International Journal of Engineering Research
Volume No.6, Issue No.11, pp : 475-478

ISSN:2319-6890 (online),2347-5013(print)
1 Nov. 2017

Analysis on Quenching Cracks of Engine Crankshaft

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Abstract: Engine crankshaft of cracks macro and micro were analyzed by morphological characteristics and quench cracks organization identified as the quenching crack, but further study showed that the root cause of this quenching cracks generated not due to the heat treatment process or other causes, but due to poor uniformity of the hot iron casting, elements gathered along the grain boundary segregation.

Keywords: crack; hardening; martensite; austenite

1 General situation

An engine crankshaft blank for the QT700-2 ductile iron pieces, the organization for the as-cast. When processing the finished product inspection found that there are cracks in the main shaft and connecting rod hole, found that after quenching of two production lines in the processing of the crankshaft are individual in the connecting rod and crankshaft spindle oil hole chamfer position and severe crack, even if the oil hole chamfer is very good also appears heavier crack.

2 Ingredient detection

Table 1 Chemical composition test results table (mass percentage,%)

Element name	C	S	Si	Mn	P	Cu	Mg
Skills requirement	3.6−4.1	=0.035	1.6~2.4	0.4−0.6	=0.035	0.6~0.7	0.02-0.08
Detection value	3.72	0.01	2.21	0.55	0.030	0.65	0.038

Traceability trace crankshaft spectral analysis report, found that crankshaft casting components meet the technical requirements, harmful elements S, P content is low, the elements are no exception [1].

3 Physical and chemical test

3.1 Crack morphology

Observe all cracks in the crankshaft, found that the crack is located in the connecting rod and spindle oil hole chamfer position and the bottom of the thinnest wall, and to the oil hole chamfering the inner wall and journal extension shown in Figure 1.

Fig.1.crack macroscopic morphology

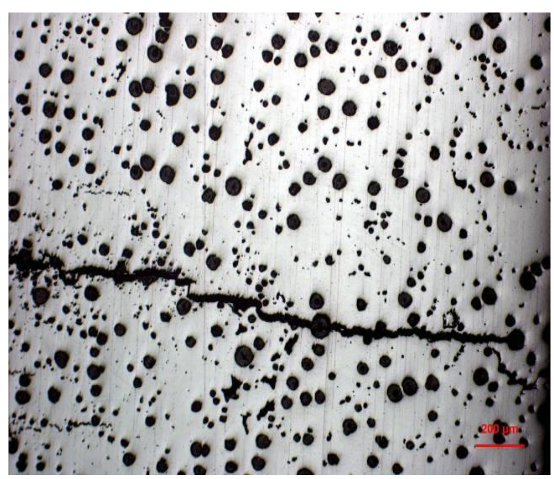

Fig.2.crack micro-morphology(50X non-corrosive)

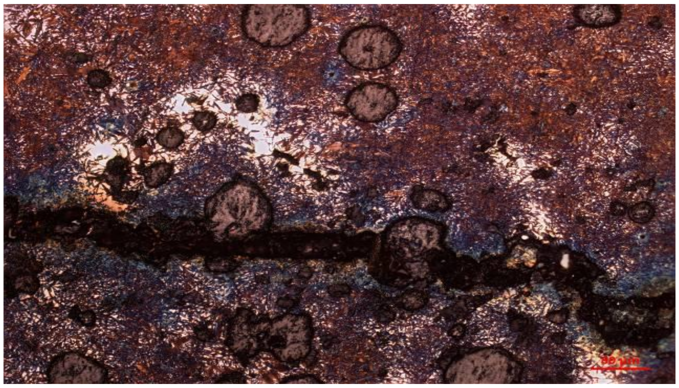

Fig.3.crack micro-morphology (200X has been corroded)

The microscopic detection of the opening of the oil hole crack. Figure 2 and Figure 3 show the microscopic morphology of the crack. .It can be seen from Figure 2 that although the main crack is sometimes broken in the middle, but the overall look at the main cracks originated in graphite. The crack passes along the graphite, and the main crack shape is strong and powerful. Cracks seem to tear because of force, and the direction of straight. Some small cracks originate in graphite, tail tip.

In order to better observe the characteristics of the crack shape, the oil hole crack cut with 5% nitric acid alcohol solution corrosion observation [2], found that the crack through the graphite, graphite shape intact, crack along the edge of the graphite line, rather than from Graphite through.

