ISSN 0543-5846
METABK 59(4) 575-577 (2020)
UDC – UDK 621.824:539.375:66.014.620.18:620.17=111

FRACTURE ANALYSIS OF CRANKSHAFT OF HEAVY TRUCK ENGINE

Received – Primljeno: 2020-05-11
Accepted – Prihvaćeno: 2020-07-12
Preliminary Note – Prethodno priopćenje

The crankshaft of diesel engine of a heavy duty vehicle broke during running. By means of macroscopic and microscopic observation of the fracture, chemical composition and metallographic structure analysis, and mechanical property test, the cause of the fracture of the crankshaft was studied. The results showed that the surface hardness of the journal was not up to standard, the wear and tear were serious, and local burns were suffered. The fatigue brittle fracture of crankshaft shaft journal and connecting rod was caused by abnormal external force. It is suggested to control the heat treatment and manufacturing process of crankshaft, optimize the structural design, improve the assembly precision and improve the lubrication system.

Keywords: crankshaft, brittle fracture, chemical composition, metallography, mechanical properties

INTRODUCTION

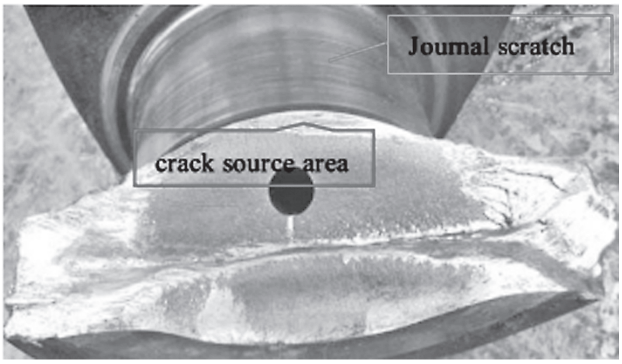
The crankshaft of an engine is subject-ed to repeated inertial forces and centrifugalforces in the working process, and is subje-cted to cyclic alternating stresses such as bending, torsional, vibration, and plug rod impact [1], which have high requirements on its material chemical composition, metallographic structure, mechanical properties, journal surface roughness, transition rounded edges, and heat treatment [2]. The common failure modes of crankshaft include fracture failure, wear failure, corrosion failure and excessive deformation failure. Because the fracture of the crankshaft is a sudden accid-ent,it is difficult to predict or find in the management. The impact caused by the fract-ure is the most serious [3,4].

According to the fracture of diesel engine crankshaft in a heavy duty vehicle, the fracture was observed macroscopically and microscopically, and its chemical composition, metallographic structure and mechanical properties were tested and analyzed in detail

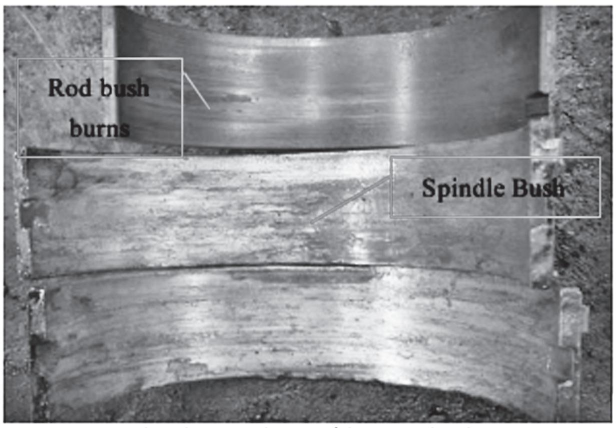
EXPERIMENT ANALYSIS
Macroscopic morphology observation

The crankshaft material is 42CrMo, the main heat treatment process is: normal-temperature-surface nitriding. The shaft is broken at the second crank, as shown in Figure 1.

From Figure 1, the crankshaft shows a short time fatigue brittle fracture. No.1 connecting rod journal is seriously scratched due to wear and tear, the tiles are burned locally until the surface is black, and there are small concave holes in the tiles, which should be caused by sundries in the lubrication system during failure and wear. The first, second and third main shaft journal were all scratched by wear, and the flange was scratched the most seriously, as shown in Figure 2. Between the flange and the gear, a gap of about 6mm was found between the two. According to this, it can be inferred that when the accident happened, the shaft journal, especial-



(a) Fracture region



(b) Abrasion burn of bearing bush

Figure 1 Fracture morphology

W. Ding: School of applied technology, University of Science and Technology Liaoning,Anshan, China.e-mail: dingwei@ustl.edu.cn.

