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ISSN 0543-5846
METABK 59(4) 517-520 (2020)
UDC – UDK 621.824:521.741/661.666:539.375:620.18:620.17 =111

FRACTURE ANALYSIS OF NODULAR CAST IRON CRANKSHAFT

Received – Primljeno: 2020-05-14
Accepted – Prihvaćeno: 2020-07-15
Preliminary Note – Prethodno priopćenje

Based on the analysis of the fracture of a certain type of QT800-2 nodular cast iron crankshaft, the cause analysis of the fracture crankshaft is discussed based on macroscopic inspection, metallographic analysis and mechanical properties test. The results show that the shrinkage and surface cracks in the casting process are the main factors leading to the fracture of the crankshaft, and the process improvement measures for the manufacturing process of QT800-2 nodular cast iron crankshaft are put forward.

Key words: crankshaft, nodular cast iron, fracture, metallographic structure, mechanical properties

INTRODUCTION

Crankshaft is one of the most important components of automobile engine.[1] Nodular cast iron is widely used in industrial production because of its good strength and toughness, good fatigue resistance and low production cost. Especially for casting important parts with dynamic loads, holes or shoulders, such as crankshafts, hubs, connecting rods and camshafts.[2-3] All the power of the engine is output by the crankshaft. when working, the crankshaft bears the periodic gas pressure and the inertia force of the reciprocating and rotating motion of the piston connecting rod group, and its working environment is very bad.[4-5] Under the action of cyclic stress such as bending, torsion, vibration, tension and compression for a long time, the crankshaft is easy to produce bending and torsional deformation, fatigue crack and even fracture.[6-7] Therefore, the failure analysis of the fractured crankshaft is of great significance to improve the quality and reliability of the crankshaft.[8-10]

The crankshaft of a truck 4-cylinder diesel engine is broken during operation. The shaft is made of QT800-4. The main process is casting→heat treatment→surface shot peening→machining. The metallographic sample is cut from the fracture, and the sampling diagram is shown in Figure 1. The hardness sample is cut from the 5th main shaft, and the tensile sample is cut from the 8th crank for testing. The crack initiation is located in the transition part of the fourth connecting rod and the eighth crank. In order to find out the cause of the fracture of the crankshaft, a failure analysis of this crankshaft was performed .

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Figure 1 Macroscopic morphology of fracture

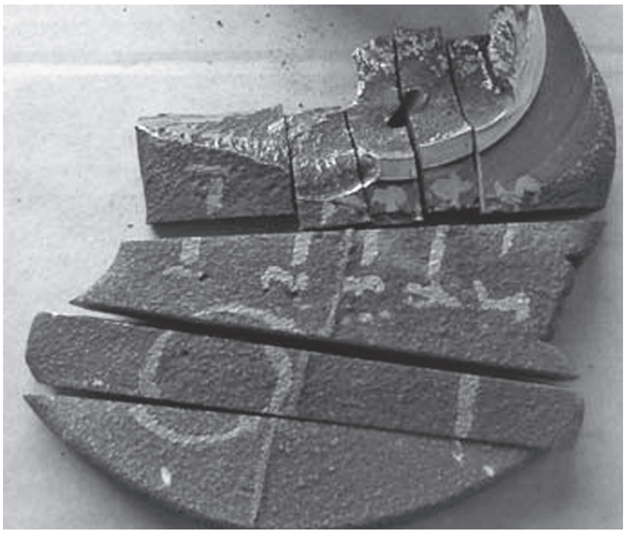

Figure 2 Schematic diagram of sample

TEST RESULTS AND ANALYSIS

Macroscopic analysis of crankshaft

The macroscopic appearance of the fracture is shown in Figure 1. The whole fracture has no fatigue crack, and it is instantaneous brittle fracture, and some areas around the fracture are worn. The crack initiation is located at the transition part of the 4th connecting rod

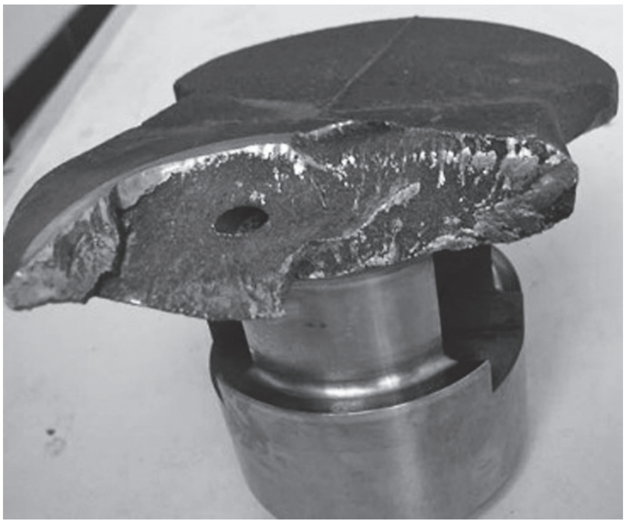
Figure 3 Macroscopic morphology of fracture

and the 8th crank. From Figure 3, it is at the bottom of the convex plate of the crank. The crack initiation is relatively flush and narrow and long. It is speculated that there may be a long micro-crack in advance, leading to flush fracture at this place.