The main crack on both sides of the phenomenon of non-oxidative decarburization, it can be sure there is no crack before quenching (see Figure 4). During the quenching and cooling process, the crack may form only when the martensitic transformation reaches a certain amount. Corresponding to this temperature, about 250 ℃ below. At such a low temperature, even if cracks are generated, decarburization and significant oxidation not occur on both sides of the crack. Therefore, the phenomenon of oxidation decarburization is non-quenched crack. If the crack is already present before quenching and does not communicate with the surface, such internal cracks will not produce oxidative decarburization, but the lines of the crack appear soft, the tail is round bald, The lines of this crack are also easily different from the lines of the quenched crack,this crack are also easily different from the lines of the quenched crack, the strong and tip of the tail.

Ductile iron workpiece quenching cracks for many reasons, such as improper cooling, inclusions, spheroidization, complex parts and the quenching temperature is too high [3]. The quenched crack in Figure 3 is due to two stresses, ie, thermal stress and tissue stress. The former is caused by uneven cooling, the latter is austenite into martensite generated. When quenching and cooling, these two stresses tend to concentrate at the edge of graphite and cause cracking.

3.2 Quenching organization analysis

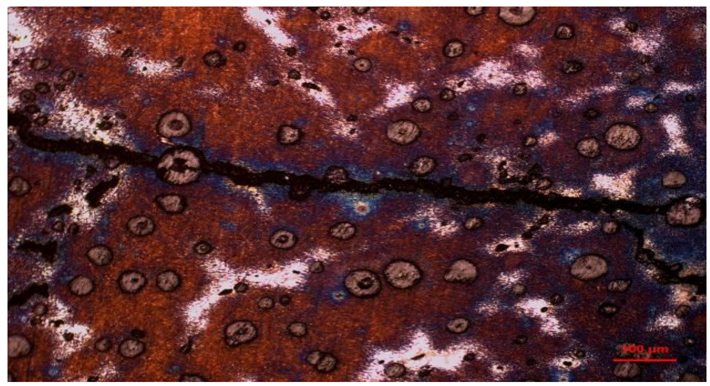

Fig.4. crack near the quenching organization (100X has been corroded)

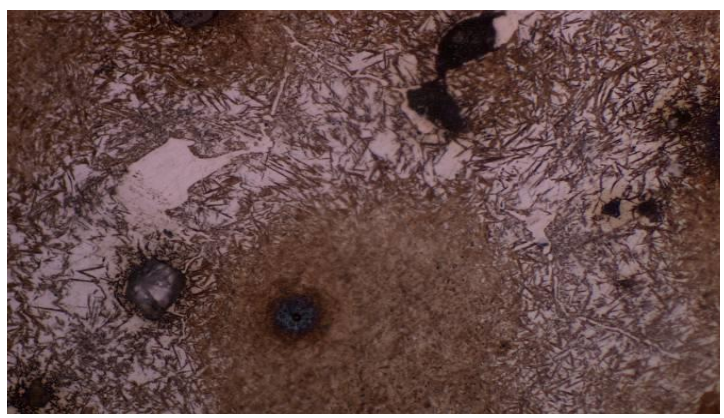

Fig.5. crack near the quenching organization (500X has been corroded)

Figure 4, Figure 5 quenching area of the microstructure to detect, microstructure characteristics are as follows:

(1)Residual austenite content> 10% at 100X;(2)most of the small graphite along the grain boundary distribution; (3)residual austenite along the small graphite distribution;

(4)500X under the observation of a network of cementite along the grain boundary distribution; (5)residual austenite and cementite area martensite coarse; (6)the white area is a mixed structure of retained austenite and carbide.

According to JB/T 9205-2008 "pearlitic ductile iron parts induction quenching metallographic examination" on the quenching area to determine the organization: quenching organization 2-3; coarse martensite, large block retained austenite, cementite, Spherical graphite. Conclusion: Quenching tissue is not qualified.

4 Quenching stress analysis

4.1 Thermal Stress

Crankshaft in the heating and cooling process, due to the surface and the heart of the cooling rate and time inconsistency, the formation of temperature difference, it will lead to volume expansion and shrinkage uneven stress, that is, thermal stress. In the induction quenching of medium frequency, with the increase of heating temperature, the degree of alloying of austenite increases, the specific volume of martensite increases after quenching, grain coarsening, and because of the existence of micro-segregation of 3.8L crankshaft, The Ms temperature of the high-Si region decreases little, and the Ms of the high-phosphorus and high-manganese regions decreases a lot, so that the martensitic transformation temperature of the two regions has a large gap, resulting in the martensitic transformation of the two regions Leading to more uneven distribution of thermal stress in the workplace [4]. This phenomenon is affected by factors such as cooling rate, material composition and process. When the cooling rate is faster, the higher the carbon content and the alloy composition, the greater the uneven plastic deformation produced by the thermal stress during the cooling process, and the greater the residual stress formed.

