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Fracture Failure Analysis on a Bolt

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Abstract—A bolt used in the production equipment broke during the use. This paper analyzes the root cause of bolt fracture. Through the analysis on the chemical composition, mechanical properties, microstructure, micro morphology and micro area composition of the broken bolt, it is considered that the physical and chemical properties of the bolt meet the requirements of the standard. Because of the existence of machining cracks, the bolt is affected by the stress in the use process, resulting in fatigue fracture.

1. INTRODUCTION

The bolts used in oil production equipment broke in service. The bolt is a large hexagon head bolt, the specification and model are 1-1/8-7unc-2a-416. The executive standard is SAE J429: 2013. The installation temperature of the bolt is between -15°C and +25°C, and the installation torque is between 1023N·m and 1130N·m. When the bolt broke, it was used for about 8 months.

Due to the different use environment and requirements of bolts, there are various forms of bolt fracture failure. González et al. [1] found that microscopic observation shows fatigue striation, which is a typical sign of progressive fracture, and hydrogen embrittlement also could have occurred, decreasing the fatigue resistance of the screw. Zhou [2] found that over burning and decarburization were the main causes of bolt fracture at the connecting fillet of bolt polished rod and flange plate. The stress concentration at the connecting fillet of bolt polished rod and flange plate was the inducing factor of bolt fracture. Jia et al. [3] found that the high yield strength ratio of bolt material resulted in the increase of brittleness of the material. In addition, there was carbon increase on the bolt surface, and the fracture property of the surface layer was intergranular cracking.

This paper analyzes the causes of the broken bolt, which is helpful for the manufacturer to check the bolt before it is put into use and prevent similar accidents.

2. MACROSCOPIC EXAMINATION

The bolt surface has been galvanized, and most of the fracture surface has been rusted. See Fig. 1. From the cross-section, there are two fatigue sources, both located at the bottom of the thread, and the two fatigue sources differ by one pitch in radial direction. No obvious plastic deformation is found on the fracture surface.





Figure 1. Bolt fracture surface.

The bolt fracture surface is roughly divided into three areas: Area A and B are the starting point of fracture, belonging to the fatigue source area; area C and D are the fatigue extension area, with obvious fatigue fracture characteristics such as bainite lines; area E is the instantaneous fracture area, with relatively small area, rough fracture surface, and a small area of shear lip shown in Fig. 2. The fracture property of the bolt can be preliminarily judged as fatigue fracture by the macroscopic characteristics of the cross section.

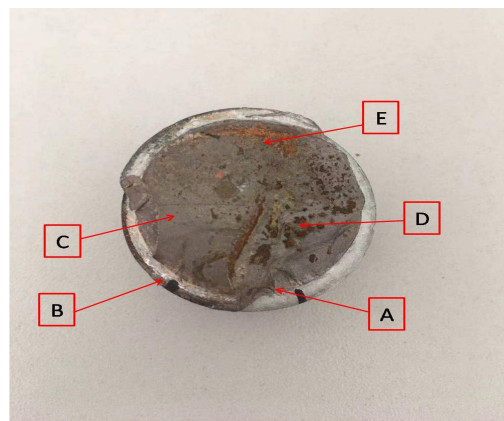


Figure 2. Different regions of fracture surface.

3. CHEMICAL ANALYSIS

Take a chemical analysis test on the sample from the bolt using Q8 MAGELLAN System spectrum analyzer, and the result is in accordance with the requirements ruled by SAE J429: 2013. The result is showed below in Table 1.

TABLE 1. CHEMICAL COMPOSITION ANALYSIS RESULTS (WT.%)

Element	Result	Requirement of SAE J429:2013
C	0.41	0.25~0.55
S	0.012	≤0.025
P	0.012	≤0.025

4. MECHANICAL ANALYSIS

Do tensile and hareness test by making test samples at the non-broken places, and the test results is showed below in Table II.

