Statistical Approach for Tapered Bearing Fault Detection using Different Methods

Sylvester A. Aye, *Member*, *IAENG*

Abstract—**The study investigated the sensitivity of using a contact and a non contact method in tapered roller bearing damage detection. Accelerometers mounted on the bearing housing and connected to Sound and Vibration Analyzer (SVAN) 958 was used to measure the radial accelerations from the bearing housing. The Laser vibrometer which uses a laser beam without making contact with the bearing housing was also used to measure the radial accelerations from the bearing housing. The data obtained from the two measuring techniques was processed to detect damage of the bearing using statistical tools and the results were subsequently compared and it was found that the laser vibrometer gave higher kurtosis values and hence was more sensitive to bearing damage than the accelerometers. However, the accelerometers which were attached directly to the tapered bearing casing gave higher vibration values. From this study it can be recommended that in places where high sensitivity is extremely important it recommended that laser vibrometers be used.**

Index Terms—**Damage detection, laser vibrometer, SVAN 958, tapered bearing**

I. Introduction

Bearing failure is one of the main causes of interruption of rotating machinery operations. This generally leads to unscheduled shutdown thereby increasing the cost of operations. One of the major concerns in bearing diagnostics is the detection of the defect at its incipient stage and subsequently alerting the operator before it develops into a catastrophic failure [1]. The ability to achieve accurate bearing diagnostics is essential to the optimal maintenance of rotating equipment with respect to cost and productivity. This study therefore investigates the sensitivity of the accelerometer mounted on the bearing housing as compared to laser vibrometer in the detecting of incipient faults in tapered roller bearings using the statistical approach.

The statistical analysis method utilizing parameters such as crest factor, the distribution of moments and kurtosis were used to detect the presence of defects in a rolling element bearing applying sound pressure and vibration signals [2]. The statistical analysis method was used because of its simplicity and quick computation. A statistical analysis method is most suitable with random signals where other signal analysis methods based on the assumptions of deterministic signals are not applicable. The effect of shaft speed on the performance of the statistical method was also studied. The results from the study showed that the statistical parameters were affected by the shaft speed due to the sensitivity of the bearing housing components to a longitudinal vibration that excites the fixing ring which holds the test bearing in its position. Under ideal conditions, the statistical method can be used to identify the different types of defect present in the bearing.

The statistical parameter kurtosis remains constant for an undamaged bearing irrespective of load and speed, yet changes with damage [3]. Normally bearing vibration is measured on the bearing housing using accelerometers. The extent of damage can be assessed from the distribution of this statistical parameter in selected frequency ranges. An assessment of bearing condition can thus be made with minimum recourse to historical information. Most other damage detection techniques rely heavily on the trend analysis of data and so the statistical method proves to be a significant advance in bearing fault detection technology, at least when viewed within the objective to provide a simple and cheap technique. As with most other simple detection techniques, the precise nature of the fault cannot be defined and for such information it is necessary to use the more sophisticated diagnostic methods.

II. Methodology

The study evaluated bearing damage using accelerometers mounted on the bearing housing and connected to Sound and Vibration Analyzer (SVAN 958) which is a contact method and laser vibrometer which uses a laser beam without making contact with the bearing housing. The tapered roller bearing was damaged on the outer race and tested in the laboratory. The accelerometer was used to measure the radial accelerations from the bearing housing as shown in figure 1 for the contact method. The data obtained was then processed using MATLAB based software. The statistical approach was used in processing and analysis of the data for damage detection and assessment of the bearing. The crest factor, kurtosis were used in the statistical approach. Subsequently the Laser vibrometer which is a with a laser beam was used to measure the radial accelerations from the bearing housing as shown in figure 2 for the non contact method. The data obtained was equally processed to detect damage of the bearing using the statistical approach as enunciated above. The results from the contact and non contact methods were subsequently compared as to which of the methods is more sensitive in the detection of faults at various speeds.

Manuscript received March 23, 2011; revised April 16, 2011.
S. A. Aye is with the Mechanical and Aeronautical Engineering Department, University of Pretoria, 0002, Pretoria, South Africa, on leave from the Mechanical Engineering Department, University of Agriculture, Makurdi, Benue State, Nigeria (e-mail: sylvester.aye@up.ac.za or aye_sylvester@yahoo.com).

