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FAILURE STUDY IN SIDE PLATES OF A VIBRATING SIEVE

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ABSTRACT

Failure of mechanical equipment is one of the most important problems in mining industry. In order to prevent sudden and unexpected failures, determination of failure mechanism is necessary. For example fretting fatigue is a reason why failure occurs in joint parts under minute cyclic stresses. In this study the fracture mechanism of the side plate in a vibrating sieve utilized in the concentrating section of a copper production factory was investigated. Extensive fractography and metallurgical analyses were carried out using a scanning electron microscope (SEM) equipped with energy dispersive spectroscopy (EDS). Analytical and mechanical testing results revealed that the failure was due to the propagation of radial and vertical cracks caused by fretting fatigue crack initiation at the bolted joints where the side plate was connected to the sieve housing.

Keywords: Fretting Fatigue, Fractography, SEM, Bolted Joints, Sieve

INTRODUCTION

"Fretting fatigue" is a well known phenomenon and is often recognized for reduction in expected component life because of relative cyclic motion with small amplitude that occurs between two oscillating surfaces. Fretting fatigue is a serious problem in engineering applications, particularly in gas turbines, steam turbines, wheel shafts, bolted plates, wire ropes and strings (Jayaprakash and Ganeh Sundara Raman, 2007; Lee and Mall , 2004; Wang *et al.,* 2006; Neslen *et al.,* 2004; Keer and Farris, 1987; Kennedy *et al.*, 1984; Liao *et al.*, 2001; Asi, 2006). Side plates of a vibrating sieve are among the several examples, which commonly fail due to fretting fatigue. These components are subjected to cyclic loading in particular sites such as bolted joints near the housing of the shaft. Figure 1 shows the general appearance of a vibrating sieve and its side plates and Figure 2 shows the failed plate. The plate, 12.7 mm thick, is fastened to outer frames of the sieve and other components such as housing, vibrating screens, liners and so on are fastened to it with numerous steel bolts in different sizes. Vibration is the result of an eccentric shaft connected to the engine, and thus vibration is most concentrated at the housing and its joints to the plate. Cracks were found at fastened regions around housing, in service. In this plate under investigation, cracks initiated from bolt holes and propagated in peripheral and radial directions with different lengths, as shown in Figure 3.

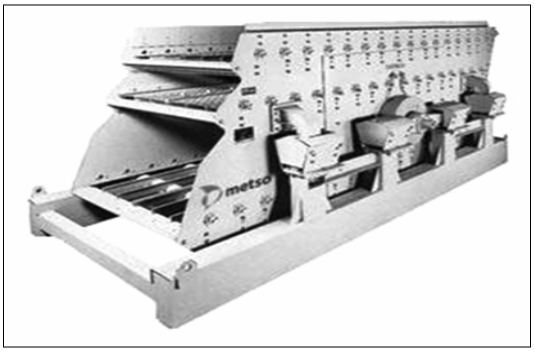


Fig. 1: A vibrating sieve.

Fretting fatigue usually involves initiation and propagation of cracks (Asi, 2006). Crack nucleation could occur without external loading and significantly reduce the initiation period. The fretting parameters that impede early cracking are the normal load contact stress and the imposed displacement amplitude. Once an embryonic crack is nucleated and starts to grow in stage II, fracture mechanics could be applied to estimate the rate of crack growth. Fretting fatigue cracks ordinarily grow in mode I (Ebara and Fujimura, 2006). However, majority of the component life under fretting fatigue is consumed during the initiation stage (Asi, 2006; Ebara and Fujimura, 2006; Kermanpur *et al.*, 2008; Hattori *et al.*, 2005; Hutson *et al.*, 1999).

Fig. 2.: Failed plate of a vibrating sieve.

The aim of the present work is to investgate the results of a failure analysis of a vibrating sieve plate used in the concentration unit of a copper production factory.

EXPERIMENTAL PROCEDURE

The failed plate was inspected visually and macroscopically; care was taken to avoid damage to the fractured surfaces. The failed plate was subjected to optical microscopy, chemical analysis and micro-hardness measurements. Also fractured surfaces were examined with the help of a scanning electron microscope (SEM) equipped with energy dispersive X-ray (EDS) facility.

