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DESTRUCTION OF CRANKSHAFTS FROM INTERNAL COMBUSTION ENGINES

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Abstract: The crankshaft, as the main detail in internal combustion engines, is subjected to a variable load caused by the dynamic forces of the combustion process and its rotation. As a result, its surface layers are loaded successively in tension and compression, which causes fatigue of the material. The destruction of crankshafts is a serious problem in the operation of internal combustion engines and creates serious costs for the maintenance of the vehicle fleet. In this research paper are presents the results of a study of damaged crankshafts from internal combustion engines. The failure mechanisms of steel and cast iron crankshafts were established, and penetrant testing was conducted to identify other fatigue cracks. The hardness of the material from which the crankshafts are made was measured, and no significant changes were found. The study was conducted on broken crankshafts from gasoline and diesel engines, and the fracture surface, hardness and local deformations of the main journals and crank pin journals were examined. The crankshafts are made of steel and cast iron, having been dismantled from a car with a mileage of about 300,000 km, a truck with a mileage of about 250,000 km and a forklift with about 8,000 motor hours.
Keywords: Crankshaft, fatigue, cracks

INTRODUCTION

The crankshaft, as the main detail in internal combustion engines, is subjected to a variable load caused by the dynamic forces of the combustion process and its rotation. As a result, its surface layers are loaded successively in tension and compression, which causes fatigue of the material. The destruction of crankshafts is a serious problem in the operation of internal combustion engines and creates serious costs for the maintenance of the vehicle fleet.

The crankshafts are manufactured from steels and high–strength cast irons (nodular cast iron) and are subjected to thermal and chemical–thermal treatment to increase fatigue durability [8,11]. However, in the auto repair industry, numerous cases of their destruction are found, which is a prerequisite for emergency repairs of the engines [10].

Establishing the causes of their destruction, as well as the mechanism and kinetics of the process, is the subject of many studies [1–7, 12–15]. In the present work, the causes, mechanism and kinetics of fatigue failure of cast iron and steel crankshafts are investigated.

The study was conducted on broken crankshafts from gasoline and diesel engines, and the fracture surface, hardness and local deformations of the main journals and crank pin journals were examined. The crankshafts are made of steel and cast iron, having been dismantled from a car with a mileage of about 300,000 km, a truck with a mileage of about 250,000 km and a forklift with about 8,000 motor hours.

RESULTS

When studying the destruction of steel crankshafts, general regularities are established in the mechanism and kinetics of destruction. The primary crack is generated on the surface of the crank pin in the section intended for the exit of the grinding disc during its manufacture. This can be explained by the fact that there is the smallest diameter with a sharp change in the design size – a transition from the main journal to the crank pin journal. This causes a concentration of stresses in the area of the main journal. In the production of crankshafts in these areas, residual compressive stresses on the surface obtained by induction hardening, surface plastic deformation, nitriding, carbonitriding and other technological methods are provided. The failure mechanism can be explained by gradual accumulation of tensile stresses until complete relaxation of compressive stresses, their gradual accumulation in the surface layers, creation of dislocations and microdefects and reaching the failure limit of the material from which the crankshaft is made. The initiation of the crack takes place in the place with the highest concentration of stresses and valley from the roughnesses from the mechanical processing. The crack slowly grows along the cross–section, in a direction perpendicular to the direction of the tensile load in the corresponding half–cycle.

