PISTON DAMAGES – CASE STUDIES AND POSSIBILITIES OF EARLY DETECTION

Jan Filipczyk, Zbigniew Stanik

Silesian University of Technology
Faculty of Transport
Krasinskiego Street 8, 40-019 Katowice, Poland
e-mail: jan.filipczyk@polsl.pl

Abstract

Damages of car engine pistons are one of the most expensive failures regarding final consequences and possibilities of engine repair. There have been many research works carried out so far regarding the materials, manufacturing techniques, geometrical shapes and reliability of engine pistons. Notwithstanding all these studies, there is a huge number of piston damage cases.

This work is concerned with causes of piston damages and possibilities of early detections. Damaged piston of petrol and diesel engines in passenger and light duty cars have been analyzed. A compendium of case studies of damaged piston causes has been presented. The analysis of different types of damage mechanisms such as thermal and mechanical fatigue, seizure due to insufficient clearances, poor lubrication, overheating and damages due to abnormal combustion have been presented in this work. Faults of electronic control system, engine management malfunction, ignition-timing faults were recognized as the most frequent initial causes of piston damages. Possibilities of early diagnostics of particular causes of damages have been elaborated and presented in the context of total costs of repairs.

Keywords: *piston, engine damages, engine diagnosing*

1. Introduction

This study has been a result of failure investigations related to spark and diesel engine piston failures, which occurred during vehicle tests, carried out in 2000–2011. Some studies have been conducted within the framework of research on the changing technical conditions of different category of vehicles, operating in various conditions and their ability to diagnose the faults [1, 2]. The analysis of causes of piston damages have been the subject of many studies. The fatigue of pistons has been classified as mechanical and high temperature mechanical, as well as thermal and thermal-mechanical [3]. The main causes of thermo-mechanical fatigue damage have been classified as a thermo-mechanical overload by insufficient intercooling and thermo-mechanical overload by over-fuelling [4]. The types of piston damages have been classified as seizure due to insufficient clearances, seizure due to poor lubrication, seizure due to overheating, damages due to abnormal combustion, piston and piston ring fractures, piston pin fractures, damage to the piston pin circlips, seizures in the piston pin bores, piston noises, increased oil consumption due to excessive wear on pistons, piston rings and cylinder running surfaces [4–6].

2. Methods of investigation

The damages of pistons, and possibilities of early fault diagnosing were the main goal of engine examinations. The investigations have been conducted in authorized service stations and specialist workshops. There were two stages of the carried out investigations. The first stage was related to the possibilities of early fault diagnosing which could be the causes of serious piston damages. Diagnostics of faulty engines using OBD systems, measurement of compression pressure, air tightness test of cylinders, measurement of electric current of a starter, measurement

of exhaust gasses have been carried out if it was possible. Endoscopy investigations of cylinders for each case of faulty engines have been performed. Two thousand faulty engines with different mileage have been examined. The faulty pistons, cylinders, valves and valve seats were recognized in 456 cases. The second stage concerned the analysis of type and causes of engine faults, which had damage pistons. The analysis was carried out for 58 completely broken-down engines due to the damage of piston. The mileage of examined engines during the first and the second stage has been presented in Tab. 1. The given mileage is related to the last engine overhaul.

Tab. 1. Mileage of examined engines

	Mileage of engine, km				Total number of engines
	< 1000	50 000 – – 100 000	100 000 – – 150 000	> 150 000	
Faulty engines (working)	2	58	100	296	456
Completely breakdown engines	1	12	17	28	58

3. Results of investigations

During the examinations of faulty working engines, 22.8% were connected with faulty piston, cylinders or valves, but only 12 cases of early piston damages were recognized using common diagnostic methods. 54 cases of piston damages were recognized during endoscopy. The structure of engine faults has been presented in Fig. 1.