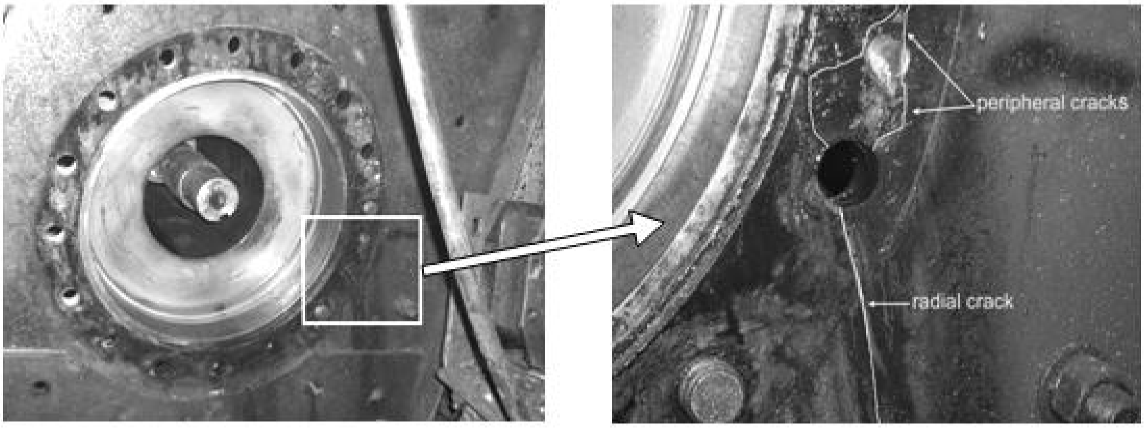


Fig. 3.: Peripheral and radial cracks in the side plate.

RESULTS AND DISSCUTION

Chemical analysis of the side plate was carried out and the results are given in Table 1 along with the standard chemical composition. It was found to be similar to ASTM St 52 steel with high contents of manganese which improves transforming ductile phases in steel.

Table 1: Chemical composition of failed plate along with chemical composition.

Element	Side Plate	Standard composition
C	0.137	0.13
Si	0.314	0.5
Mn	1.468	Max 1.5
P	0.015	0.035
S	0.014	0.03
Cr	0.016	0.015
Ni	0.088	0.3
Cu	0.055	Trace
Mo	0.56	Trace
Co	0.032	Trace
Al	0.037	Max 0.020
B	0.001	Trace
Ti	0.004	0.05
V	0.014	0.08
Fe	97.746	Balance

Visual inspection showed that there were severe damaged regions at bolt holes, and cracks initiated from these regions and propagated in peripheral and radial directions with different lengths. All cracks become through-thickness crack. There were some corrosion spots observed on the local bolt hole surfaces. The inner surfaces were rough and fretting wear scars could be observed on cracked surfaces, as shown in Figure 4.

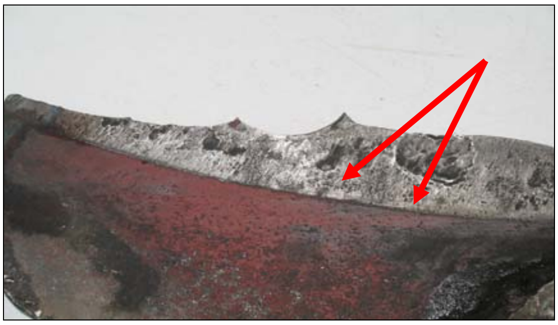


Fig. 4; The inner surface of bolt holes ×1

Results of micro-hardness measurement combined with the use of experimental relations given below, determined the tensile strength of the failed plate and it was in good agreement with actual strength of ASTM St 52 steel.

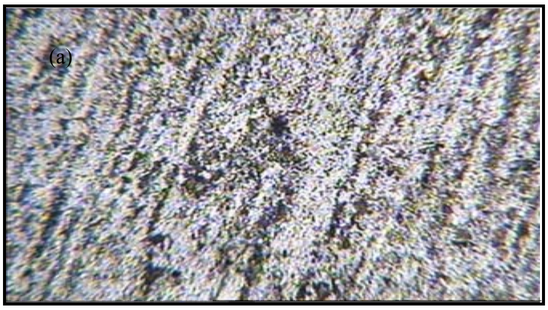
(1) $HB=0.951\times HV$

(2) $\sigma=3.54\times HB$ (N/mm^2)

