A. Y. JIAO, B. H. LIU, G. F. ZHANG, M. S. XU, J. P. LI, F. L. CHEN

ISSN 0543-5846
METABK 59(3) 381-384 (2020)
UDC – UDK 669.17-661.666/621.775:621.824:539.375:544.62=111

FAILURE ANALYSIS OF EB03 CRANKSHAFT

Received – Primljeno: 2020-01-03
Accepted – Prihvaćeno: 2020-04-03
Preliminary Note – Prethodno priopćenje

Study on the fracture specimen of EB03 crankshaft which produced by a crankshaft company. It is found that there is a phenomenon of high temperature oxidation on the surface of EB03 fractured crankshaft's journal by the macroscopic analysis of the fracture of the crankshaft. And there are a lot of sintered metal particles on the surface of the neck journal. These phenomena indicate that the axle diameter of the connecting rod is gradually locked in the process of operation, during this process, a lot of heat is generated with the holding of the tile and causes the phenomenon of burning and melting. It is found that the graphite has different degrees of deformation by observing the graphite morphology on the surface of the neck journal.

Keywords: ductile iron, crankshaft, fracture, energy spectrum analysis

INTRODUCTION

The crankshaft is an important part of the engine and the key part of engine power transmission. It can be said that the quality of the crankshaft determines the service life of the engine. So, it plays an important role in improving crankshaft processing technology and improving crankshaft performance to study the crankshaft fracture by means of macroscopic analysis, microstructure analysis, scanning electron microscope, energy spectrum analysis and comprehensive analysis. This paper mainly studies the EB03 broken crankshaft of automobile engine. The failure probability of this crankshaft is obviously higher than that of other crankshaft products. In order to improve the research on the process and the quality of products, it is necessary to analyze the failure reasons. The fracture diagram of EB03 crankshaft is shown in Figure 1.

It is known that the material of EB03 crankshaft is qt 800 - 3. Its strengthening process is shaft-journal induction hardening. The rounded corners are formed by rolling of the sinkhole.

First, when the EBO3 crankshaft was put into bench test at full speed and under full load, the engine suddenly stopped after running for 65 hours. After disassembling the engine, a fracture was found at the back neck of the second connecting rod of the crankshaft. Then, analyzed the fractured crankshaft as follows.

A. Y. Jiao: School of applied technology, University of Science and Technology Liaoning, Anshan, China. E - mail:jay@ustl.edu.cn.
B. H. Liu, G. F. Zhang, M. S. Xu, J. P. Li: School of mechanical Engineering and automation, University of Science and Technology Liaoning, Anshan, China

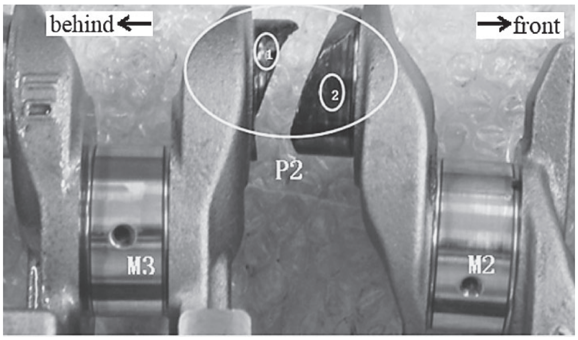

Figure 1 The fracture diagram of EB03 crankshaft

MACROSCOPIC ANALYSIS

By observing the fracture area of crankshaft, it was found that the fracture source area, extension area and transient fracture area were obviously distributed. As the Figure 2 shows, the whole fracture had not obvious impact marks, which indicates that the crankshaft broke for a while. High temperature oxidation exists on the surface of the journal and there were a lot of sintered metal parti-

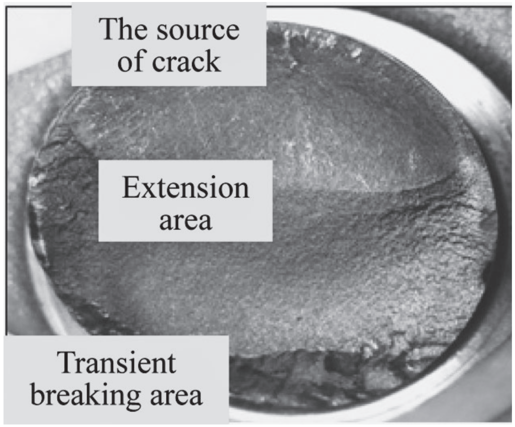

Figure 2 The fracture of the crankshaft

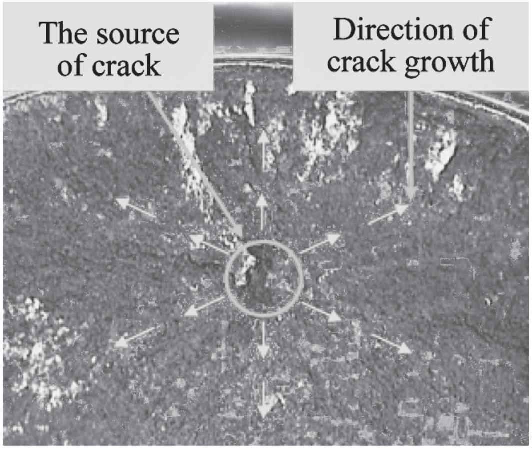

Figure 3 The source of crack

cles on the surface. The part of the visual observation presents white luster and suspected of iron filings. It indicates that the shaft diameter of the connecting rod was gradually locked in the process of operation.

