poszczególnych części tej jednostki napędowej. Omówiono kierunki działania sił na poszczególne uszkodzone części.

1. INTRODUCTION

Passenger cars included in the fleet of company vehicles are mostly supplied with diesel oil and overcome high annual mileages than in civilian cars. They are exposed to the risk of engine faults at much shorter intervals, compared to civilian cars. This results from the need for more frequent use in the fleet of vehicles and from the use of such an car by many drivers with different driving characteristics [1, 2].

2. RESEARCH PROBLEM

An example of such a malfunction is a motor failure showing a loss of feed-forward power and a problem with heating the interior of the vehicle, which starts to work properly after a distance of approx. 30 km. During identification of these problems, a loss of coolant in the expansion tank has been found which results in a heating failure. In addition, gas bubbles were observed in the coolant expansion tank. The test for CO2 in the tank clearly showed the presence of flue gas (including CO2). A gasket defect under the engine head or a crack in the engine block has been found, which leads to the ingress of exhaust gases into the coolant expansion tank [3÷5].
The repair of the engine block and the engine head of the vehicle in question involved, among others, washout of the motor block, planning and disassembly and installation of cylinder bushings of the said motor.
After doing so, the motor has been mounted back to the vehicle. After a distance of approx. 600 km, the car crashed again, which prevented further driving. The injectors have been verified.

3. OWN ANALYSIS

As a result of the analysis of the data of the tested injectors feeding the said motor, their correct operation was determined. The tightness of the injector refers to its volume flow rate and is critical for the correct atomisation of fuel in the combustion chamber and temperature inside the combustion chamber. The tightness is kept within the limits of the standard and the discrepancies in the injectors of subsequent cylinders are not significant.

The engine block is shown in Figure 1. The organoleptic inspection of the condition did not reveal any visible cracks in the unit.

Figure 1 Motor block where fault occurred

Figure 2 shows the piston that worked in the cylinder where the failure occurred.
The piston has numerous longitudinal and lateral cracks, which indicate high forces acting on the element during engine operation. The outer structure of the piston bottom shows numerous surface losses in the form of characteristic traces of impacts and fractures in its surface. These traces result from repeated contact between the piston head and metallic or foreign bodies. The piston also has a large amount of loss in the upper part. Such a loss had to be detached from the basic piston structure as a result of the action of high longitudinal force. The view of the piston bottom is shown in Figures 3 and 4. There are no signs confirming the operating conditions at elevated (degrading) temperature. Heat aggregating structures, such as piston edges or elements protruding over the plane of the piston head, do not exhibit overmelting in pistons operating at temperatures higher than those designed for this purpose.

Figure 2 Piston that worked in the cylinder where the failure occurred

Figure 3 Piston bottom surface

Figure 4 Surface of the piston head (numerous losses in the surface are visible)

The upper piston ring is characterized by the deformation of the shape caused by the influence of a large force acting in the upper-bottom axis of the piston operation. The occurring deformation of the ring exerted pressure on the upper part of the piston. This confirms the direction of bending of the ring. The ring exerted force on the upper part of the piston, causing its cracking and solidification of its parts into pieces. The broken piston pieces were located in the combustion chamber during engine operation. The piston with deformed upper ring is shown in Figure 5.

Figure 5 Piston with deformed upper ring

Figure 6 shows the disassembled end of this motor.
The surfaces adjacent to the combustion chambers in 3 cylinders show typical signs of operation which are not related to this defect. The surface adjacent to the combustion chamber in the cylinder where the failure occurred is characterised by numerous mechanical damage.

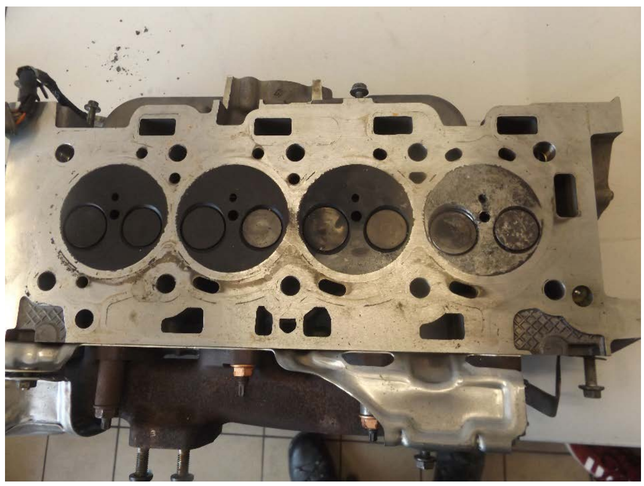

Figure 6 Head presented for visual inspection

Figure 7 shows the area of the head adjacent to the cylinder where the failure occurred. There are signs of multiple metallic impacts of foreign bodies on this surface. In addition, the disc of the suction and exhaust valve in this cylinder is deformed. This condition of the valves prevents maintaining the tightness of the combustion chamber and proper operation of the combustion engine. The surfaces of the valve mushrooms also have numerous brushes, which indicate a large number of impacts of foreign bodies with high hardness. No traces of overmelting of the edges of valve sockets indicate the combustion temperature of the fuel and air mixture within the limits of the standard.