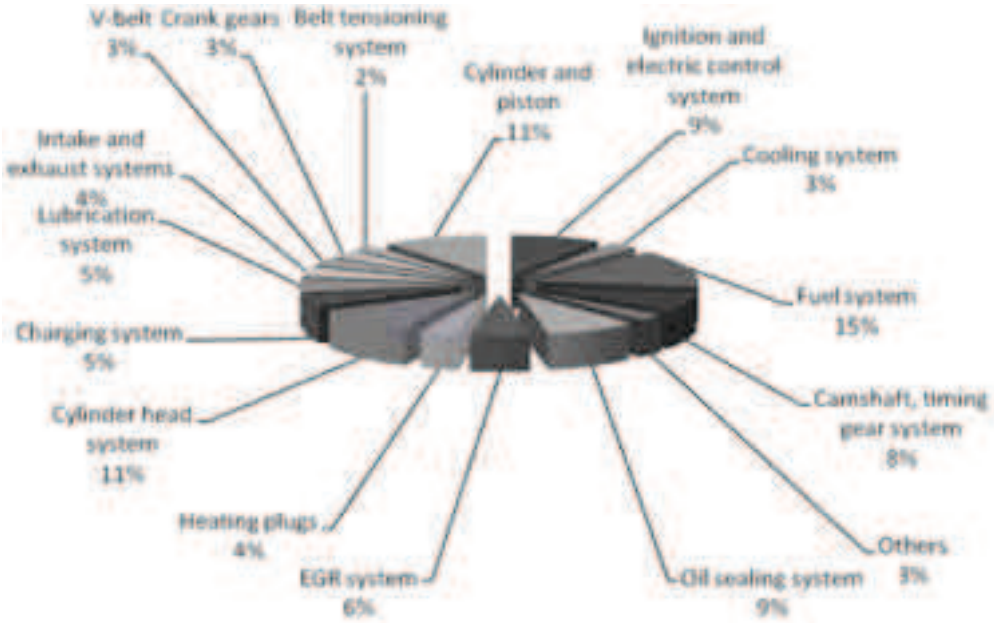

Fig. 1. Structure of engine faults

The types of piston damages, which have been recognized, can be classified as piston skirt seizing in the early phase, piston head seizing, small damages in the ring and skirt panel. The structure of recognized piston damages has been shown in Fig. 2.

Poorly made repair, material melting on the piston crown in diesel engines and piston fracture due to mechanical contact between the piston crown and the cylinder head were the main causes in examined broken-down engines. The types of piston damages due to operational causes can be classified as piston crown scuffing, piston crown erosion, piston skirt scuffing, piston ring

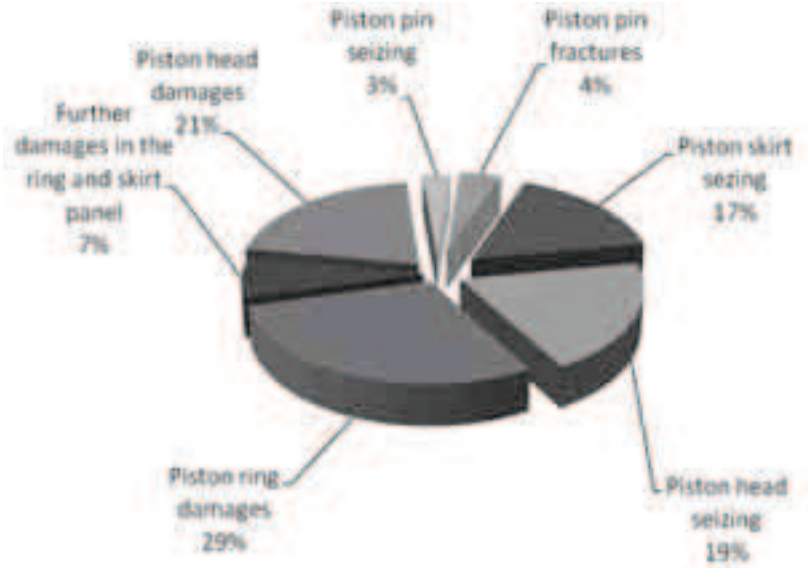

Fig. 2. Structure of piston damages

scuffing. The wear of crown, skirt surface and piston ring faults were in many cases the results of normal operation. Piston crown erosion in many cases was initialled due to incorrect air-fuel ratio balance and poor quality of fuel. The operational causes of piston damages, which were recognized during the examinations, can be classified as follows: over-fuelling of cylinder, exhaust restriction, improper injection timing, poor piston crown cooling, engine operation at excessive load. It is significant that the number of assembly errors, being the cause of piston faults in working engines, was relatively small. The structure of causes of piston faults has been presented in Fig. 3.

