ANALYSIS OF CRANKSHAFT DEFECTS FROM AUTOMOBILE INTERNAL COMBUSTION ENGINES AND THEIR CLASSIFICATION

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Abstract: The following research investigates the main damages that the crankshafts from internal combustion engines may experience. Operational damage is associated with significant changes in shape, dimensions and mutual arrangement of their surfaces. Defects are classified as natural (primary) and consequential (secondary), and are caused by failures in other components that make up the engine.

Keywords: crankshaft, defects, classification

1. INTRODUCTION

The accident-free operation of the car and the safety of traffic depend on the quality maintenance of the internal combustion engine. However, with the passage of time and the accumulation of engine hours, the resource of the engine is exhausted, and it is necessary to perform an overhaul. The reliability of internal combustion engines is largely determined by the wear time and resistance to sudden emergency failures of crankshafts. The predominant part of the failures is due to improper periodic maintenance, repair, and, in some cases, structural or technological defects. The need for repair and restoration of crankshafts is determined by the technical condition of their working surfaces, reflected in the deterioration of engine power as well as its environmental characteristics.

Establishing and analyzing the main and less frequently manifested defects will improve the choice of optimal technology for the restoration of crankshafts and increase their operational reliability. Some studies have been devoted to these problems [1-9]. Detailed and in-depth studies on damaged crankshafts have been carried out by [2, 6, 8]. The authors conducted extensive microstructural studies of fatigue-destroyed crankshafts. The results of the research conducted in [2] show that the crankshaft failure is due to a structural problem, the removal of which terminates the crankshaft failure. The findings in [6] are also similar, as despite the different construction of the crankshaft, the cause of destruction is identical to that found by the authors of [2] – the presence of an oil pump gear near the place of destruction. Improvement of crankshaft manufacturing technology and selection of higher quality steel grades are recommended in [8]. Research on the fatigue failure of the material of crankshafts is mostly focused on changing the design or manufacturing technology. However, the destroyed crankshafts cannot be rebuilt and reused in the internal combustion engine. Only crankshafts without cracks and severe deformations are subject to restoration, and a restoration technology is prepared for each specific case. However, crankshaft failures are most often secondary, and regardless of the technology used to restore them, without removing the root cause of the engine failure, the likelihood of repeated failure is significant. Lower reliability

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indicators of repaired machines are often due to the insufficient quality of non-destructive control of details, the low level of technological equipment used in the repair and the insertion of non-original spare parts into the repaired engines, or those restored using technologies that do not meet the technical requirements for the details.

The purpose of the research is to identify the main failures in crankshafts and to analyze the reasons for their occurrence.

2. EXPERIMENTAL SETUP

The research was conducted on crankshafts from diesel and gasoline engines with different types of damage. Non-destructive capillary testing according to ISO 3452-1:2013, ISO 3452-2:2013, ISO 3452-3:2013 and ISO 3452-4:2013 and its application in auto repair production was carried out [10, 11]. The tested crankshafts were washed, degreased and dried. “Pentrix 100” penetrant was then sprayed onto the surface of the main and crankpin journals. Penetration time is 60 min. “Metaclean 300” detergent was used to remove penetrant in excess. After drying, “Rivelex 200” developer was applied. The observation and evaluation of capillary control results are performed under bright lighting. The deviation from ovality and the radial runout of the main journals were measured with a concentricity tester with a measurement accuracy of ±0.005 mm. The nominal dimensions of the main and crankpin journals were measured using a micrometer with a measurement accuracy of ±0.005 mm.

3. RESULTS AND DISCUSSION

Crankshafts are made of cast iron or steel [12]. The investigated crankshafts from internal combustion engines show many similar characteristics of the defects and deviations from the technical requirements set by the manufacturer. Penetrant testing of all crankshafts did not show the presence of a crack caused by fatigue of the material, although in the series of shafts examined, there were fatigue failures. Based on this, it can be said that the fatigue of crankshafts, although fatal for them, is not the most common defect [13, 14]. Most often, scratches and sticking are observed on the main and crankpin journals, regardless of whether the crankshaft is from a gasoline or diesel engine. These scratches and scuffs can be summarized as relatively weak scratches on the support surfaces due to the passage of solid particles through the oil hole – Figure 1a and Figure 1b.