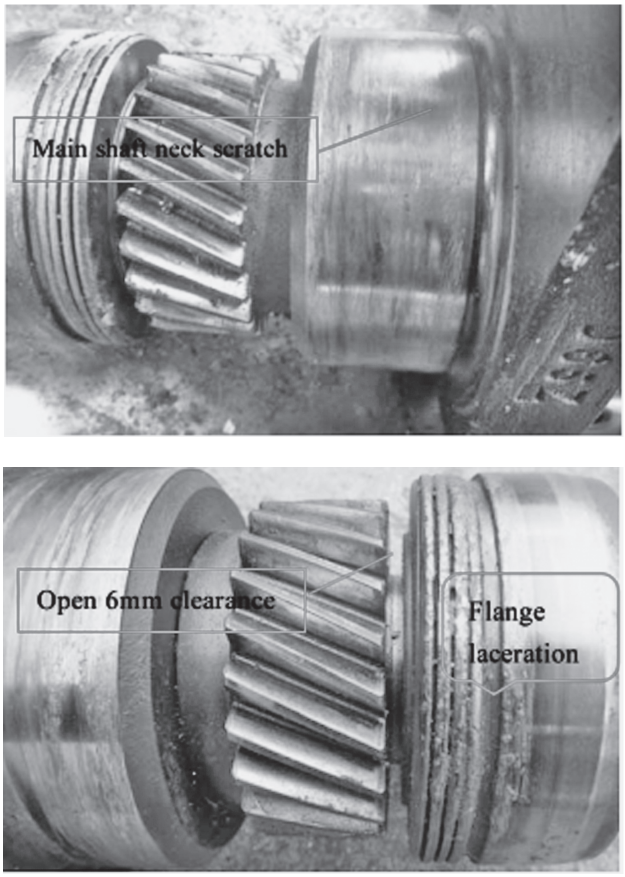


Figure 2 Scratch and wear of spindle journal Chemical composition analysis

ly the round corner and the connecting rod were under abnormal stress, resulting in serious grinding and failure of all the accessories of the cylinder block [5,6].

Chemical composition analysis

The composition sample was taken from the crank fracture and the chemical composition of the sample was analyzed by direct reading spectrometer. The chemical composition of the crankshaft is shown in Table 1. According to Table 1, the chemical composition of the crankshaft conforms to the requirements of GB/ t3077-2015 for 42CrMo steel.

Table 1 **Chemical composition of broken axis /wt.%**

Name	Crankshaft	Technical requirements
C	0,43	0,38 - 0,45
S	0,028	≤0,035
Mn	0,77	0,50 - 0,80
Si	0,26	0,17 - 0,37
P	0,007	≤0,025
Cr	1,04	0,90 - 1,20
Mo	0,199	0,15 - 0,25
Cu	0,011	≤0,20

Nitriding treatment test

The sample taken from the crank was tested for hardness detection by Vickers hardness tester. The detection results are shown in Table 2.

Table 2 **Test results of nitriding treatment**

Name	Crankshaft	Technical requirements
Stiffness of nitriding	257/mm	HV10≥300
Depth of nitriding	0,26/mm	No request

As can be seen from Table 2, the hardness of the middle surface of the journal is unqualified. It is generally believed that the tensile strength and fatigue strength of materials have a certain linear relationship with the hardness, and the insufficient hardness will affect the tensile strength, fatigue strength and wear resistance of parts, resulting in the deterioration of the product resistance to damage, which is one of the main reasons for the parts to pull and fracture failure [7].

Microstructure

The surface cross section samples were prepared on the journal of the first connecting rod.

According to GB/ t10561-2005, nonmetallic inclusions were inspected and evaluated.As can be seen from Figure 3, there is a grade A1,5 sulfide inclusion near the lower rounded corner. The 42CrMo is mainly composed of endogenous inclusions of MnS t-ype. The content, spacing, size and shape ofinclusions are direct-

Figure 3 Surface topography near the fracture 100 X

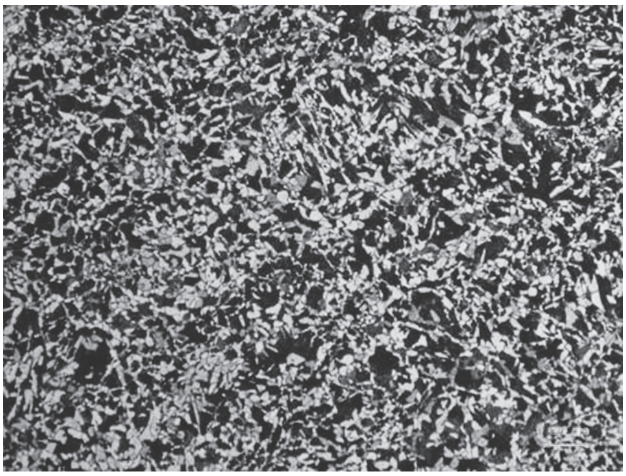


Figure 4 Tissue near fracture 100 X

ly related to the fracturetoughness of 42CrMo steel. The fracture to-ughness can be improved by controlling the-content of sulfur or spheroidizing treatment of sulfide[8].