When the "live section" decreases due to the growth of the crack, it cannot withstand the applied external load and a brittle failure occurs, visible from Figure 1 and Figure 2. The advance of the failure front occurs slowly but steadily – with each cycle of the load. On the fracture, the wavy lines of the crack movement are visible, which have a radial character relative to the initial microcrack and have the appearance of approximate concentric arcs

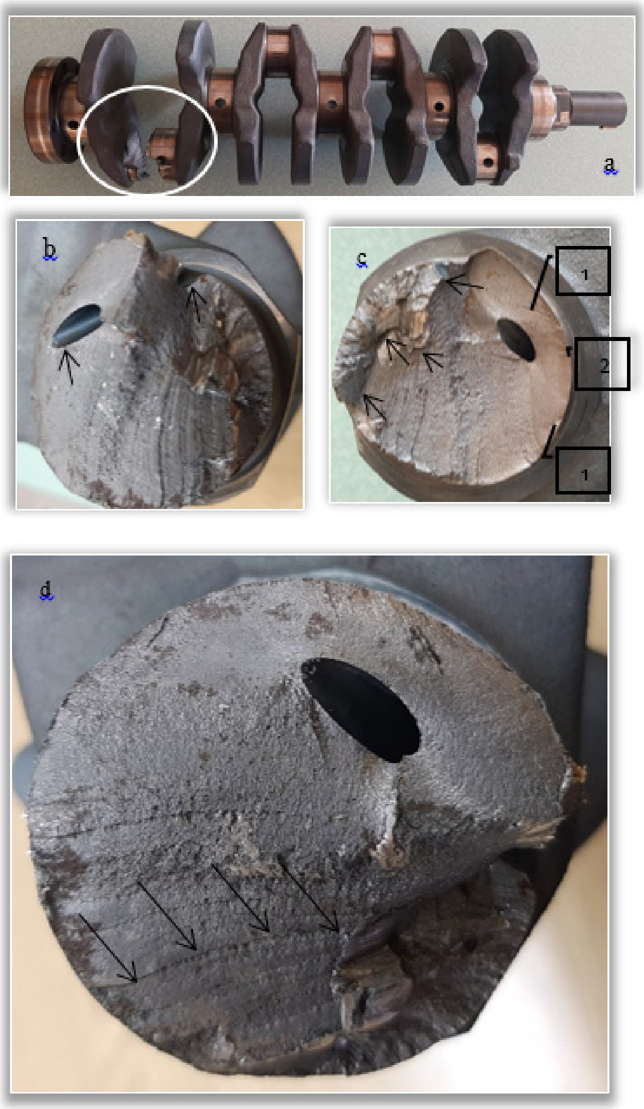

Figure 1. Crankshaft from a car with a mileage of about 300,000 km: a) general appearance and place of destruction; b) failure surface with lubricant hole c) fracture surface – 1) river marks, 2) fracture origin, ⟶) overload fracture; d) beach marks

Secondary cracks located perpendicular to the crack propagation front can be observed in the fracture of the examined crankshaft. Their origin and development can be explained by the special load on the shaft – bending and twisting. While bending stresses promote the development of the primary crack, torsional stresses promote the development of secondary cracks. Secondary cracks can be of "open" and "closed" type. Open cracks start from the surface and develop in depth, while closed cracks start and develop completely surrounded by the material – Figure 2c. The length of open cracks reaches the end of the fatigue crack propagation front and the onset of brittle failure.

Closed cracks are of particular interest Figure 2 and Figure 3. Their appearance can be associated with structural inhomogeneity in the material – presence of non–metallic inclusions, different phases or high–angle grain boundaries, the scale effect. Non–metallic inclusions in steels and graphite in cast iron are stress concentrators. On the other hand, the dimensions of the crankshafts, considered as a scale effect, have a significant influence on the occurrence of secondary closed cracks. It is found that in damaged crankshafts with smaller diameters, secondary cracks do not initiate and develop, and as the dimensions of the crankshafts increase, the secondary cracks propagate perpendicular to the fatigue crack propagation front. This can be explained by the fact that with crankshafts of smaller dimensions, the distance to be traveled is less and there is no possibility for the initiation and development of secondary cracks.

