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Experimental Computations to Assess Surface Wear in Roller Bearing using Integrated Approach of Vibration Analysis and Spectroscopic Techniques

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Abstract: The main objective of these experimental investigations is to correlate the results of vibration analysis and spectroscopic studies of degraded grease in assessing the surface wear of outer race of the roller bearing. Fourier Transform Infrared Radiation (FTIR) is adopted to observe degradation of grease with running hours. Kurtosis value is computed from time domain signals captured to find out progressive wear in the bearing. It is found in FTIR spectrum of 450 h aged grease sample that an absorbance peak occurred around a wavelength of 1750 cm^{-1} which indicated the formation of oxidation products. Further, at 1000 h FTIR spectrum indicated that there is formation of phenyl group and degradation of anti-wear agents of grease samples as evident by an absorbance peak at 717 cm^{-1}. Analysis of time domain signals revealed that kurtosis values increased for the bearing at1000 h of run compared to that of healthy bearing. A maximum bearing temperature of 700°C occurred after 1000 h of run as depicted by temperature indicator. Further, SEM morphology of bearing surfaces illustrated wear tracks and ploughing marks as a result of wear with running hours. Atomic Absorption Spectroscopy (AAS) was used to measure Fe concentration level in the grease of different run hours. AAS concentration of 5.350 mg/L was observed at 1000 h of running which was only 0.432 mg/L at 50 running hours. These investigations offer a better correlation between spectroscopic and vibration variables and can be used to assess the wear in bearing surfaces effectively.

Key words: Kurtosis, FTIR, AAS, wear, bearing surfaces effectively, vibration

INTRODUCTION

Condition Monitoring (CM) is the method to find the working condition of a machine or machine components with the aim of identifying impending failures before they develop into functional failures. Typical CM practices comprise vibration analysis, lubricant investigation, wear particle study, ultrasonic analysis, thermo graphic study, etc. (James, 2001).

Though inexpensive, checking the performance of a bearing is very essential since it forms a vital component in machinery. It is very essential to monitor and check working conditions such as degradation and oil film depth in a periodic manner in order to sustain an adequate lubrication (Rakic, 2004; Bartz, 1993). The features like shield against dust, erosion and friction, comfort of usage made grease as a better preference for the lubrication of bearings (Mota and Ferreira, 2009; Sanchez *et al*., 2011; Lugt, 2009). But, grease showed reduced mechanical stability and restricted life (Ji *et al*., 2011).

Farcas and Gafitanu (1999) conducted an investigational study for checking the performance of two grease samples with the aim to observe the wear in bearing. Researchers, examined the SEM images of samples and found that the grease film declines with the decline in fibroid structure of proposed grease. Amarnath and Kankar (2014) carried out failure analysis of cylindrical roller bearing using FTIR spectroscopy and SEM analysis and inferred that due to misalignment, worn out particles are detached from the inner element and passed between the working surfaces which resulted in wear of contact surfaces. Kurtosis is the chief diagnostic index which is defined as the fourth normalized statistical moment and it has been widely used for finding the damage in rolling element bearings (Dyer and Stewart, 1978; Heng and Nor, 1998; Aye, 2011). Hiremath *et al*. (2015) conducted experiments to assess surface wear of TiN and AlCrN PVD coatings using statistical values of vibration signals. They noticed significant increase in kurtosis values as more wear progressed in AlCrN coated bearing. Amarnath and Lee (2015) assessed the fatigue damage due to surface contact in spur gears using integrated approach of tribology and vibration analysis. Researchers carried out vibration analysis using the study of RMS values, crest factor and kurtosis values of signals captured at different running hours followed by FFT spectra of signals.

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Table 1: Specifications of test bearing

Features	Details
Bearing type	Roller (DPI N-304)
Number of rollers	10
Outside diameter	52 mm
Inside diameter	20 mm
Pitch diameter	36 mm
Roller diameter	07 mm

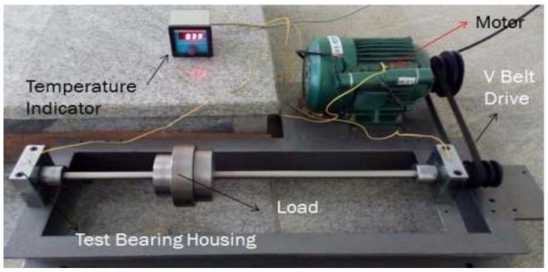


Fig. 1: Experimental test rig

In this research, a bearing test rig has been fabricated to conduct series of experiments. Grease is sampled at various intervals for degradation studies using FTIR Spectra. An accelerometer of B and K 4525 type is employed to capture vibration signals in time domain. AAS study is performed to assess Fe concentration in degraded greases at different running hours. To inspect bearing wear, microstructure of outer race is examined using Scanning Electron Microscope (SEM).