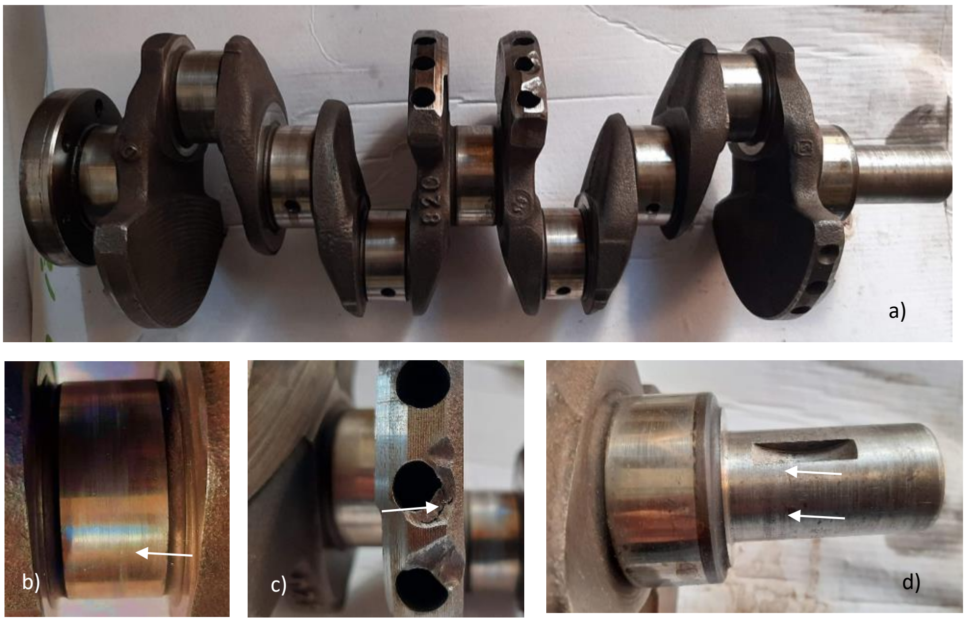

Fig. 1. Damaged crankshaft from 4-cylinder engine: a) general appearance; b) surface destruction of the rod journal; c) deformation of the balancing holes; d) fretting corrosion of the crank nose.

In repair practice, such minimal defects do not significantly affect the durability and reliability of crankshafts, and replacement of only the main and crank bearings is usually applied to compensate for the relatively uniform wear along the diameter of the main and crank journals. This is not the case with relatively heavy scuffs - Figure 2 and Figure 3. In the practice of restoring the crankshafts by grinding, it is found that in these case of severe binding of the crankpin journals - Figure 4b restoration by grinding is carried out to the last permissible size, and the main journals are ground to the second repair size of the bearings – Figure 4c. This fact can be explained by the fact that, as a result of the binding of the crankpin journal, the gap between it and the bearing increases significantly. In doing so, the acting gas-dynamic forces begin to shock-load the crankshaft, which distorts the most near the damage around the main journals. This requires additional grinding. Despite the technological possibilities of restoration, not all crankshafts can be subjected to this procedure. So, for example, at crankshaft Figure 2a, the measured runout of the crankpin journal – Figure 2b is so large that it does not allow the use of standard repair bearings offered by various spare parts manufacturers, necessitating its scrapping. Similar is the case with crankshaft Figure 3a, where a sudden loss of oil leads to cold welding of the bearing shell for the crankpin journal and a complete lock-up of the engine. In this process, the temperature of the crankshaft in the damage zone has increased significantly above 350°C, which is judged by the change in the color of the metal to blue and dark grey – Figure 3b,c. The existing technological options for restoration by welding or powder coating in these cases are economically unfeasible. Relatively often wear of the output journals is observed, both on the cylindrical surface and on the flat surfaces to which various gears, chain wheels, flywheels, and others are attached - Figure 1d and Figure 4d. At first glance, these damages are not dangerous, but they change the phases of gas distribution, and in some cases the gear pulleys roll and cause an impact between the pistons and valves.