TABLE 2. TEST RESULT

Items	Requirements by Standard SAE J429: 2013	Result
R _{p0.2}	$\geq 558\text{MPa}$	663MPa
R	$\geq 723\text{MPa}$	801MPa
A	$\geq 14\%$	22%
Z	$\geq 35\%$	60%
Hardness	19HRC~30HRC	23.5HRC 22.5HRC 24.0HRC

5. METALLOGRAPHIC ANALYSIS

Take a metallographic analysis on the sample from the crack place using Imager.A1M microscope and the microstructure is tempered sorbite which is shown in Fig 3.

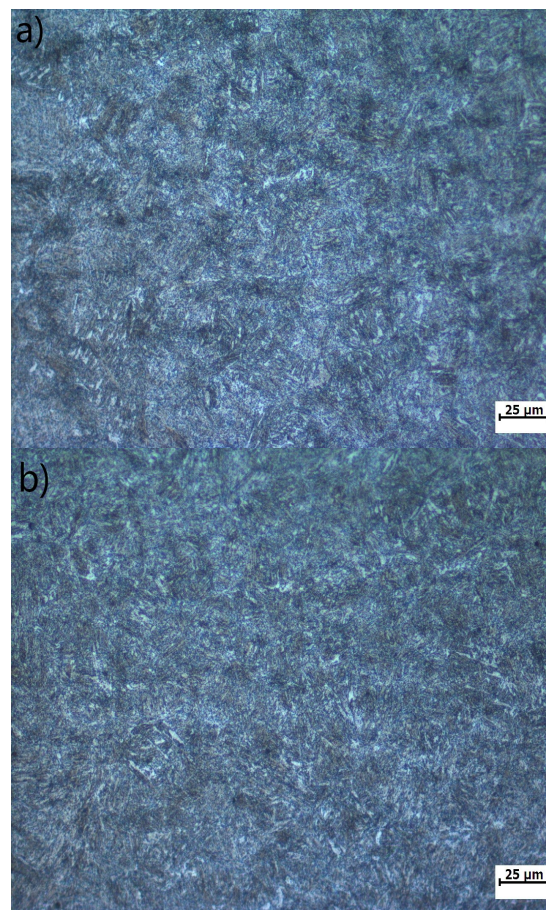


Figure 3. Microstructure of crack area.

6. ANALYSIS OF MICRO MORPHOLOGY AND COMPOSITION OF MICRO AREA

The micro morphology of the fatigue source region, the fatigue propagation region and the instantaneous fracture region were analyzed by using Quanta200 SEM as shown in Fig. 4. The fracture appearance of the extension area shows muddy flower pattern which is the typical pattern of stress corrosion [4].

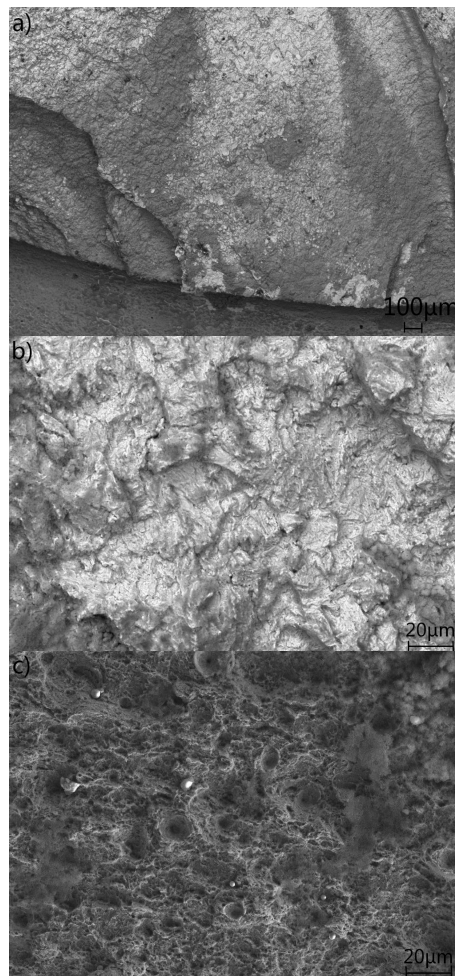
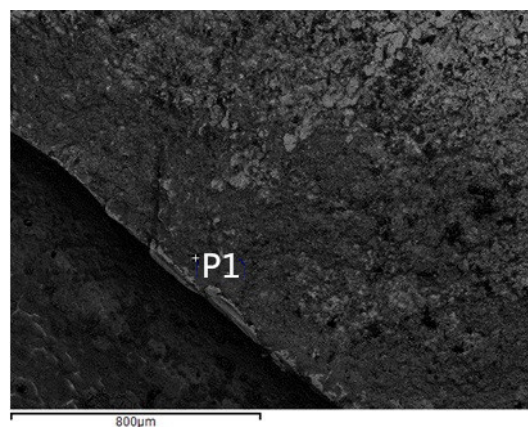