Table 2: Mechanical properties of the failed plate and ASTM St 52 steel

Material	Tensile strength (N/mm^2)
Failed plate	400-550
ASTM St 52 steel	492

Light optical metallographic analysis was carried out on the failed plate. Samples for optical microscopy were prepared by grinding, polishing and then etched in 2% Nital. The microstructure is presented in Figures 5a and b. As it can be seen, the surface predominantly consists of lamellar ferrite and pearlit plates which are due to hot work done on the plate. Figure 6 shows the inner surface of the bolt hole, which seems to have severely suffered due to a rubbing mechanism between the bolt and the bolt hole surface, thus offering many available sites for crack initiation. The inner surface of the bolt hole which is indicative of the fretting damage zone provides many crack initiation sites. The X - ray diffraction analysis carried out on these sites indicated their chemical composition as iron oxides,



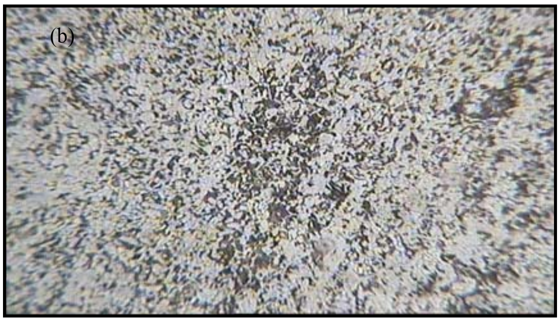


Fig. 5.: a) Microstructure of failed plate ×50, b) Microstructure of failed plate ×100.

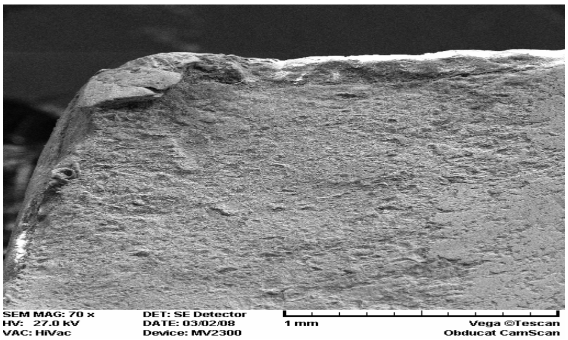


Fig. 6.: Inner surface of the bolt hole.

as shown in Figure7. Figure 8 shows optical macrofracture appearance after separation. The fracture surfaces are roughened showing characteristic of fretting fatigue. Figure 8a shows details of the multiple cracks formed on fracture surfaces. Beach marks and radial lines can be observed in region 1 of the fracture surface. Figure 8b illustrates the fatigue beach marks in region 2. The brittle fracture mode can be clearly seen in the fracture surface as shown in Figure 8c. Many debris particles as an indication of wear were found on the bolt hole surface and at the mouth of cracks. Figure 9 shows the fracture surface of the bolt holes that contains a high amount of debris particles. The EDS analysis of debris particles represented in Figure 10 showed a high amount of oxyg[illegible]us confirming oxidation of Fe during the service. (b) [illegible] is responsible to form abrasive Fe_2O_3 particles in fracture surface.