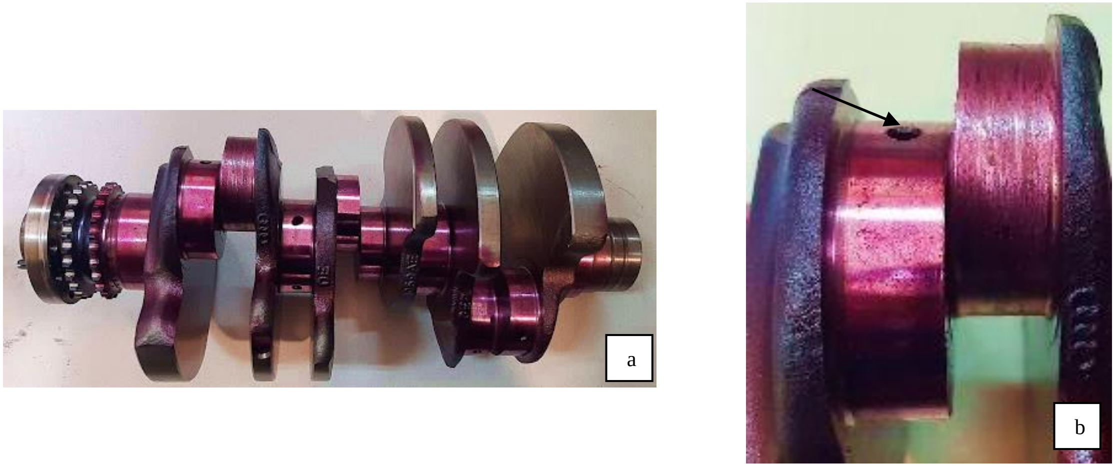

Fig. 2. Crankshaft failure from V6 engine: a) general type and location of the damage; b**)** scratch and pitting on the surface of connecting rod journal.

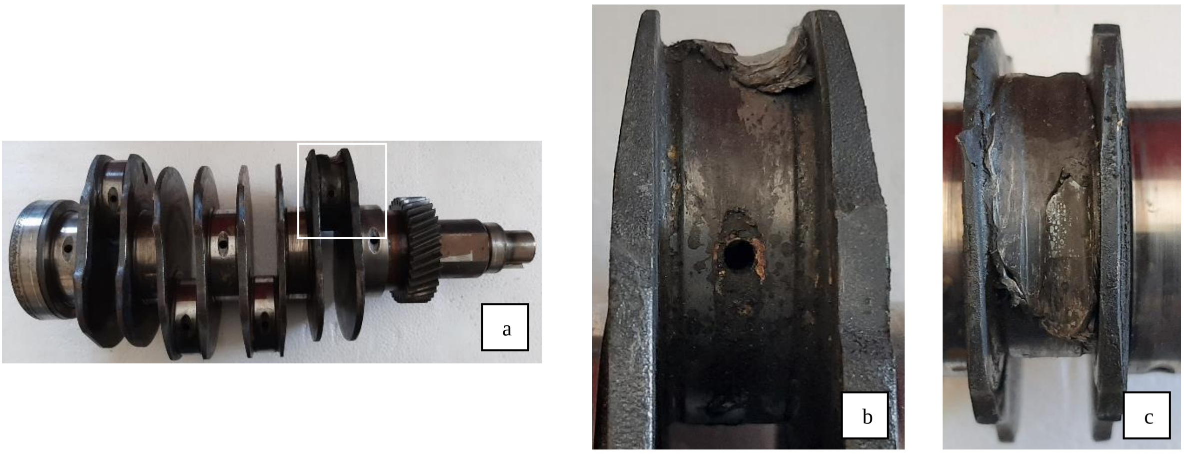

Fig. 3. Damaged boxer engine crankshaft a) general appearance and location of the main fault; b) the bearing material embedded in the crankshaft; c) melting of bearing shell.