As can be seen from Figure 4, the matrix structure of the crankshaft is qualified pearlite + reticular ferrite. The grain size is determined to be grade 8 according to GB/ t6394-2017 (requirements). Grade (5-8), band 1 (≤1). The requirements are met.

Mechanical property testing

The mechanical properties of the samples from the crank were tested by brinell hardness tester, tensile testing machine and other experimental instruments. The test results are shown in Table 3.

Table 3 **Test results of mechanical properties**

Name	Crankshaft	Technical requirements
R_m/MPa	676	610 - 750
$R_{p0,2}$/MPa	383	≥350
A/%	23,2	≥17
Z/%	46,1	No request
HB	193	180 - 228

It can be seen from Table 3 that according to GB/ t2975-2018, the mechanical properties of the crankshaft are qualified.

Radius detection of rounded corners

From the above data, the position of the maximum stress of the crankshaft is in the region of transition fillet at both ends of the connecting rod journal or spindle journal, and stress concentration is an important reason for the fatigue fracture of the crankshaft [9]. The circular corner radius of the first connecting rod journal was measured, and the results are shown in Table 4.

As can be seen from Table 4, the radius of the rounded corner is within the required range.

Table 4 **Circular corner radius of the journal of the first connecting rod**

Name	Crankshaft	Technical requirements
Fillet radius	4,99/mm	4,5 - 5/mm

CONCLUSIONS AND SUGGESTIONS

1 The chemical composition of the crankshaft meets the requirements. The matrix structure is qualified pearlite reticular ferrite, and there is no obvious defect in the fracture. The rounded corners are relatively smooth, and the radius of the rounded corners is within the required range. There are grade A1,5 sulfide inclusions near the lower fillet. It is suggested to pay attention to spspherification of sulfide inclusions to improve fracture toughness of 42CrMo steel

2 The mechanical properties of the crankshaft are qualified.

3 The hardness of the middle surface of the shaft journal is unqualified, which seriously affects the tensile strength, fatigue strength and wear resistance of the parts, and leads to the deterioration of the ability of the crankshaft to resist damage. It is suggested to improve the nitriding process and to determine the depth of nitriding layer.

4 From the macroscopic and microscopic point of view, the crack develops rapidly and the brittle fracture features are clear. Each journal is seriously scratched by wear, and the tiles are burned locally and blackened, which indicates that the friction between the crankshaft and the axle bush produces high temperature, which causes the surface of the journal to produce greater thermal stress, and the crankshaft material has the tendency of brittleness of overheating. The appearance of small concave holes in the tile indicates that the lubricating system has sundries. The gap between flange and gear is about 6 mm, which indicates that the abnormal forces on the journal, especially the forces at the fillet and the connecting rod are the main reason for the short-time fatigue brittle fracture of the crankshaft. It is suggested to optimize the crankshaft structure design, control the crankshaft manufacturing process, especially improve the surface quality of the transition rounded corners, improve the assembly precision, and improve the lubrication system, so as to prevent similar accidents.

REFERENCE

[1] Fonte M., Li B., Reis L., et al. Crankshaft failure analysis of a motor vehicle. Engineering Failure Analysis (2013) 35; 147-152

[2] Hou S. S., Zeng X. C., Shi C., et al. Fracture Cause of Marine Diesel Engine Crankshaft.Materials for Mechanical Engineering 8(2019), 69-74.

[3] F. S. Silva. An Investigation into the Mechanism of a Crankshaft Failure. Key Engineering Materials 245-246 (2003) 351-358.

[4] Sun Z., Ren Y. J., Sui Y. W. Failure Analysis: Basises and Application, 2th Edition. China Machine Press 2017, pp. 136-163.

[5] Ma X. M., Wang X. T. Fracture Cause of Reciprocating Methane Compressor Crankshaft. Materials for Mechanical Engineering 3(2020), 83-86.

[6] G. Atxaga, A. M. Irisarri. Failure analy-sis of the end of a shaft of an engine. Engineering Failure Analysis 17 (2010), 714–721.

[7] Cue H., Zhuang Z. C., Cao T. Relationship Analysis Between Vickers Hardness and Yield Stress of Structure Material. Journal of Xi'an University of Science and Technology 2(2017), 274-279.

[8] Cui Z. X, Qin Y. C. Metal Science and Heat Treatment, 2th Edition. China Machine Press 2011, pp.123-129.

[9] Li W., Liao R. D., Zuo Z. X., et al. A Study on The Fillet Stress Calculation of Crankshaft in A Highly - intensified Diesel Engine.Automotive Engineering 6(2013), 565-572.

Note: The responsible translator for English is Xiyu Wang, University of Science and Technology Liaoning, Anshan, China