MATERIALS AND METHODS

Experimental procedure: Test rig employed in proposed work is as shown in Fig. 1. It comprises of a shaft held between 2 roller bearings. The specification of bearing to be tested is presented in Table 1. Stainless steel shaft is run by a V-belt and stepped pulley combination with the drive from 1HP single phase motor. A constant load of 500 N and a speed 1760 rpm are chosen as operating conditions to test the bearing. Lithium based lubricating grease of NLGI 3 type is used for lubrication purpose.

RESULTS AND DISCUSSION

Grease analysis: Diagnostic facts about the chemical reactions happening in grease which extracts options for analyses with the effectiveness of the technique between 0.5 and 1% can be revealed by FTIR spectrum (Gol'eva *et al*., 2005). FTIR spectrum becomes the evidence for certain chemical links and functional compounds existing in considered grease model. Deprivation owing to the oxidation can be noticed with the peak in spectrum corresponding to carbonyl group due to the realization of organic acids.

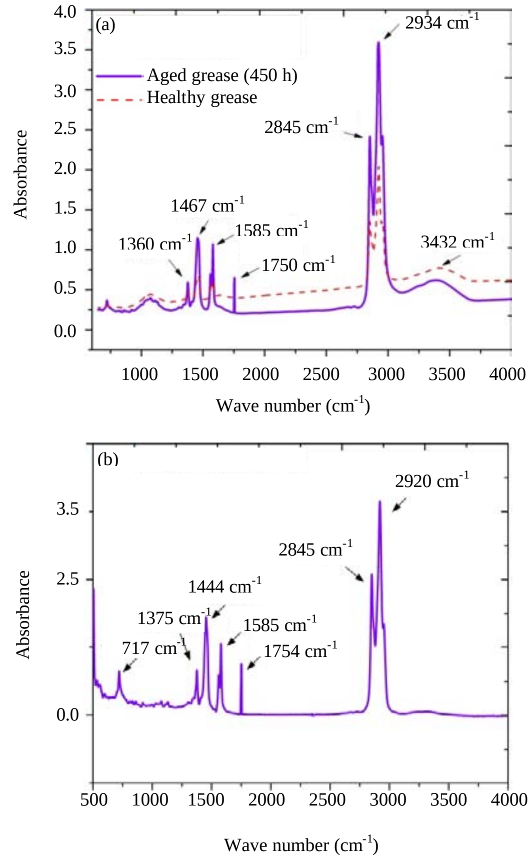


Fig. 2: FTIR spectra of grease samples: a) at 450 h and b) At 1000 h

Parkin Elmer spectrum is utilized to plot IR spectra: Spectrometer with wave number range of 300-6000 cm^{-1} is chosen. But, the range of 300-4000 cm^{-1} is sufficient to examine absorbance bands associated with the components of thickener of grease, base oil and degradation compounds. About, 12-hydroxystearic acid is the main constitute for the lubricating grease. The bearing fatigue investigations were conducted for the interval of 1000 h. Grease was sampled from the cage pockets of bearing at regular interval of hours.

Figures 2a and b represent FTIR spectra of the sampled greases. Figure 2a shows the Infra-Red spectrum of fresh grease and grease sampled at 450 h. The absorption heights at 3432 cm^{-1} indicates the presence of polymeric O-H group. The peak at 2845 cm^{-1} corresponds to deformation vibration of methyl C-H groups. The important rise in the absorbance peak at 2934 cm^{-1} shows the existence of simple alkanes in the lubricating grease at 450 h of run. An important observation made in Fig. 2a is that absorbance peak has occurred at the wavelength of 1750 cm^{-1} which indicates the C = O vibration of ketones,

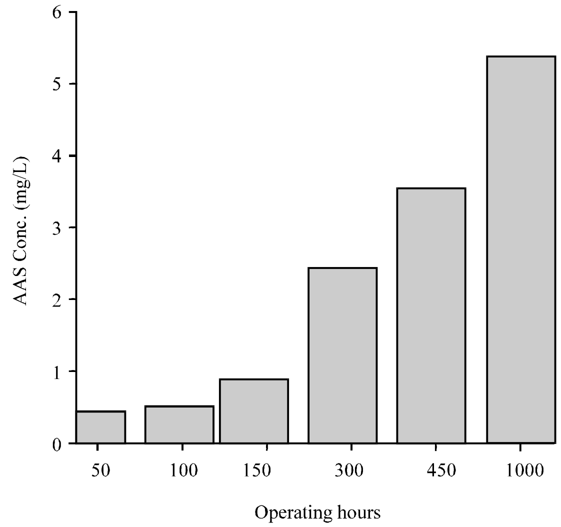


Fig. 3: Fe level versus operating hours

acids and aldehydes which are oxidation products. This clearly indicates the initiation of degradation of grease after 450 h which was not noticed in the IR spectra of grease samples collected after 150 and 300 h. Figure 2b depicts the infra-red spectrum of grease sampled at 1000 h. The absorption peak at 717 cm^{-1} indicates the formation of phenyl group and degradation of anti-wear agents of grease.