4.2 structural stress

In the quenching, due to the different internal and external cooling rate caused by the phase change of different timeliness, martensitic transformation always began on the surface and then to the heart of the development. The surface of the martensitic transformation has exerted tensile stress on the original austenite of the heart due to its volume expansion, which itself is subject to compressive stress due to the limitation of the heart. The peak of the stress moves toward the center with the phase transition. When the martensitic transformation occurs in the heart, accompanied by the volume expansion, due to the hindrance of the hardened surface of the transformed martensite, the opposite of the former tissue stress, and ultimately the formation of surface tensile stress. The ultimate result of structural stress changes is the tensile stress of the surface, the compressive stress of the heart, and the opposite of thermal stress [5]. The size of the tissue stress is related to the cooling rate, shape, chemical composition of the workpiece in the martensitic transformation zone.

5 Cause Analysis of Quenching Crack Formation

In order to clearly show the reasons for the formation of quenching cracks in the crank hole, the author deduces the root cause of the quenching crack formation at the crank hole.

First, the hot metal due to low temperature, mixed uneven and other reasons, resulting in molten iron casting cooling, carbon, manganese, phosphorus and other segregation elements in the grain boundary segregation, resulting in cementite, phosphorus eutectic, small graphite appears near the grain boundary; followed by carbon, manganese, phosphorus and other elements to reduce the critical heating temperature, and IF induction quenching is still using a normal 870 ℃ heating temperature, which caused the element segregation area overheating, cementite and small graphite carbon dissolved, resulting in the regional carbon Concentration increased,; when the rapid cooling, in the early cooling to form a large number of retained austenite, the formation of martensite needle is also very large, and because of the increase in carbon content, excess carbon in the form of massive, mesh cementite , And the segregated phosphorus element also appears in the form of phosphorus eutectic near the grain boundary, and at the same time due to the larger non-uniform plastic deformation, and produce greater thermal stress; Finally, when entering the late cooling, crankshaft external tissue transformation has been

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completed, While the internal retained austenite is still converted into martensite, resulting in volume expansion, so that the crankshaft surface withstand large tissue stress - that is,Thermal stress, tissue stress, superheated organization, reticular cementite on the body of the split and other comprehensive role when the thinnest hole in the thinnest hole area of the material strength limit, the oil hole crack of thin wall position

Also in the tempering process, the unconverted completed austenite will be repeated during the later quenching. Part of the retained austenite will continue to be converted into martensite, the volume of expansion, so that the workpiece surface to withstand excessive tensile stress, when the tensile stress exceeds the material to withstand the limit, resulting in the workpiece surface cracks.

6 Conclusion

(1) Cause of crack is the quenching.

(2) the occurrence of cracks is mainly due to uneven composition; eutectic grain boundary segregation caused by a large number of retained austenite, mesh cementite formation; the distribution of the residual austenite on along the grain boundary network cementite, fragmentation effect to the substrate, results in the decrease of grain boundary strength; a large amount of retained austenite also causes a large amount of retained austenite to be converted into martensite at the later stage of quenching and tempering, and the transformation of the external structure has been completed, and the internal retained austenite transformed martensite volume expands so that The surface withstand too much tensile stress, when the tensile stress exceeds the grain boundary to withstand the limit, resulting in the workpiece surface cracks.

References

i. S. K. Bhaumik. A View on the General Practice in Engineering Failure Analysis. Journal of Failure Analysis and Prevention, 2009, Vol.9 (3), pp.185-192.

ii. M. Fonte, P. Duarte, L. Reis, M. Freitas, V. Infante. Failure mode analysis of two crankshafts of a single cylinder diesel engine. Special Issue of ICEFA VI 2014.

iii. BKareem. Evaluation of failures in mechanical crankshafts of automobile based on expert opinion. Case Studies in Engineering Failure Analysis, 3 (2015) 25-33.

iv. Schneider, Giri.Microstructural and crystallographic characteristics of modulated martensite, non-modulated martensite, and pre-martensitic tweed austenite in Ni-Mn-Ga alloys. Acta Materialia. Aug2017, Vol. 134, p93-103. 11p.

v. Myung Hyun, Sung Geun. A comparative study for the fatigue assessment of a ship structure by use of hot spot stress and structural stress approaches. Engineering Fracture Mechanics. Dec2008, Vol. 75 Issue 18, p5187-5206. 20p.