Microscopic analysis of crankshaft

- Metallographic structure analysis

According to the metallographic examination of GB/T9441-2009 ductile iron, Figure 4 - Figure 7 shows the metallographic photos near the fracture. Figures 4 and 5 show that a large number of shrinkage porosity has been found in different areas of the matrix, with a maximum length of about 170μ*m* and a maximum width of about 130μ*m*. The spheroidization rate is 2-3 (requirement 1-4), and the ball diameter is 5-6 (requirement 5-8). Figure 6 shows that the pearlite content is 85 % - 95 % (requirement ≥ 85%). A part of cementite in the matrix can be observed in Figure 7.

- Mechanical property test

According to the GB/T228-2002 tensile test method of metal material at room temperature and the mechani-

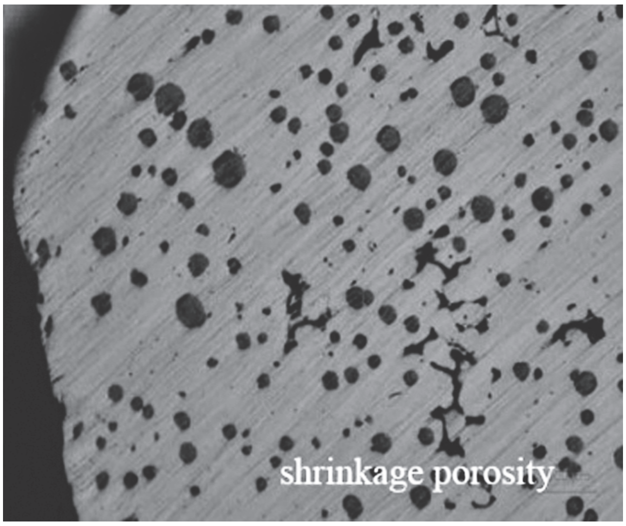

Figure 4 Surface morphology near oblique oil hole (100 ×)

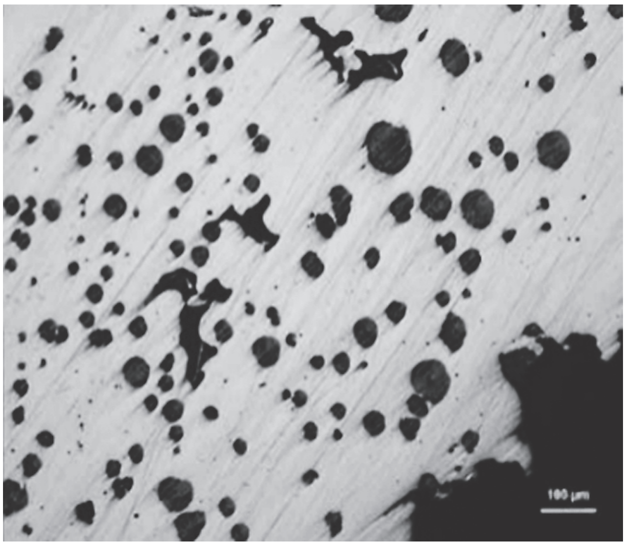

Figure 5 Surface topography near fracture(100 ×)

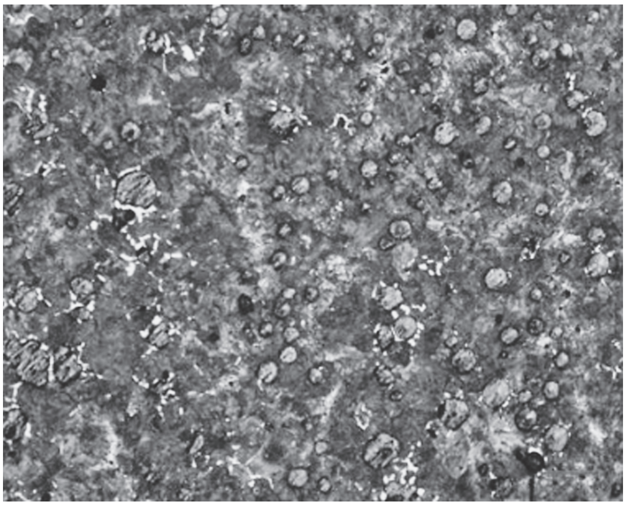
Figure 6 Tissue near fracture (100 ×)

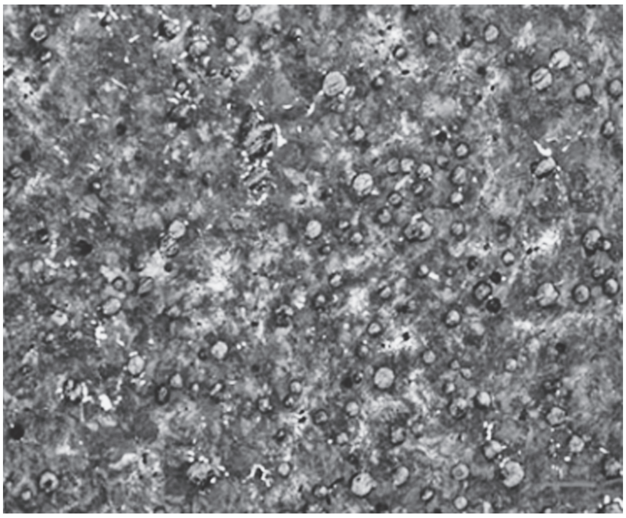
Figure 7 Matrix structure (100 ×)

cal properties of crankshaft were tested. The results are as follows: It can be seen from Table 1 that the mechanical properties of the shaft are all qualified, and the hardness test points of the matrix are taken from the center to the near surface of the journal, and their values are 265;266;268;269;271 HB, respectively, with an average value is 267,8 HB.