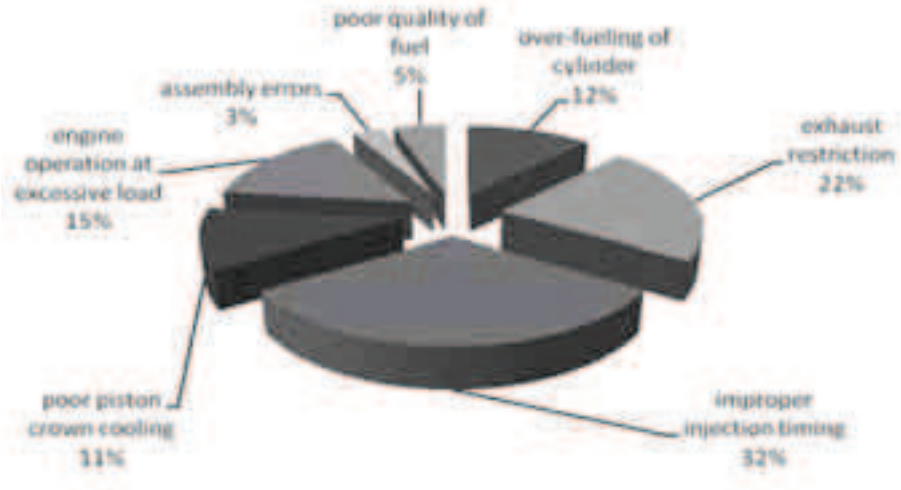

Fig. 3 Structure of causes of piston faults

Early detection of piston and cylinder damages was only possible applying endoscopy. Fault of fuel injection has not been detected using OBD-system examinations in any cases. It was recognized only through the endoscopy examination, as the cause of piston crown erosion at the early phase. It is very important because of a large number of cases of completely broken-down engine, due to faulty injection systems in diesel engines. Faulty injection system, poor service, assembly errors during a repair, overheating as a result of overloading or faulty cooling system were the most common causes of total engine failure. The results of investigations of causes of total engine failures with piston damages, which were carried out in the second stage, have been shown in Fig. 4.

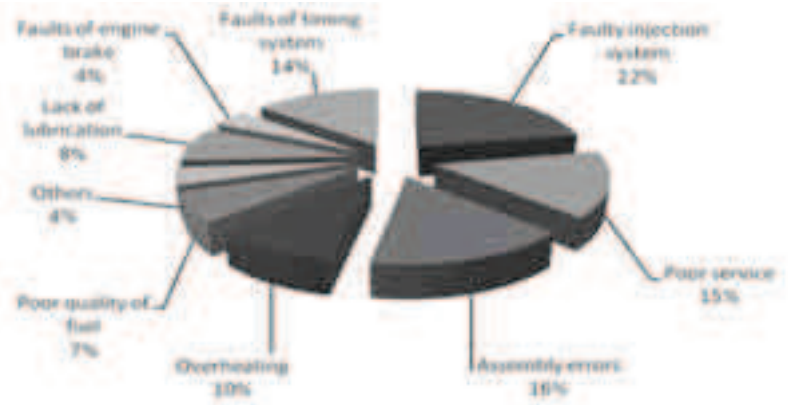

Fig. 4. Structure of causes of total engine failures with piston damages

The most common errors made during repair which were recognized in first and second stage of investigations have been classified as follows: improper assembly of engine timing system, insufficient clearances between piston and cylinder liner, improper handling of the piston pin during installation, inaccurate measurements before installation (e.g. cylinder axis not rectangular to crank shaft axis), bending or twisting of the connecting rod, piston ring end gap misalignment, insufficient cleanness in the process of repair. The structure of repair errors has been presented in Fig. 5.