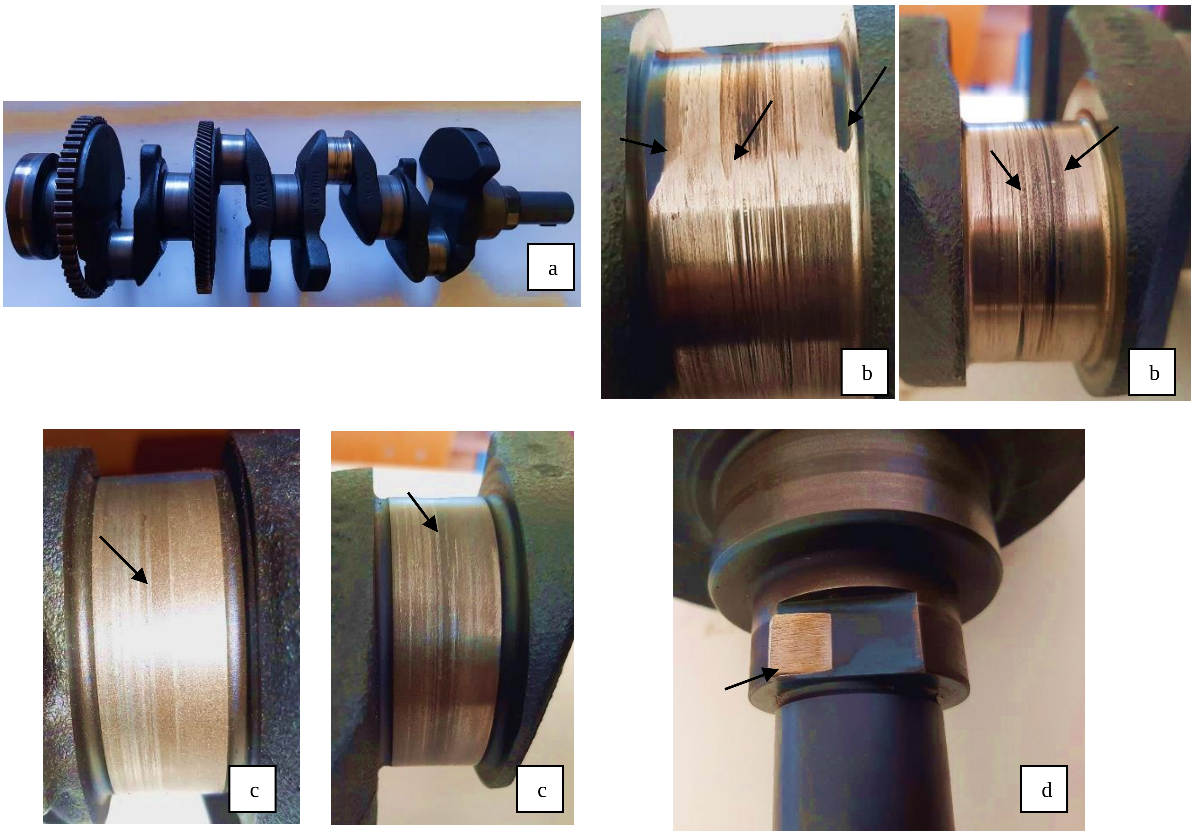

Fig. 4. Scratches on the surface of crankshaft: a) general type of crankshaft; b) deep scratches on connecting rod journal; c) deep scratches on main journal d) crank nose journal damage.

There is also damage to the crankshafts because of an impact on them from a broken connecting rod- Figure 1c. In these cases, the most common cause of damage is liquid entering the fuel cylinder and starting the engine with it. As a result, hydraulic shock is formed, where the connecting rod breaks, distorts, and sometimes destroys the cylinder block, as in the case shown. With this type of damage, the crankshaft is deformed, and its restoration by grinding cannot be carried out.

Relatively rarely, fretting corrosion is observed on the joining surfaces - Figure 1d. Oil in this area is rare and due to the presence of a defect in other elements that make up the engine. Fatigue failure of crankshafts is relatively rare (Figure 5). However, in repair practice, it is accepted that before restoring crankshafts, non-destructive testing should be carried out.

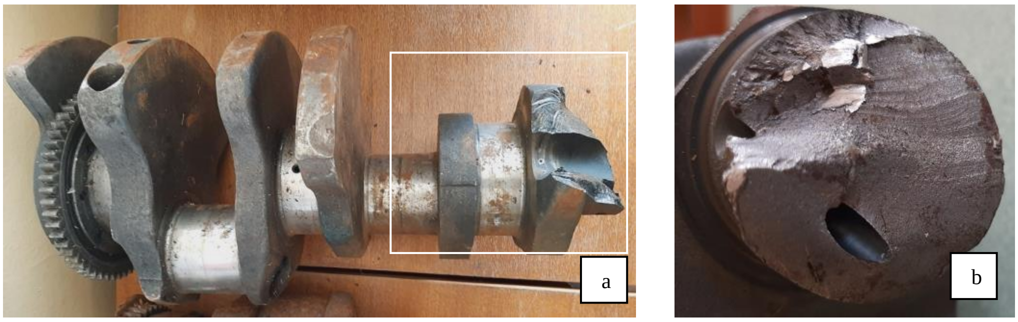

Fig. 5. Fatigue failure of crankshafts: a) destruction of a cast iron crankshaft from a truck; b) destruction of a steel crankshaft by a car.