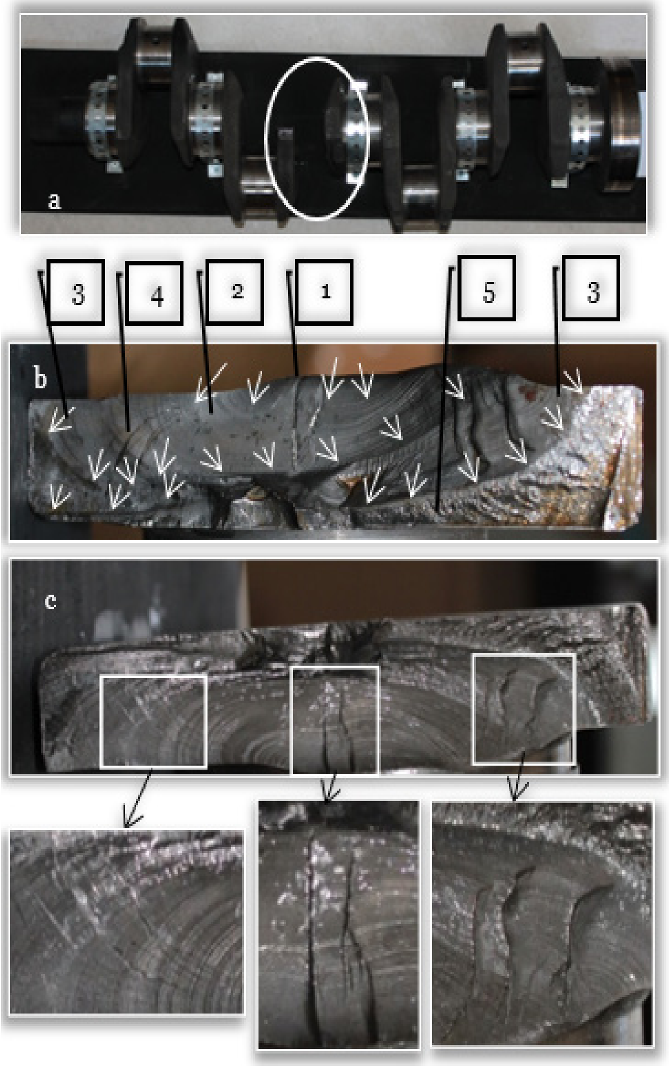

Figure 2. A broken crankshaft from a forklift: a) general appearance and place of destruction b) failure surface: 1–crack initiation, 2–primary beach marks, 3–secondary beach marks, 4–river marks, 5–overload fracture c) failure surface from the second part with closed cracks, secondary cracks and beach marks

In addition, as the dimensions of the crankshafts increase, the mechanical properties of castings and forgings deteriorate, because the non–uniformity of the metal increases, the degree of deformation during forging and stamping decreases, it becomes difficult to carry out quality heat treatment in the entire volume of the material.

Regardless of the reasons for the appearance of the secondary cracks, their propagation is facilitated by the sign–changing stresses arising during operation of the crankshaft and their concentration at the sharp edges.

When examining the destroyed cast iron crankshaft, significant deformation was observed in the crank pin journal, which can be explained by the sudden destruction during engine operation and the impact that occurred between the connecting rod and the cylinder block (the cylinder block was also destroyed).

Figure 3. Destroyed cast iron crankshaft from a truck: a) general appearance and place of destruction b) secondary crack "closed type"

Similar deformations in the steel crankshafts were not detected, and the measured diameters fell within the permissible values determined by their manufacturer. Penetrant testing was conducted on all crankshafts, and the occurrence of another fatigue crack was not detected.

The measured hardness in the cross section of the journals is 250HB in the center of the crankshaft to 280HB on the surface – for steel crankshafts and 200HB to 260HB – for cast iron crankshafts.

Figure 4. Destroyed cast iron crankshaft from a truck: a) secondary cracks "open type" b) Rivers marks.

CONCLUSION

Initial research conducted on failed internal combustion engine crankshafts found that in–service material fatigue was a major cause of failure. The occurrence of more than one fatigue crack is not detected. Measurable significant changes in the hardness of the material are not observed.

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