Figure 4. Micro morphology of different fracture areas (a) The starting point of fracture (b) The fatigue extension area (c) The instantaneous fracture area.

It is found that there are a lot of zinc in the fatigue source by analyzing the composition of the fatigue source as shown in Fig. 5. No zinc is found far away from fatigue source as shown in Fig. 6.



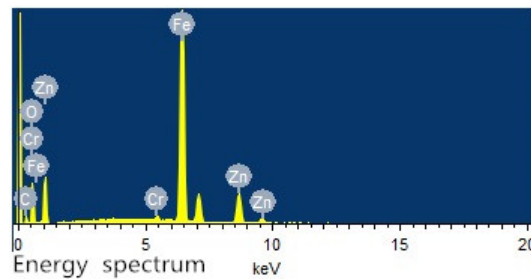


Figure 5. Energy spectrum of fatigue source.

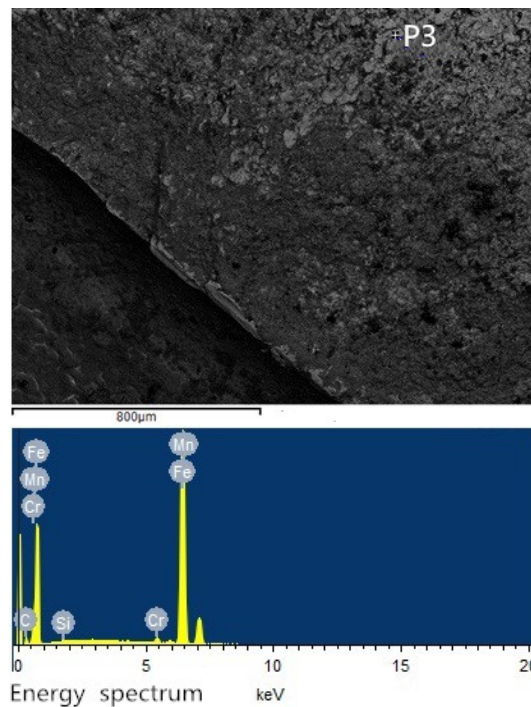


Figure 6. Energy spectrum away from fatigue source.

7. DISCUSSION

It can be seen from the test results that the chemical composition, mechanical properties and metallographic structure of the bolt meet the requirements of the standard.

According to the results of micro region composition, a large number of zinc is found in the fatigue source, but not in the area far away from the crack source. Under normal circumstances, there should be no large amount of zinc in the fatigue source. The bolt is subject to over heating galvanizing treatment, so the zinc inside the fatigue source should be infiltrated into the fatigue source by the zinc liquid. That is to say, there are microcracks on the bottom of thread before galvanizing.

The existence of microcracks at the bottom of screw thread is the direct cause of bolt fracture. When the bolt works under stress, the microcracks continue to expand, which eventually leads to fracture failure.

8. SUGGESTION

For bolts under stress, micro crack detection should be carried out before use to eliminate the fatigue source caused by processing factors.

ACKNOWLEDGMENT

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