Fe concentration analysis: In the current research, the grease sampled at regular intervals of operation is also subjected to study the contamination which might have been by wear particles. Figure 3 shows the experimentally calculated Fe concentration in the grease from Perkin-Elmer AAS.

From this bar graph, it is evident that in early period of running the concentration of Fe level is relatively small. Rise in cycles of fatigue loading results in hike of surface roughness and thereby, it causes more probability of increasing the asperity contacts. Continued running under the condition of such a contact results into material dislodge from bearing surfaces that reasons the hike in Fe adulteration in grease. Hence, the adulteration level also advances as working hours elapse. It is evident in Fig. 3 that there is rise of Fe concentration level at the period of 1000 h.

Time domain analysis: OROS make data acquisition system having 4 channels (Model Sl.No-900159) was employed to gain the vibration signals from the bearing through B and K 4525 accelerometer installed on the housing of test bearing at scheduled intervals of running hours. The signals are amplified and fed into a computer

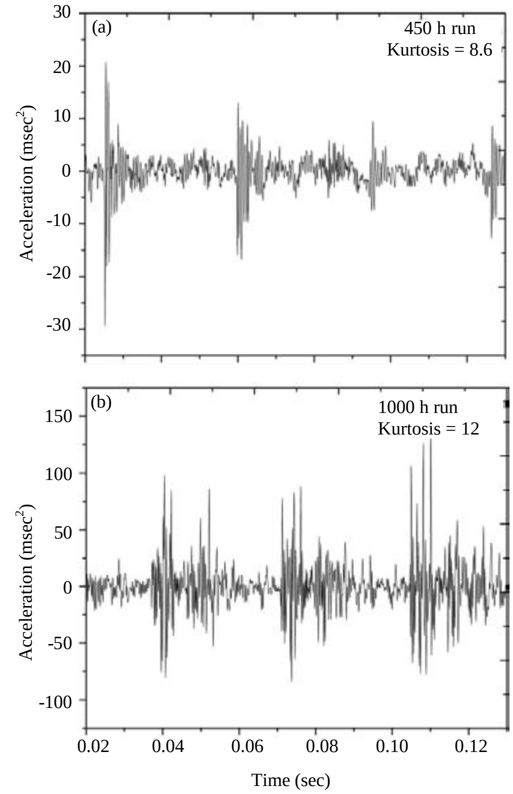


Fig. 4: Time domain waveforms of bearing at: a) 450 h and b) 1000 h

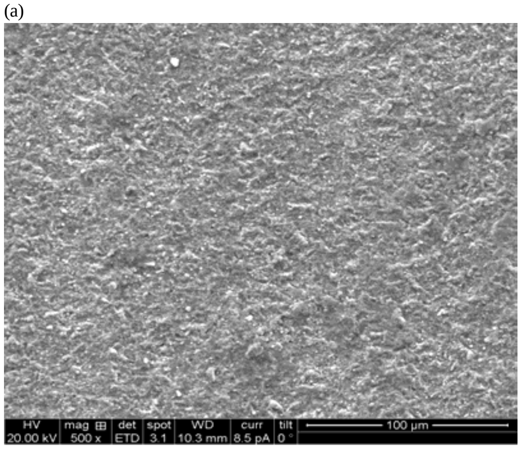
for post processing. Vibration data is analyzed in the time domain to study the effects that results from the revolution of the rolling elements across the wear for every rotation of shaft. Time domain signals were post processed in MATLAB R2013b to extract kurtosis values. Increase in wear results into the rise of kurtosis values. x(t) is time signal having N data points:

$$\text{Kurtosis} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x(i)-\bar{x})^4}}{RMS^4} \quad (1)$$

Figure 4a and b depict time domain wave forms of bearing at different intervals of running hours. The x-axis designates time in sec and acceleration is designated on y-axis in $msec^{-2}$. It can be observed that the kurtosis values show an increase in trend with the running hours since kurtosis is an indicator to identify defects in rotating machines. A maximum value of 12 is noticed for the kurtosis of signals at 1000 h.

SEM analysis: Samples for morphology study were prepared by cutting the outer race of the bearing in slow speed wire EDM (Electro Discharge Machining) machine.