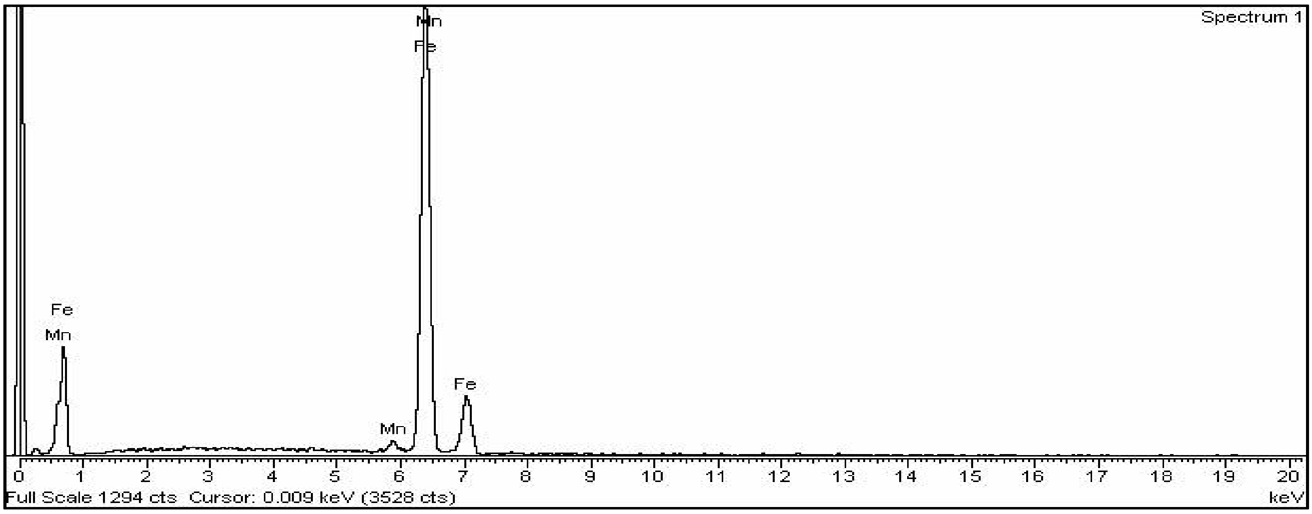
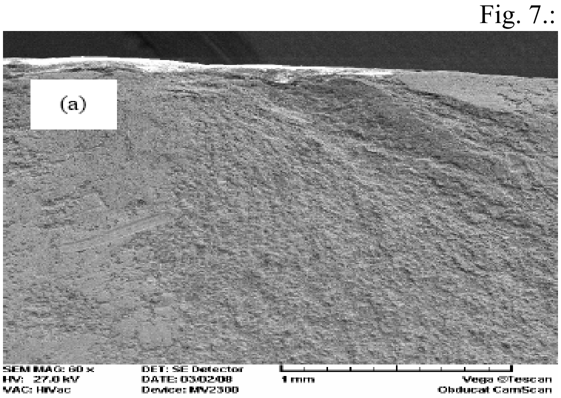
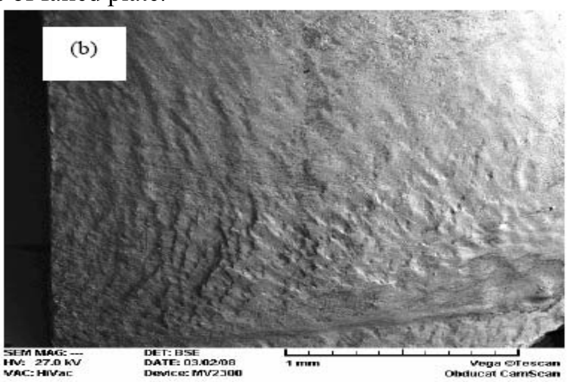


Fig. 7.: EDS results of failed plate.





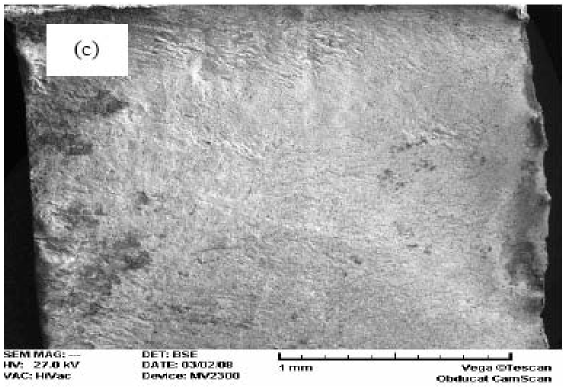


Fig. 8.: Macrofracture appearance. a) details of the multiple cracks on fracture surface, beach marks and radial lines in region 1, b) fatigue beach marks in region 2, c) brittle fracture mode.

Scanning electron microscopic examination of the failed plate revealed roughness, microcracks, and pits in the surface-damaged regions. These are features of fretting damage. The cause of the fretting, in this case, was believed to be due to the self-loosening of the bolts. Fretting wear occurs from repeated shear stresses that are generated by friction during small amplitude oscillatory motion or sliding between two surfaces pressed together in intimated contact. In bolted joints, fretting fatigue cracks are normally initiated under a combination of local shear stress, produced by the frictional forces between rubbing surfaces, plus long-range cyclic stresses in the component. Those shear stresses are vital to cracking initiation. The shear stresses promote relative slip. Hence, crack nucleation due to fretting must involve a stress concentration or discontinuity.