Through it, dedicated fatigue cracks are established – Figure 6. Based on numerous observations from different car brands, engine types and piston placement, the following main types of defects occurring in crankshafts during their operation can be summarized:

- Natural wear of main and crankpin journals and axial surfaces (working surfaces);
- Deformation, torsion and radial runout of the crankshaft;
- Clogging of the oil holes with wear products;
- Scratches or pitting on the journals and axial surfaces;
- Fatigue
- Fretting-corrosion;
- Wear or destruction of keyseats, threaded joints and connecting surfaces for washers, rollers and flywheels.

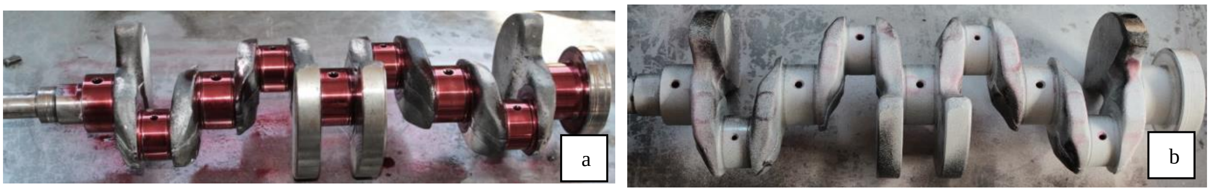

Fig. 6. Penetrant testing of a crankshaft: a) applying penetrant; b) applying developer.

The observations made, allow us to classify the damage on the crankshafts into two main groups: primary and secondary – Figure7. Natural damage is normal damage to the crankshafts during their operation and is caused by the force load and wear of the working surfaces. Natural damages are primary and independent damages. Secondary damages are those damages that occur when some of the components involved in working together with the crankshaft are damaged or changed. They are dependent damages. Depending on the type of defects on the crankshafts, the technological path for their restoration is determined by observing the basic geometric dimensions and mechanical characteristics of the part.

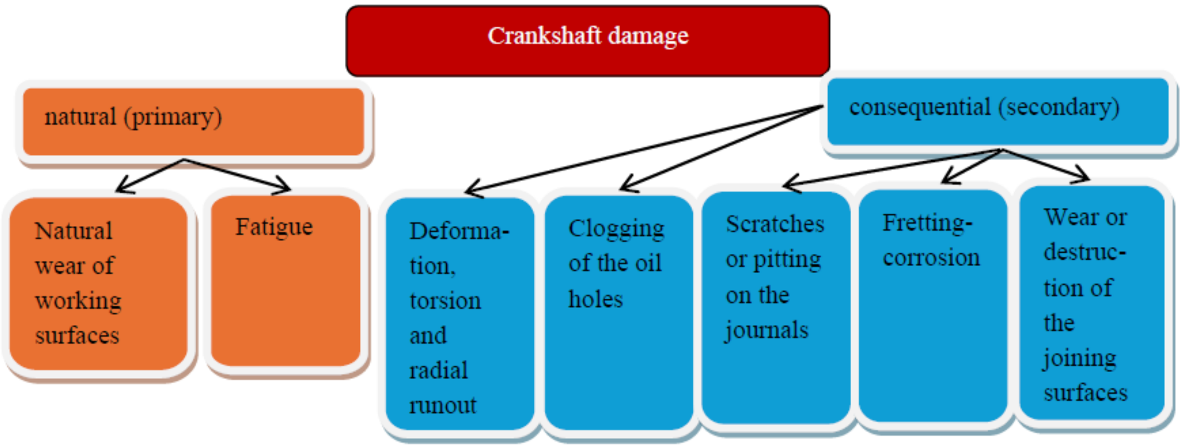

Fig. 7. Classification of crankshaft defects.

4. CONCLUSIONS

From the long-term observations made on crankshafts from internal combustion engines, numerous operational damages are found, leading to a deterioration of the power and environmental characteristics of the engine. As a result, it is necessary to repair the crankshafts and extend their service life. The longest service life of crankshafts is found in defects resulting from natural wear and damage of the shafts, while secondary defects are the reason for the shorter life of crankshafts and more frequent scrapping between overhaul periods.

Data Availability Statement: *The author confirms that the data supporting the findings of this study are available within the article*

Conflicts of Interest*: The author declares no conflicts of interest.*

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