The vast quantities of heat generated when the bearing bush locked, and lead to the melting phenomenon. It was found that the crack source was in the sub-surface layer under the surface of the journal by low-power detection of the crack source area. The crack source which was about 4 mm away from the surface of the journal was obviously radial and extended around, as shown in Figure 3.

MICROCOSMIC ANALYSIS

The specimen was cut at the position of crack source by using wire cutting. Then, detected the vertical plane of crack source according to “GB/T 9441-2009 metallographic examination of ductile iron.” The detecting device was Olympus GX71 metallographic microscope.

The results showed that the graphite spheroidization level near the fracture of the crankshaft was level 2. The diameter of graphite ball was 5 grades. The pearlite content was 95 %. There is no cementite phosphorus eutectic at the fracture location. The distribution and size of graphite were very uniform, no shrinkage porosity and other defects, so it meets the technical requirements. as shown in Figure 4, 5.

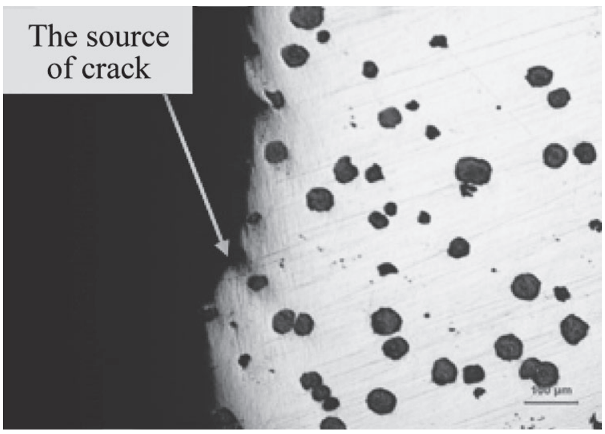

Figure 4 The fracture diagram of EB03 crankshaft

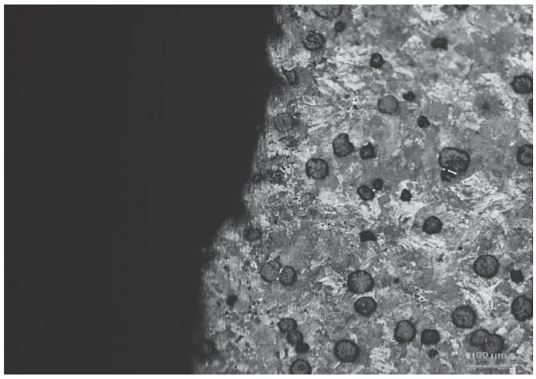

Figure 5 The fracture diagram of EB03 crankshaft

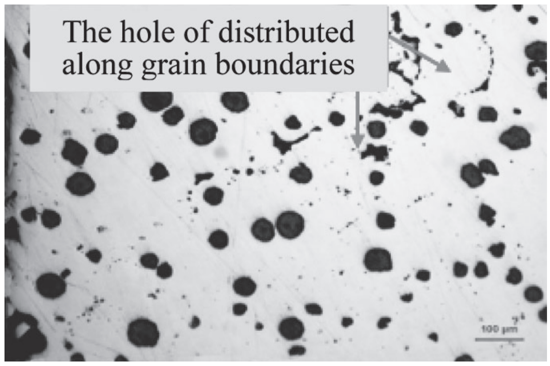

Figure 6 Graphite morphology of crack source

It is found that there were a lot of continuous voids and discontinuous point - like holes in the attachment by observing the crack source. The void was obviously distributed along the grain boundary of the eutectic cluster, and its regional range was 0,45 mm × 0,35 mm. Therefore, the location of the void can easily become a source of fatigue cracks. As shown in Figure 6.

By observing the graphite morphology on the surface of the journal, we found that the graphite on the surface of the journal had varying degrees of deformation. Many cracks had been generated along the deformed graphite due to the acute angle effect of the deformed graphite. And part of the cracks had been rapidly extended to completely tear apart from the metal matrix. The graphite deformation area distributed from the surface of the journal to the axis, and the deepest part extended to about 0,5 mm. As shown in Figure 7.

