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Bearing Fault Diagnosis of a Mine Stone Crasher by Vibration Condition Monitoring Technique

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Abstract: To maintain an efficient operating unit and avoid failure of mineral critical equipment, it is necessary to maintain the critical parts of that equipment. Recently, rotary machines with rolling bearings have become highly advanced and the environments in which the machines are being used have diversified. The improvement of the reliability of the rolling bearings for special environments such as corrosive, high temperature, high speed, or high vacuums environments, has become very important. The objective of this research was to investigate the correlation between vibration analysis and fault diagnosis. This was achieved by vibration analysis of two bearings of stone crasher in Pirbakran mineral mine company. The vibration analysis was run under regular interval during stone crasher life. Overall vibration and numerical data produced by vibration analysis were compared with vibration spectra in a standard condition of healthy machine, in order to evaluate the effectiveness of the vibration condition monitoring technique. The results of this paper have given more understanding on the dependent roles of vibration analysis in machine faults predicting and diagnosing.

Keywords: Fault detection, maintenance, rotary machine and vibration analysis

INTRODUCTION

Vibration analysis has been used in fault diagnosis of rotating machines with rolling bearings for decades (Rokkaku, 1992; Matsunaga, 1997). Recent evidence shows that vibration condition monitoring technique provides greater and more reliable information, thereby resulting in a more effective maintenance program with large cost benefits to industry (Want and McFadden, 1996; Maxwell and Johnson, 1997; Luo *et al*., 2000). Vibration analysis in particular has for some time been used as a predictive maintenance procedure and as a support for machinery maintenance decisions (Mathew and Stecki, 1987).

As a general rule, machines do not break down or fail without some form of warning, which is indicated by an increased vibration level. By measuring and analyzing the vibration of a machine, it is possible to determine both the nature and severity of the defect, and hence predict the machine's useful life or failure point. The overall vibration signal from a machine is contributed from many components and structures to which it may be coupled. However, mechanical defects produce characteristic vibrations at different frequencies, which can be related to specific machine fault conditions. By analyzing the time and frequency spectra, and using signal processing techniques, both the defect and natural frequencies of the various structural components can be identified (Barron, 1996; Eisenmann, 1998).

Vibration characteristics can be distinctively divided into two types: forced vibration and free vibration. Typical forced vibration relates to problems such as mass unbalance, misalignment, and excitation of electrical or mechanical nature. Free vibration is a self-excited phenomenon that is dependent on the geometry, mass, and damping of the system, and typically caused by structural, acoustic resonance, and by aerodynamic or hydrodynamic excitation (Byrne *et al*., 1995).

The wear mechanisms, primarily sliding and rubbing for element of bearing such as inner race, outer race, or balls wear, can be represented by an increase in vibration amplitudes, and a narrowband region of increasing energy content in the frequency spectrum. An evident offset of the spectrum from the baseline or zero amplitude may also provide an indication of wear of the bearing elements (Rokkaku, 1992).

Over the past few years several studies have been made on the performance of all-ceramic ball bearings with regard to fatigue life and temperature rise (Swab and Sweeney, 1995). The previous studies (Gustafsson, 1962; Wardle, 1988a, b; Yhland, 2002) on ball bearing vibrations concluded that the excitation is caused by the waviness of the raceways and balls while ball bearings rotate at certain speeds under an axial load. From the previous studies, the relationship between the order of the waviness and the frequency of excitation was derived theoretically.

The purpose of this study was to explain vibration characteristics of a stone crasher bearing and to investigate the correlation between vibration analysis and fault diagnosis. This was achieved by vibration analysis of two bearings of a stone crasher in Pirbakran mineral mine company.

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Experimentation and Testing: The bearings of stone crasher were SKF 22340C, and the shaft speed was 276 rpm. Fig. 1 is a photograph of a bearing of stone crasher. Vibration data was collected on a regular interval during the stone crasher life. The experimental procedure for vibration analysis was consisted of taking vibration readings at two selected locations over the housing of stone crasher left and right side bearings. The radial and axial vibrations for various conditions were taken using a sensor mounted on the outer ring of bearings while the inner ring was rotating at 276 rpm.