(a)



(b)

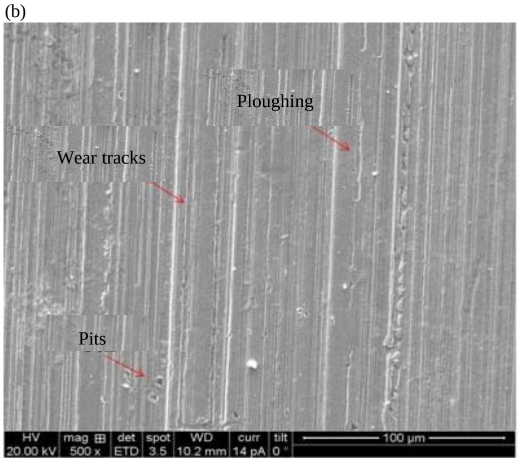


Fig. 5: Surface morphology of bearing at: a) 0 h and b) 1000 h

The surfaces were observed by using Scanning Electron Microscope (SEM) for healthy bearing surface and bearing after the run of 1000 h.

SEM Morphology for bearing after the run hour of 1000 clearly shows that wear tracks and pits are formed on the surface and also ploughing took place at certain places as depicted in Fig. 5b in contrast to morphology of healthy bearing surface as in Fig. 5a. This is because of the reason that wear particles from the grease rooted on the outer race surface and ploughs the surface. The material detached by this action may be coupled with the roller surface. Wear tracks and pits are also formed due to surface fatigue damage after running the bearing for 1000 h. It is also evident from increase in kurtosis values at 1000 h of run.

CONCLUSION

In this research, roller bearing is experimented so as to assess its surface wear. Following inferences can be drawn from the study carried out: Wear process was slow till 300 h of run and no significant change occurred in FTIR Spectra of sampled grease till 300 h. Because of few misalignments after 400 h of run, metal contact took place which resulted in increased wear rate. Due to accelerated wear, grease thickness was not sufficient between outer race and rollers. Hence, at 450 h, degradation initiated in grease as it is clear evident from FTIR plot.

Vibration analysis was also carried out in conjunction with grease analysis. Increase in kurtosis values of time signals with running hours supported the study of grease degradation. SEM images of the outer race have shown the occurrence of wear tracks, pits and plough marks at the bearing contact faces as a result of fatigue of surface contacts.

REFERENCES

Amarnath, M. and P.K. Kankar, 2014. Failure analysis of a grease-lubricated cylindrical roller bearing. Procedia Technol., 14: 59-66.

Amarnath, M. and S.K. Lee, 2015. Assessment of surface contact fatigue failure in a spur geared system based on the tribological and vibration parameter analysis. Meas., 76: 32-44.

Aye, S.A., 2011. Statistical approach for tapered bearing fault detection using different methods. Proceedings of the World Congress on Engineering Vol. 3, July 6-8, 2011, WCE, London, UK., ISBN:978-988-19251-5-2, pp: 6-8.

Bartz, J.W., 1993. Lubrication of Gearing: Lubricants and their Properties, Design of Gears, Practical Gear Lubrication, Failure Analysis. University of Michigan, Ann Arbor, Michigan, ISBN:9780852988312, Pages: 504.

Dyer, D. and R.M. Stewart, 1978. Detection of rolling element bearing damage by statistical vibration analysis. ASME. J. Mech. Des., 100: 229-235.

Farcas, F. and M.D. Gafitanu, 1999. Some influence parameters on greases lubricated rolling contacts service life. Wear, 225: 1004-1010.

Gol'eva, V.E., M.I. Rudnev and V.A. Pisanov, 2005. Determination of esters in motor and industrial oils by IR spectrometry. J. Anal. Chem., 60: 719-722.

Heng, R.B.W. and M.J.M. Nor, 1998. Statistical analysis of sound and vibration signals for monitoring rolling element bearing condition. Appl. Acoust., 53: 211-226.

Hiremath, N., D.M. Reddy and S. Swamy, 2015. Health monitoring of surface wear of TiN and AlCrN based PVD coated bearings using statistical values of vibration signals. J. Mater. Sci. Surf. Eng., 3: 312-315.

James, R., 2001. Machine condition monitoring, a catalist for change in industrial equipment maintenance. PPM. Technol., 14: 20-40.

Ji, X., Y. Chen, G. Zhao, X. Wang and W. Liu, 2011. Tribological properties of CaCO3 nanoparticles as an additive in lithium grease. Tribol. Lett., 411: 113-119.

Lugt, P.M., 2009. A review on grease lubrication in rolling bearings. Tribol. Trans., 52: 470-480.

Mota, V. and L.A. Ferreira, 2009. Influence of grease composition on rolling contact wear: Experimental study. Tribol. Intl., 42: 569-574.

Rakic, R., 2004. The influence of lubricants on cam failure. Tribol. Intl., 37: 365-373.

Sanchez, M.C., J.M. Franco, C. Valencia, C. Gallegos and F. Urquiola et al., 2011. Atomic force microscopy and thermo-rheological characterisation of lubricating greases. Tribol. Lett., 41: 463-470.