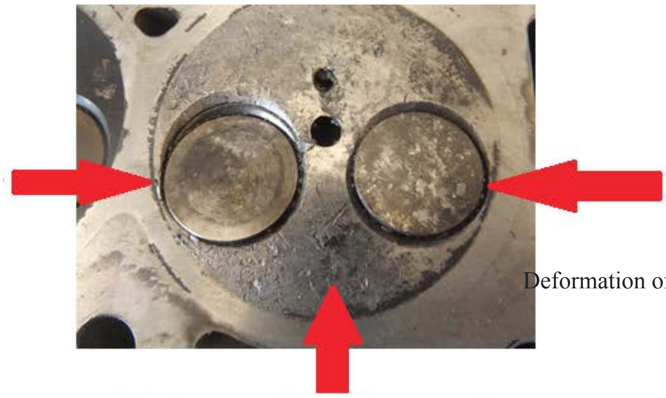

Figure 7 Head surface over defective cylinder

The cylindrical bushes of 3 cylinders show normal traces of operation. The cylinder cylinder sleeve where the failure occurred shows that there is no sleeve flange on which it was supported in the motor block. This flange was destroyed and its fragments were located in the combustion chamber during engine operation causing damage to the piston surface, valves and head. Additionally, the elements of the cylindrical bushing flange, as foreign bodies, were the cause of deformation of the inlet and outlet valve. The flange had to be destroyed as a result of heavy forces directed toward the bottom of the motor block. The broken flange cylindrical sleeve is shown in Figure 8.

Figure 8 Cylinder bushing missing flange

A lateral crack of about 32 mm length was observed on the surface of the cylindrical sleeve. This crack could be caused by the development of an internal microcrack during engine operation. An internal micro-crack may have occurred due to a cylinder sleeve striking on a hard surface (e.g. when falling from height) prior to its mounting to the engine block. This microcrack could also be caused by assembly errors, i.e. incorrect placement of the cylinder sleeve in the cylinder, or inaccurate cleaning of the cylinder lining before installation of the cylinder sleeve. The microcrack increased its size under the influence of the motor operating temperature and vibrations, reaching at the critical operating moment of the motor a size of approx. 24 mm in width and approx. 32 cm in length, covering the flange which was damaged. The crack is shown in Figure 9.

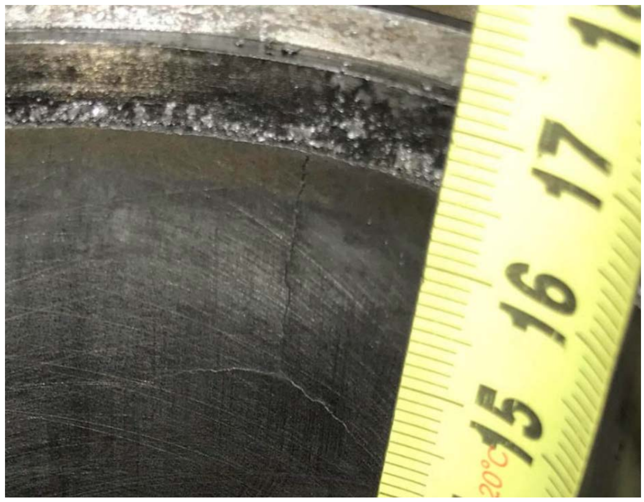

Figure 9 Cylinder sleeve cracking

A significant reduction in the level of deposition of the cylinder sleeve in the cylinder where the failure occurred was also noticed. This is due to considerable force that pushed the bush down in the motor block while breaking its flange. In the lower part of the cylindrical sleeve a significant loss of cylindrical sleeve was observed. When the cylindrical bushing is displaced downwards in the cylinder, the crankshaft could break a part of the bushing hitting it. The loss of the cylindrical bushing is shown in Figure 10.