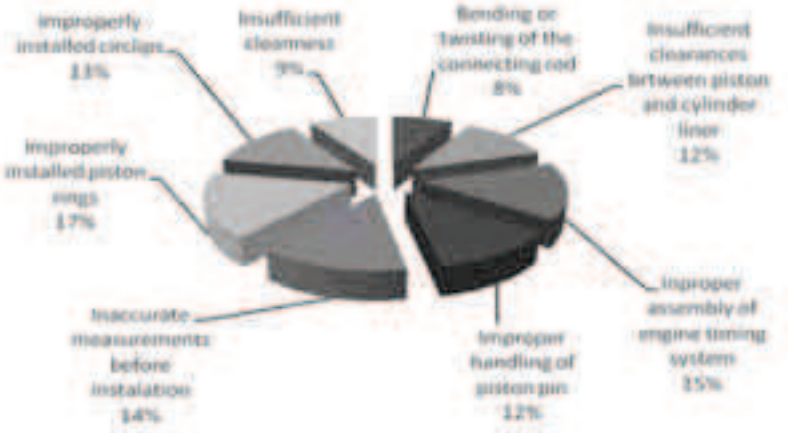

Fig. 5. Repair errors

Insufficient maintenance has resulted in poor lubrication or even no lubrication at all, inadequate circulation of the coolant, excessive water in fuel etc. Some examples of piston damages have been presented in Fig. 6-8.

Fig. 6. Removal of material by melting on the piston crown

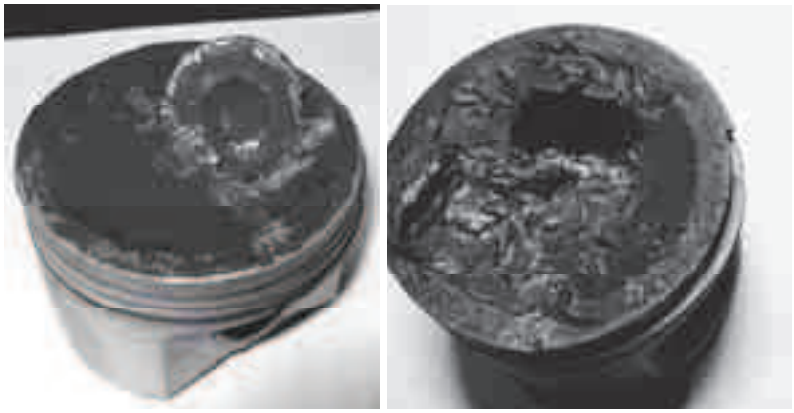

Fig. 7. Piston crown damage due to hitting against the valve

Fig. 8. Piston damage due to incorrect engine timing

4. Conclusion

The causes of engine faults with piston damages can be classified as follows: those ones due to normal wear during operation, maintenance errors, damages of lubrication and cooling systems, faults of injection and timing systems, manufacturing defects. A high percentage of faulty engines with low mileage shows that early diagnosis of damages is extremely important. The faults of electronic control system, ignition timing and engine management malfunction may be the reason of a complete destruction of the engine. The commonly used methods of diagnosis may not be sufficient to detect certain types of failures. It is important to kip in mind that a lot of piston damages can be caused by many different types of faults. Therefore, finding the cause of piston damages can be sometimes extremely difficult. For example, the piston with a damage caused by improper quality of fuel might look like the piston in the engine, which was working at incorrect injection timing. The development of diagnostic methods of engines is much slower than the progress in the area of new engine construction.

References

[1] Filipczyk, J., Madej H., *The typical faults of automotive engines and analysis for fault diagnosis possibility,* Combustion Engines, 2009-SC2, pp. 229-233.
[2] Filipczyk, J., Madej H., *The application of on-board diagnostics systems for assessing the technical state of automotive vehicles*, Journal of KONES, Powertrain and Transport, Vol. 17, No. 3, pp. 99-104, 2010.
[3] Silva, F. S., *Fatigue on engine pistons – A compendium of case studies,* Engineering Failure Analysis 13, pp. 480-492, 2006.

[4] Floweday, G., Petrov S., Tait, R. B., Press, J., *Thermo-mechanical fatigue damage and failure of modern high performance diesel pistons*, Engineering Failure Analysis 18, pp. 1664-1674, 2011.
[5] Waldhauer, U., Schiling, U., Schnaibel, S., Szopa, J., *MSI Motor Sevice International*, Part-No. 50 003 973-02.
[6] Jimenez Espadafor, F., Becerra Villanueva, J., Torres Garcia, M., Carvajal Trujillo, E., *Analysis of a diesel generator cylinder failure,* Engineering Failure Analysis 18, pp. 913-925, 2010.