The graphite is not vermicular or flake graphite produced by spheroidizing decay or inoculation failure during casting, but formed by deformation after extrusion. Extrusion may be caused by improper machining of the crankshaft.

The structure of the quenching layer was detected according to “JB / T9205 - 2008 Induction quenching metallographic examinat - ion of pearlite ductile iron parts”.

By analyzing the quenching structure, it is found that the tissue is severely overheated and the martensite is coarse martensite. There was a lot of bright white microstructure, which is suspected to be a secondary quenching mic - rostructure, and the microstructure needs to be further confirmed by hardness testing. As

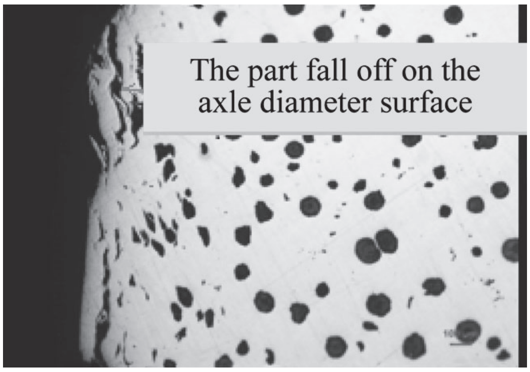

Figure 7 Graphite morphology on the surface of the journal

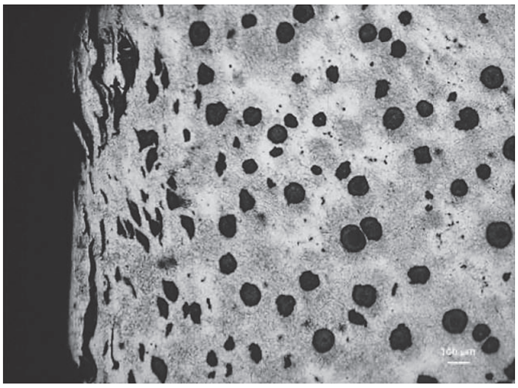

Figure 8 Structure of shaft neck quenching zone

shown in Figure 8. In addition, there is no obvious decarbonization in the structure near the crack, which indicates that the crack was generated after the quenching process. Otherwise, decarburization would occur in the quenching heating process. That is, the extrusion defor - mation of graphite was formed after quenching.

ELECTRON MICROSCOPY ENERGY SPECTRUM ANALYSIS

The crack source was analyzed by electron microscopy, as shown in Figure 9,10 and the results were shown in Table 1. It can be found from Table 1 that about 0,27 % of Cr and about 0,30 % of O were clustered around the crack source.

A lot of heat is generated when the crankshaft holds the tile, the phenomenon of burning and melting occurs.

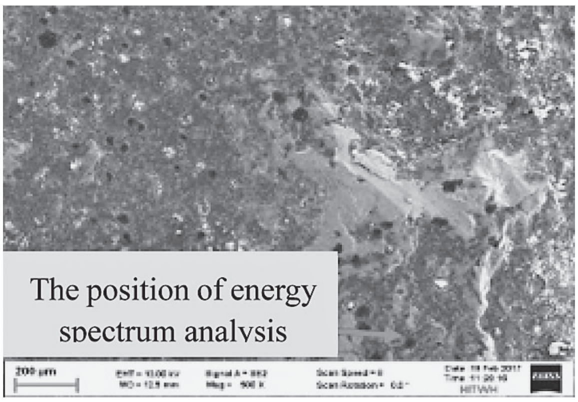

Figure 9 Electron microscope picture

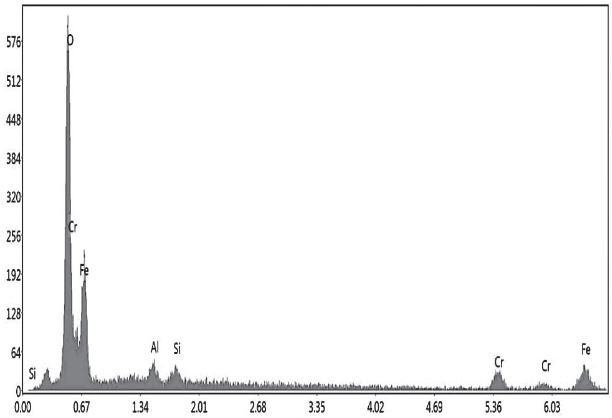

Figure 10 Energy spectrum analysis diagram

Table 1 **The results of crack source energy spectrum analysis**

Element	Weight /mas.%	Atomic /mas.%
O	0,422	0,40 – 0,45
Fe	0,281	0,17 – 0,37
Al	0,738	0,50 – 0,80
Si	0,0050	≤ 0,025
Cr	0,0055	≤ 0,025

So, the high temperature oxidation of the shingles during the crankshaft operation leads to generate the detected oxygen element.