The sensor used was a piezoelectric accelerometer (VMI-102 model) which was mounted on the flat surface using stick mounting technique. The accelerometer was connected to the signal-conditioning unit (X-Viber FFT analyzer), where the signal goes through the charge amplifier and an analogue-to-digital converter (ADC). The vibration signal in digital form was fed to the computer through a USB port. The software SpectraPro-4 that accompanies the signal-conditioning unit was used for recording the signals directly in the computer's secondary memory. The signal was then read from the memory and processed to extract the Fast Fourier Transform (FFT) of vibration spectrum. The maximum frequency of the signal was 1 kHz, with 4010 sampled data and giving a measured time of 2.1 second.

The most basic form of vibration analysis is called an overall vibration measurement. This reading provides a single number that describes the total amount of vibration energy being emitted by a machine. The idea is that vibration with high amplitude indicates a problem. A number of standards and guides were developed to explain what levels are acceptable for various machine types (Barron, 1996). In the field of machinery vibration monitoring and analysis, a variety of relevant standards are developed and published by International Organization for Standardization (ISO). Standards for evaluation of vibration severity are considered one of the most important activities of ISO/TC108 and ISO/10816 series (6 parts) (ISO TC108, 1963; ISO 10816-1, 1995).

RESULTS AND DISCUSSION

The experimental results of the overall vibratory velocity of left side bearing are shown in Fig. 2. The warning and critical reference values are 2.8 and 7.1 mm/s, respectively (ISO TC108, 1963). Fig. 2 shows that overall vibration velocity of the left side bearing tends to excess than warning and critical level in third and fourth measurements. Ball condition of the left side bearing was also in critical status in last measurement (see Fig. 3).

Table 1 shows the measuring date, root mean square (RMS) of vibration, ball condition (BC), and alarm status for overall vibration and BC for the left side bearing of stone crasher. The results showed that the RMS values were on warning and critical status in two last measurements and ball condition value was on critical condition in last measurement. Mean of overall vibration was 5.08 and standard deviation of that was 3.01. Results showed that RMS and BC values of last measurement

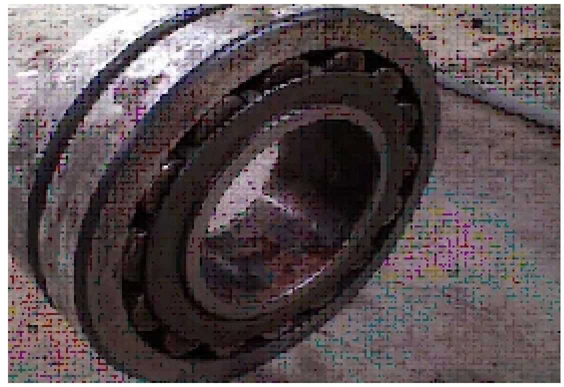


Fig 1: Photograph of a bearing of stone crasher

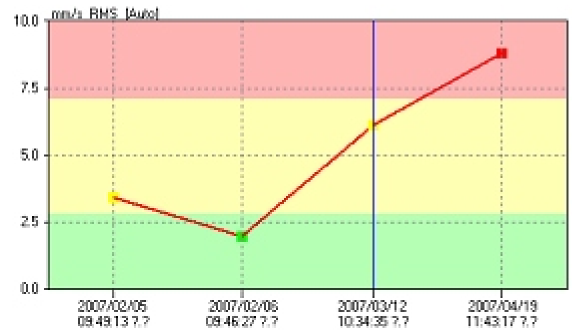


Fig 2: Overall vibrations of the left side bearing of stone crasher

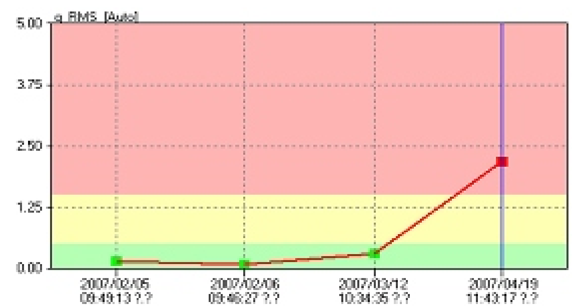
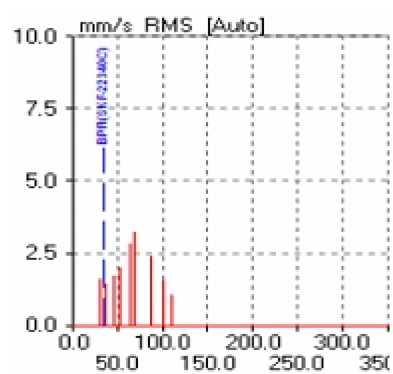