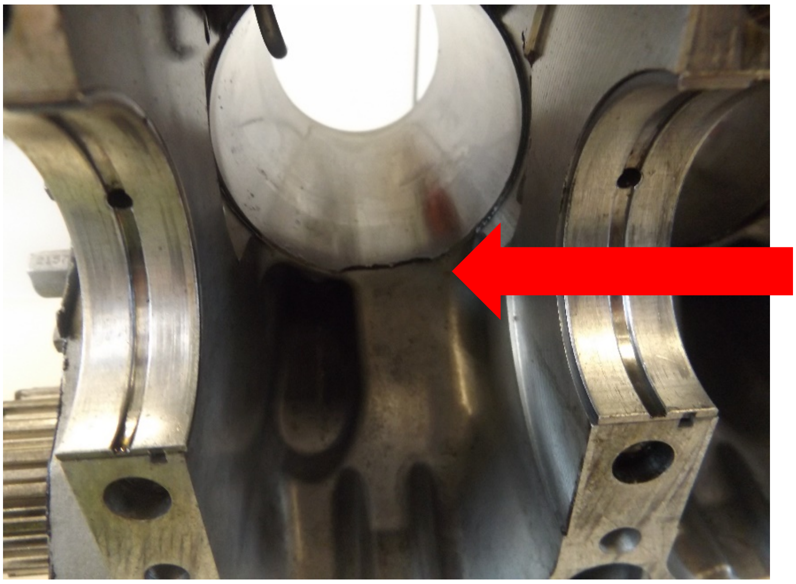

Figure 10 Loss at the bottom of the cylindrical sleeve

4. SUMMARY

The following final conclusions may be formulated on the basis of tests and visual inspections:
1. The injector test reports confirm that the injectors of this motor retain their tightness at the required level,
2. Increased temperature in the combustion chamber, caused by injector leakage, shall be eliminated as the main cause of damage to the engine,
3. There are no material indications that occur in the case of occurrence of too high operating temperature of this type of components,
4. The waveform recorded since the previous service is too small to achieve accelerated wear of the injectors,
5. The upper surface of the piston, valves and the cylinder head in which the failure occurred bear traces of impact with metallic foreign bodies,
6. Foreign bodies were the elements of the broken flange of the cylinder bushing and the fragments of the piston present in the combustion chamber during operation of the engine,
7. The flange of the cylindrical bushing was broken due to the hooking of the upper ring of the piston with cracks on the cylindrical bushing,
8. A crack on the cylindrical bushing occurred by striking the bushing with a hard surface before fitting the cylindrical bush to the motor (e.g. falling onto the floor),
9. A crack on the cylindrical bushing could also be caused by errors in the assembly of the cylindrical bush in the motor block due to inaccurate clean the cylinder surface before inserting the cylinder sleeve.
10. As a result of the mistakes in the assembly of the cylindrical bushing in the motor block, the microcrack increased its size during motor operation to reach approx. 20–30 mm after approx. 600 km,
11. The edge of the resulting crack of the cylinder sleeve is located in the working area of the piston,
12. Being in the upper dead point, the piston, while moving downwards, hooked the upper piston ring with the deformation listed in section 11,
13. This confirms the direction of bending of the upper piston ring,
14. The upper piston ring, hitting the edge of the fracture on the cylindrical bushing, pulled the cylindrical bush down while breaking the fragments of the flange which, when entering the combustion chamber, caused mechanical damage to the piston surface, head and valves. They were also the cause of deformation of the exhaust and suction valve,
15. The upper piston ring, by pressing on the upper part of the piston, has released many smaller piston pieces which were located in the combustion chamber during engine operation,
16. The cylindrical bush, moving downwards, hit the rotating crank shaft, creating a loss in its surface,
17. Errors occurring during the assembly of cylindrical bushings were crucial for the failure.

BIBLIOGRAPHY

[1] Wajand J. A., Wajand J. T., Tłokowe silniki spalinowe średnio- i szybkoobrotowe. WNT, Warszawa 1993.

[2] Płaza S., Margielewski L., Celichowski G., Wstęp do tribologii i trybochemia. Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2005.

[3] Ambrozik A., Wybrane zagadnienia procesów cieplnych w tłokowych silnikach spalinowych. Wyd. Politechnika Świętokrzyska, 2003.

[4] Ambrozik T., Internal combustion engine. Wyd. Politechnika Świętokrzyska, on-line: http://wmibm-moodle.tu.kielce.pl, Kielce, 2013.

[5] https://www.autocentrum.pl/publikacje/eksploatacja-auta/w-gore-i-w-dol-najczestsze-przyczyny--uszkodzen-tlokow-w-silnikach-spalinowych/