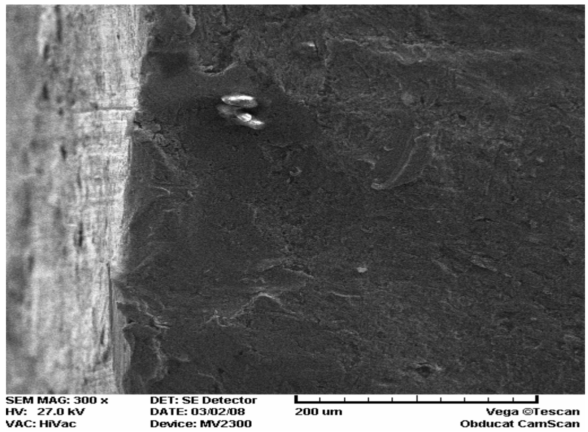


Fig. 9.: fracture surface containing a high amount of debris particles.

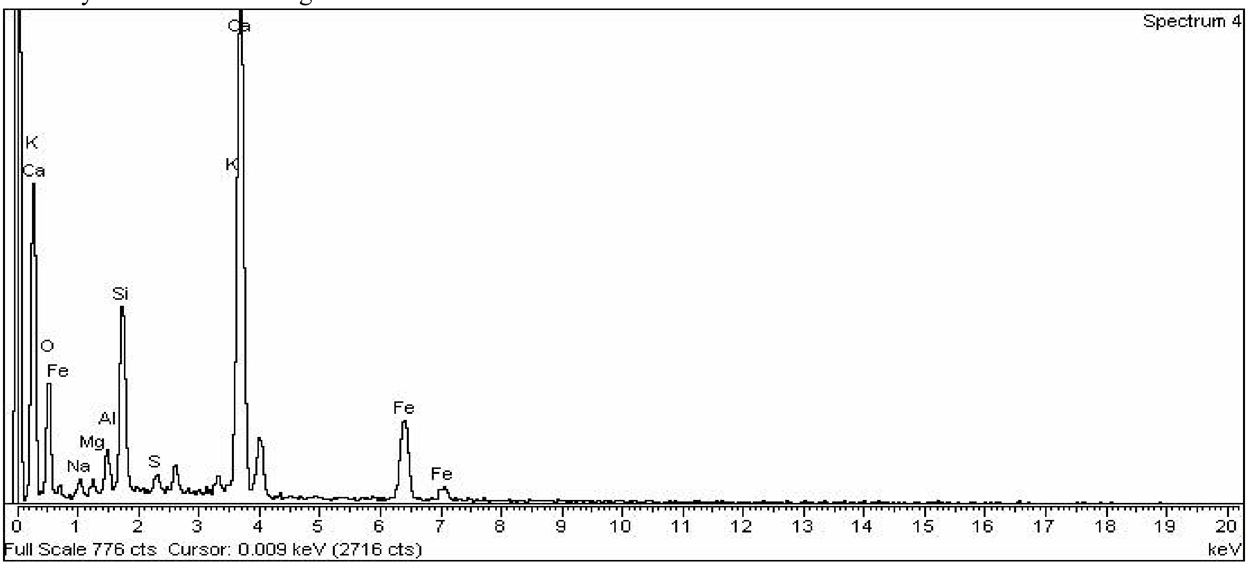


Fig. 10.: EDS analysis of debris particles represented in Figure 9.

CONCLUSIONS

In this investigation, the fretting fatigue mechanism as the main cause of several premature failures of steel side plates of vibrating sieves was characterized. No metallurgical and mechanical deviations were found for the side plate material with respect to standards. Instead, the fretting characteristics were distinguished in the fracture surfaces. Spectrum analysis and EDS results identified the material of the side plate as carbon steel. Mechanical properties and the chemical composition of the side plate were found to be similar to ASTM St52 steel. Cracks initiated from bolt holes in the plate and propagated in peripheral and radial directions with different lengths. Cracks initiated around the bolt holes boundary because of fretting damage. The cause of the fretting was believed to be self-loosening of the bolts under vibration. The cracks are fretting fatigue cracks caused by high vibration stress around the bolt hole.

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