Fig 3: Ball condition of the left side bearing of stone crasher



Frequency, Hz

Fig 4: Frequency spectrum result of the left side bearing of stone crasher

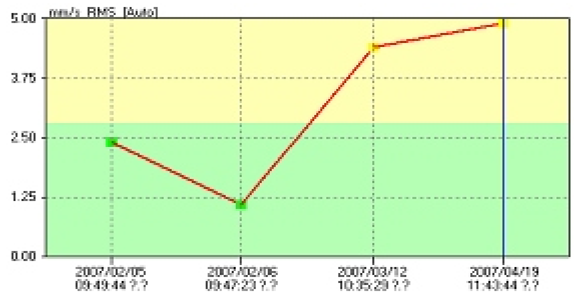


Fig 5: Overall vibrations of the right side bearing of stone crasher

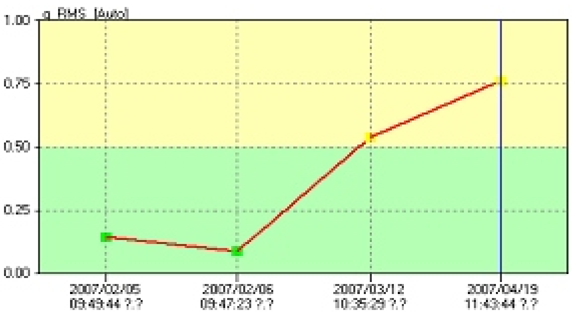


Fig 6: Ball condition of the right side bearing of stone crasher

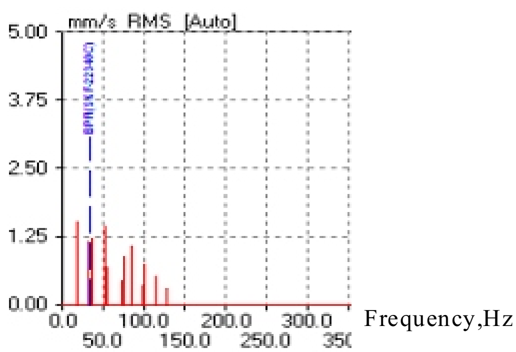


Fig 7: Frequency spectrum result of the right side bearing of stone crasher

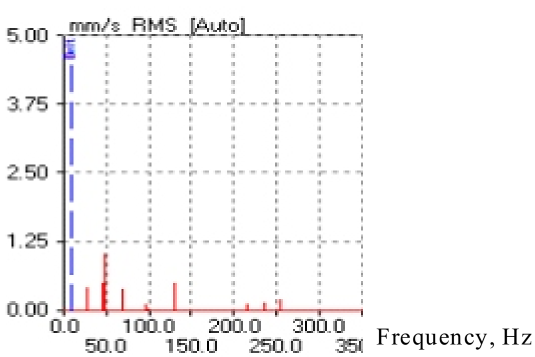


Fig 8: Belt frequency spectrum of the left side bearing of stone crasher

were higher than the average of RMS and BC values plus 1 times of standard deviation. This shows that the bearing is in an unhealthy status.

The typical vibration spectrum of the left side bearing of stone crasher is shown in the Fig. 4. This Figure shows the measured vibration spectra and the arrows show the main vibration peaks. The velocity frequency spectrum of the left side bearing showed an inner race ball pass frequency. The frequency corresponding to the rate at which balls or rollers in a bearing pass a particular location on one or other of the races. The inner race and outer race ball pass frequencies are different from each other, and are dependent on the geometry of the bearing and the rotation speed of the bearing. They are generally not harmonics of the turning speed, and are difficult to predict exactly due to variations in bearing geometry, contact angle, and load. Ball pass frequencies are some of the fault frequencies which are noted in the spectra of machine vibration.

