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FAILURE ANALYSIS OF 48MnV ENGINE CRANKSHAFT

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Preliminary Note – Prethodno priopćenje

Investigation was conducted on the failure of the crankshaft made from 48MnV alloy steel used in automotive engines. Magnetic flaw defects were detected at the transition fillet between the third main journal and the counterweight of the crankshaft. Macroscopic examination, chemical composition analysis, metallographic analysis, and scanning electron microscopy observation were performed on the crankshaft samples. The testing results were summarized, and the causes of the crankshaft cracking were systematically analyzed. The results indicate that longitudinal cracks occurred on the surface of the crankshaft journal due to the combined effect of thermal stress and normal operating stress, exceeding its load-bearing capacity. These cracks propagated inward, forming magnetic flaw cracks, ultimately leading to crankshaft failure.

Keywords: 48 MnV, crankshaft, X-ray research, cracks, morphology

INTRODUCTION

As a core component of the engine, the crankshaft directly impacts the operational efficiency and lifespan of the engine[1-2]. Operating under varying conditions and subjected to complex loads, crankshafts are prone to failures such as cracking and fracture[3-4]. Therefore, conducting macroscopic analysis, microscopic structure analysis, fracture surface scanning, and spectroscopic analysis on failed crankshafts is crucial for investigating the causes of cracks or fractures[5].

MACRO DEFECT INSPECTION

Macroscopic condition

Figure 1 shows two failed crankshaft samples. It can be observed from the Figure that both Sample 1 and Sample 2 exhibit wear at the third main journal and bearing. The remaining journals and bearings appear to be relatively intact with no significant signs of wear.

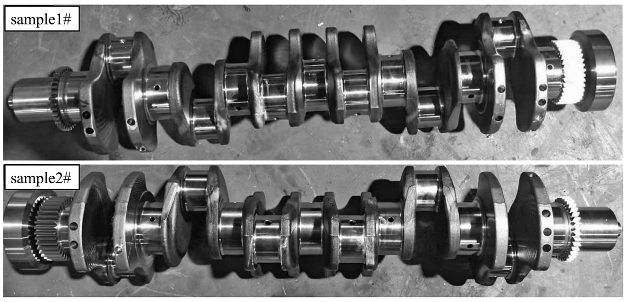

Figure 1 Failed crankshaft samples

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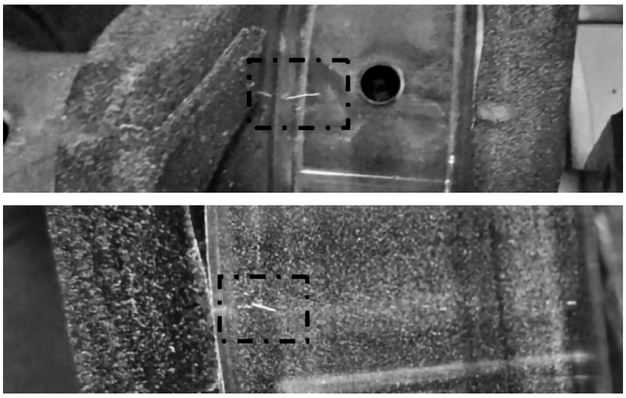

Figure 2 Fluorescent magnetic particle inspection magnetic flaw defect image

Magnetic flaw inspection

To further analyze the defects present in the crankshaft, fluorescent magnetic particle inspection was conducted on the third journal sample of the crankshaft. The resulting image, as shown in Figure 2, depicts magnetic flaw defects at the third main journal of the crankshaft. Irregular serrated magnetic flaw defects are observed at the transition fillet between the crankshaft journal surface and the counterweight, with irregular pointed ends. The defects exhibit a clear outline, with dense and distinct magnetic particle accumulation.

CHEMICAL COMPOSITION ANALYSIS OF THE CRANKSHAFT

The material of the crankshaft is alloy steel, specifically 48 MnV. Samples were taken from the interior of the crankshaft, and chemical composition analysis was conducted using spectroscopic analysis. The analysis

Table 1 **Chemical composition /wt%**

Element	C	Si	Mn	P	S
Sample1	0,49	0,27	1,09	0,018	0,010
Sample2	0,49	0,27	1,07	0,017	0,009
Required value	0,49	0,26	1,07	0,015	0,009
Element	Cu	Ni	Cr	V	Mo
Sample1	0,02	0,02	0,10	0,076	0,012
Sample2	0,02	0,02	0,10	0,074	0,012
Required value	0,02	0,02	0,10	0,075	0,010

results indicate that the chemical composition of the crankshaft samples is essentially within the technical requirements range and meets the specifications[6-7]. Table 1 presents the chemical composition analysis results of the crankshaft samples.

MICROSCOPIC STRUCTURE ANALYSIS

High-magnification inspection and analysis

After immersion in a 4 % nitric acid alcohol solution, the defect site of the crankshaft specimen was observed. The corroded morphology is shown in Figure 3. It can be observed from the Figure that there are streaks and circumferential black burn marks on the surface of the crankshaft sample where the magnetic flaw crack defect is located. This is attributed to chemical reactions or physical interactions between the surface of the crankshaft and certain substances under high temperature, pressure, or frictional conditions during operation. Such abrasions may originate from lubricants, coolants, or other media that the crankshaft comes into contact with during operation, or may result from frictional heating of the journal surface leading to surface material oxidation or thermal decomposition.