Table 1 **Test results of mechanical properties**

Crankshaft	Technical requirements	Measured value
Tensile strength *Rm*/ Mpa	≥784	39
Yield strength $R_{P0,2}$/ Mpa	≥548,5	88
Elongation / %	≥4	6,3
Hardness value / HBW	260-310	65-271

- Heat treatment process test

According to GB/T231.0-2002 metal Brinell hardness tests were done, and the results are as follows:

Table 2 **hardness and nitride layer test results**

Crankshaft	Technical requirements	Measured value
Nitride layer depth	≥ 0,15 mm	0,16 mm
Nitrided surface hardness / HV_1	≥ 500	506-520

It can be seen from Table 2 that the depth and surface hardness of the nitrided layer are qualified.

Cause analysis of defective tissue

The mechanical properties and heat treatment process of the shaft are within the required range, but in the observation of metallographic structure, it is found that there are a large number of shrinkage porosity near the matrix and fracture. In addition, some cementites are observed, the bulk hardness is slightly lower, and other indexes are qualified. In the macroscopic observation of the fracture, it is found that the crack initiation is flat and narrow, and there is no fatigue trace on the whole fracture. It is speculated that there is a long crack at the crack initiation, which eventually leads to the sudden fracture of the crankshaft.

Analysis of the causes of shrinkage

The shrinkage hole generally appears in the place where the molten iron finally solidifies, which is the branch shrinkage caused by the volume shrinkage of the molten iron when it is solidified without the timely replenishment of the molten metal. Shrinkage is divided into concentrated shrinkage and porosity. The influencing factors of shrinkage include chemical composition of molten iron, carbon equivalent, inoculation and spheroidizing treatment, mold stiffness, pouring temperature, casting modulus, gating system, riser and so on.

Cause analysis of surface cracks

The crack of crankshaft can be divided into hot crack, cold crack and warm crack. The defect produced in crankshaft casting is hot crack defect. Engine crankshaft casting hot cracking is the occurrence of crankshaft casting hot cracking site when linear shrinkage is hindered due to various reasons in the process of starting linear shrinkage after the formation of solid phase basic skeleton of engine crankshaft. Different from the medium and low temperature environment in the process of use or hot processing, the hot cracking formation temperature is high temperature, so it is called hot cracking. Most of the hot cracks occur in the last cooling and solidification part of the crankshaft casting, especially in the part where shrinkage occurs. The main influencing factors of hot cracking are the properties of casting alloy, the properties of medium sand in casting process and pouring conditions.

METHODS TO REDUCE DEFECTS

Methods to reduce shrinkage and looseness

At present, the general solutions at home and abroad are: application of subsidy and cold iron; pressure shrinkage method; adjustment of pouring conditions; hot metal composition and nodularizer control method; reasonable gating system design and riser application and so on. Combined with this case, it is feasible to add pure lanthanum nodularizer and replace sand riser with PB riser. In addition, the computer numerical simulation technology is used to assist the study of the relevant factors affecting the crankshaft shrinkage, which can further improve the problem-solving efficiency.

Methods to reduce surface cracks

The optimization measures for casting hot crack defects of engine crankshaft are as follows: improving the properties of casting alloy, using casting alloy raw materials which are more suitable for this application condition, ensuring the humidity of molding sand and ensuring that the temperature of molding sand is not too high; reduce the content of organic matter in the core and so on. Combined with this case, it is feasible to improve the pouring conditions, ensure the temperature of the gate and riser and set the gate and riser evenly. In addition, further improve the crankshaft magnetic particle flaw detection and other operating specifications and evaluation system, timely find defects, avoid entering the next process, and ensure the reliability of crankshaft products.

CONCLUSIONS

Fatigue fracture is the main failure reason of crankshaft for this crankshaft. the crack source is distributed in the area of high stress concentration such as the transition part of the fourth connecting rod and the eighth crank. there are cracks on the surface of the crankshaft in advance, and there are a large number of shrinkage and a small amount of cementite in the interior of the crankshaft. it is the main reason for the fracture of the crankshaft. It is suggested that in the casting process, adding pure lanthanum nodularizer, using PB risers instead of sand risers to reduce shrinkage defects; in addition, pay attention to improve the crankshaft magnetic particle flaw detection and other operation specifications and evaluation system, and strengthen the process quality management.

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Note: The responsible translator for English is T. Pan, University of Science and Technology Liaoning, Anshan, China