The experimental results of overall vibration velocity for the right side bearing of stone crasher are shown in the Fig. 5 and 6. Results showed that the overall vibration velocity and BC of the right side bearing tend to excess than warning level in two last measurements. The results of Table 2 show that the RMS and BC values are on warning status in two last measurements. According to the Results, RMS and BC values of last measurement were higher than the average of RMS and BC values plus 1 times of standard deviation.

A typical vibration spectrum of the right side bearing of stone crasher is shown in Fig. 7. The velocity frequency spectrum of the right side bearing shows an inner race ball pass frequency.

Effects of pulley defects are shown in Fig. 8. One of the most prevalent pulley failure modes is end disc failure (Swab and Sweeney, 1995). End disc failure normally occurs through cyclic fatigue failure of the weld between the hub and the end disc in welded-in hub designs. Rim limitations are familiar cause of pulley failure. Two common types of rim failure include circumferential and longitudinal rim cracks. Lagging can help prevent wear on the pulley rim from abrasive or corrosive materials contacting the pulley. A pulley in an abrasive environment absent of lagging may promptly experience wear along the rim’s outside diameter. As this wear increases, the thickness of the pulley rim decreases well below its intended design limits, and it will soon experience a full crack and/or catastrophic failure.

Undersized shafting or excessive shaft deflection can easily cause tremendous stress levels within the end disc. For problematic pulleys with recurring end disc failures, it may be necessary to increase the shaft size of the pulley at the hub in order to minimize deflection and the bending stresses within the end disc. Additional failures can occur as a result of operating conditions, the most common of which may be tracking. Tracking may be adversely affected by such factors as alignment of the idler, pulley,or frame/structure. Tracking can also be influenced by build-up on pulleys or idlers, uneven loading, or belt/splice defects. Other common problems that can

Table1: Overall vibrations and ball condition of the left side bearing of stone crasher

Test	Measuring date	mm/s RMS	Alarm status	BC	Alarm status
1	2007/02/05	3.4	Warning	0.16	Ok
2	2007/02/06	1.99	Ok	0.09	Ok
3	2007/03/12	6.12	Warning	0.31	Ok
4	2007/04/19	8.79	Danger	2.18	Danger
Mean		5.08		0.69	
Standard		3.01		1.00	

Table 2: Overall vibrations and ball condition of the right side bearing of stone crasher

Test	Measuring date	mm/s RMS	Alarm status	BC	Alarm status
1	2007/02/05	2.42	Ok	0.14	Ok
2	2007/02/06	1.1	Ok	0.09	Ok
3	2007/03/12	4.39	Warning	0.54	Warning
4	2007/04/19	4.91	Warning	0.76	Warning
Mean		3.2		0.38	
Standard Deviation		1.77		0.32	

cause pulley failures include overloads/jam-ups, over-tight manual take-up, and excessive take-up weight or friction. Manual take-ups are commonly over tensioned, possibly causing problems to the pulley assemblies. Manual take-ups should be tightened through a trial and error process to provide just enough tension to prevent belt slip during start up.

Correlation of Vibration and Fault Diagnosis: Vibration analysis technique was used to assess the condition of stone crasher bearings and diagnose its problems. The results from vibration analysis of this practical study indicated some defaults in our bearings. From the vibration analysis of the stone crasher left and right side bearings, it was determined that bearings were in an unhealthy condition. The correlation between the vibration analysis and fault diagnosis was able to present a broader picture for machine condition. Vibration analysis technique was capable in covering a wider range of machine diagnostics and faults within the bearings.

CONCLUSION

The ball bearing, as all the machine elements have a characteristic natural frequency vibration. At the same time however we can also calculate the frequencies with which their components are vibrating, as the exterior ring, the internal ring or their balls. With the Fourier transformation as well as with the calculation of spectrum of frequencies we can distinguish the frequencies of ball bearing's elements and conceive if there is any damage in the particular component, so that the interruption of machine's operation will happen timely. In this study, vibration condition monitoring technique, namely vibration analysis, was used in order to diagnose the bearing faults of a mine stone crasher. Results showed that vibration monitoring technique is a practical technique for bearing defect detection of stone crashers.

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