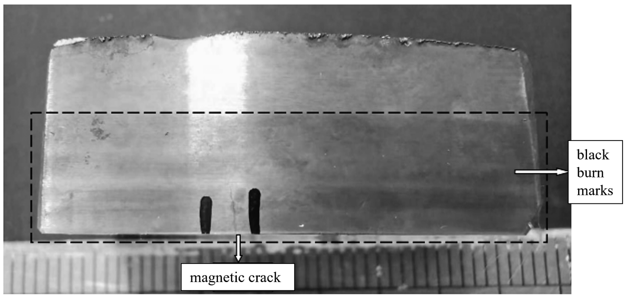

Figure 3 The corroded morphology of the crankshaft specimen

Metallographic examination and analysis

At the location of the magnetic flaw crack on the crankshaft sample, a sample was taken for metallographic examination. After grinding and polishing, the sample was observed under a metallographic microscope, as shown in Figure 4. It can be seen from the Figure that the crack widens outward and narrows inward, with a depth of approximately 500 μm. It exhibits a serrated morphology extending inward from the surface of the journal, with a sharp tip at the end. Additionally, no metallurgical defects such as inclusions, which could have caused the cracking, were found inside the crack or in its vicinity, indicating that the crack formation was not due to metallurgical defects. The metallographic sample was further immersed in a 4 % nitric acid alcohol solution for corrosion observation. It was found that there was no decarburization on either side of the crack, indicating that the crack formation was not caused by decarburization, as shown in Figure 5. These characteristics suggest that the crack on the crankshaft may have formed under certain stress conditions.

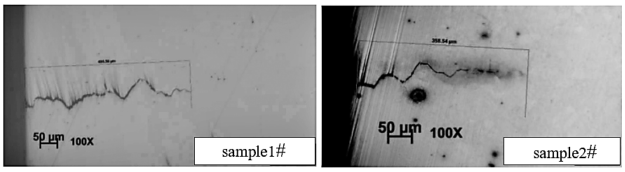

Figure 4 Metallographic image of magnetic flaw crack

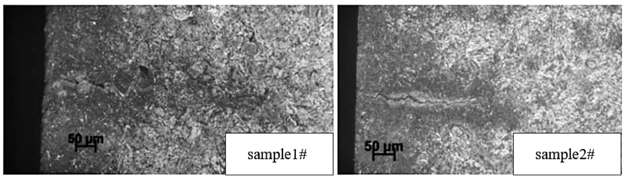

Figure 5 Metallographic image of magnetic flaw crack under corrosion condition

Observation under SEM

The sample was observed under a SEM, and the results are shown in Figure 6. It can be observed from the Figure that the magnetic flaw crack extends longitudinally from the surface of the journal, and no metallurgical defects such as inclusions that could have caused the cracking were found inside the crack or in its vicinity. Figure 7 shows the results of energy dispersive X-ray

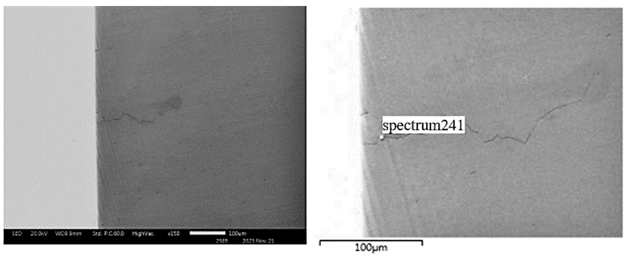

Figure 6 The microstructure of magnetic flaw crack

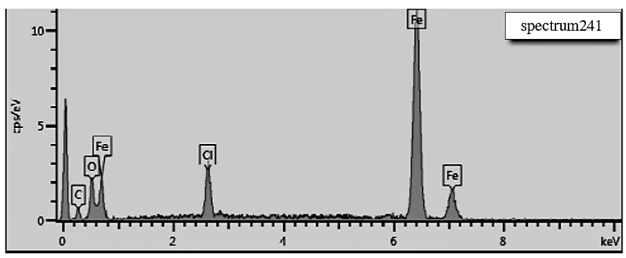

Figure 7 The energy dispersive X-ray spectroscopy (EDS) analysis results at the fracture surface of the magnetic flaw crack

spectroscopy (EDS) analysis at the fracture surface, revealing trace amounts of oxygen. This is attributed to the generation of a large amount of heat when the crankshaft grips the bearing, resulting in charring. Therefore, the high-temperature oxidation of the bearing during crankshaft operation led to the detection of oxygen.

ANALYSIS AND DISCUSSION

The crankshaft sample exhibits magnetic flaw cracks at the transition fillet between the third journal surface and the counterweight. The cracks appear serrated with irregular pointed ends. Spectral analysis confirms that the chemical composition meets specifications. Metallography and scanning electron microscopy reveal band-like circumferential black burn marks on the surface of the journal where the magnetic flaw crack is located. The crack depth is approximately 500μm, exhibiting a serrated morphology extending inward from the journal surface, with a sharp tip at the end. No metallurgical defects such as inclusions causing the cracking were found inside the crack or in its vicinity. Additionally, there is no decarburization observed on either side of the crack, and trace amounts of oxygen were detected at the fracture surface.

These findings suggest that the crankshaft experienced high temperatures due to contact with the bearing. Friction-generated heat led to thermal stresses in the surface region of the crankshaft journal. Furthermore, the journal surface experienced certain levels of stress during operation. Under the combined influence of thermal stress and normal operational stress, when the applied stresses exceed the crankshaft's tolerance limit, longitudinal cracking occurs on the surface of the crankshaft journal. This leads to the formation of magnetic flaw cracks, ultimately resulting in crankshaft failure.

CONCLUSION

The location and type of failure of the crankshaft are cracks occurring at the transition fillet of the third main journal.

The chemical composition of the crankshaft meets specifications, indicating that the formation of the crack is not related to the quality of the raw material.

The crack defect is a typical stress fracture, resulting from the combined effects of various stresses leading to cracking in the journal.

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Note: The responsable for the English language is lector from University.