Cr element is easy to segregated near grain boundary and reduces the phase transition temperature here. The grain boundary strength of Cr element is the lowest, so it is easy to overheat or even overburn when heated. Simply put, it is easy to produce grain boundary melting phenomenon. First, form point-like holes are formed at the grain boundary, and then expand into cracks. The existence of oxygen element indicates that high temperature exists at the crack source. Many cracks have been generated along the deformed graphite due to the acute angle effect of the deformed graphite. It is found that Cr element tends to segregate around grain boundaries by electron microscope scanning and energy spectrum analysis. Because the grain boundary strength of Cr element is the lowest, the phenomenon of overheat or even overburn is caused during heating, so point-like holes are formed in the grain boundary, and cracks are formed along with the expansion of the holes. The cracks gradually expand with the imbrication and eventually fracture occurs.

COMPREHENSIVE ANALYSIS

First of all, the main reason for the engine bearing bush to lock is that the lubricating oil is too dirty and the bearing clearance is too large to form an oil film. Considering the short running time of the equipment and no oil channel cleanliness test report, so all of these factors could have been eliminated.

Secondly, there is a graphite deformation zone with a depth of about 0,5mm in the surface quenching zone of the shaft neck, and a large number of micro-cracks are generated due to the sharp angle effect of the graphite deformation. These cracks are affected by the increase of temperature and the running force of crankshaft during engine operation. And the quenching structure on the crankshaft surface is hard and brittle, so the micro-cracks will gradually become larger. When the cracks expand to a certain extent, part of the journal surface will fall off, which will cause the phenomenon such as oil circuit blockage and bush locking. A lot of heat is generated during this time and the cracks expand toward the axial diameter center. Due to the cooling effect of the lubricating oil and bearing cover, the surface of the journal will be cooled in a relatively timely manner, which will lead to secondary quenching or tempering of the shaft diameter. Since the heat inside the axle diameter is not emitted, high temperature will be generated and Cr element reduces the temperature of grain boundary melting, which eventually leads to the formation of pores or cracks along the grain boundary.

Finally, the cracks along the grain boundary become the fatigue source and extend to all sides as the bearing bush is completely locked, and then fracture occurs.

CONCLUSION

(1) The reason of crankshaft fracture is that improper crankshaft processing technology causes the deformation of crankshaft diameter graphite, and this deformation causes micro - cracks.

(2) The crack expanded and the surface of the journal is partially detached in the process of engine running. The bearing bush began to be locked;

(3) High temperatures by holding the tile cause melting of grain boundaries of Cr element segregation position. The grain boundary crack is formed and a fatigue source is formed;

(4) The grain boundary crack extends in all directions as the bearing bush is completely locked. Eventually, the crankshaft broke.

Acknowledgement

The paper is supported by University of Science and Technology Liaoning Talent Project Grants (601011507-32).

REFERENCE

[1] D. F. Li, J. Liu, C. P. Wang, H. S. Mei, Failure Analysis of QT700-2 Ductile Iron Engine Crankshaft. Precision Forming Engineering 11 (2019), 108-113.

[2] J. Anyuan, L. Xiwei, D. Junwei, C. Chanchan. Analysis of fracture reason of ductile iron G6135Z crankshaft. Coal mine machinery, 38 (2017)11, 145-147.

[3] B. Kareem, Evaluation of failures in me chanical crankshafts of automobile based on expert opinion, Case Studies in Engineering Failure Analysis 3 (2015) 25-33.

[4] M. Ming. Process oriented crankshaft fracture analysis. Diesel engine design and manufacturing, 23 (2017) 04, 43-47(+5).

[5] L. Yuhui. Analysis of fracture failure reason of crankshaft of a piston engine. Aviation maintenance and engineering, 08 (2017):31-33.

[6] L. Fang. Research on the cause of crankshaft fracture of automobile engine and preventive measures. Internal combustion engine and accessories, 15 (2017):81.

[7] L. Shen, W. Zhanhua, Z. Xiuming. Fracture failure analysis of automotive crankshaft with 49MnVS3 non-quenched and tempered steel. Hot processing technology, 45 (2016) 16, 253-256 (+262).

[8] Z. Zhen, Z. Bing, Z. Jian. Analysis of crankshaft fracture in automobile engine. Failure analysis and prevention, 11 (2016) 04, 261-264.

[9] G. Atxaga, A.M. Irisarri, Failure analysis of the end of a shaft of an engine, Enginee- ring Failure Analysis 17 (2010), 714-721.

[10] O. A. Zambrano, J.J. Coronado, S.A. Rodrı´guez, Failure analysis of a bridge crane shaft, Case Studies in Engineering Failure Analysis 2 (2014), 25-32.

Note: The responsible translator for English is Yanming Li, School of Applied Technology, University of Science and Technology Liaoning, Anshan, China