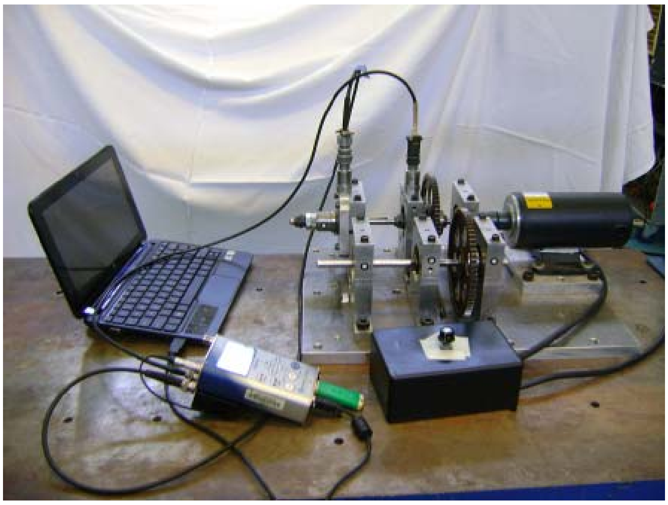

Fig. 1. Contact measurement with accelerometers and SVAN 958

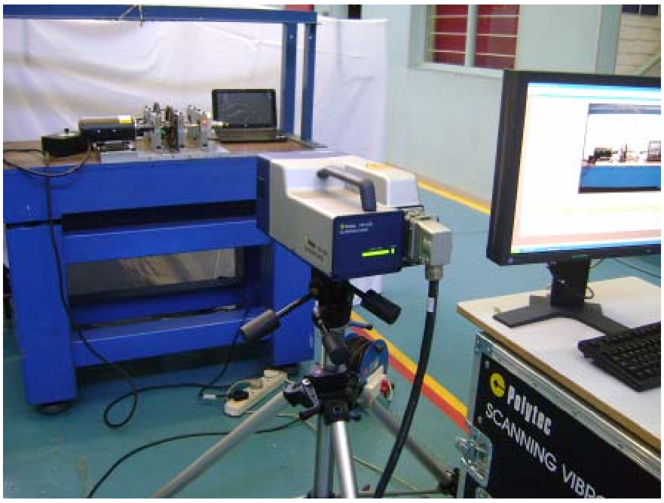

Fig. 2. Contact measurement with laser vibrometer

In the time domain, the vibration data waveform is analyzed for impacts that correspond to the rotation of the rolling elements past the damage for each shaft revolution. Time domain statistical parameters such as root mean square (RMS), peak, crest factor, and kurtosis shown in equations 1-4 are calculated for a sample of time domain data. As the damage occurs, an increase in these values should occur. The bearing time domain metrics are calculated based on the following equations where equals the mean value of the time signal x (t) having N data points [4]:

$$peak = \frac{1}{2}\left(\max(x(t)) - \min(x(t))\right) \quad (1)$$

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x(i) - \bar{x}\right)^2} \quad (2)$$

$$CrestFactor = \frac{peak}{RMS} \quad (3)$$

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

Statistical parameters can be calculated for the entire frequency range and for user selected frequency bands.

III. Results

Accelerometers were used to measure the radial accelerations from the bearing housing as shown in figure 1 for the contact method and the time domain acceleration plot for one of the measurement is shown in figure 3. The data obtained was then processed using MATLAB based software to obtain the statistical parameters. The computed statistical parameters are the peak, RMS, crest factor and kurtosis which are tabulated as shown in table 1.

Subsequently the Laser vibrometer which uses a laser beam was then used to measure the radial accelerations from the bearing housing for the non contact method and the time domain data plot for one of the measurements is as shown in figure 4. The data obtained was equally processed and the statistical parameters such as the peak, RMS, crest factor and kurtosis were obtained and tabulated as shown in table 2.

The percentage difference between the statistical parameters is shown in table 3.

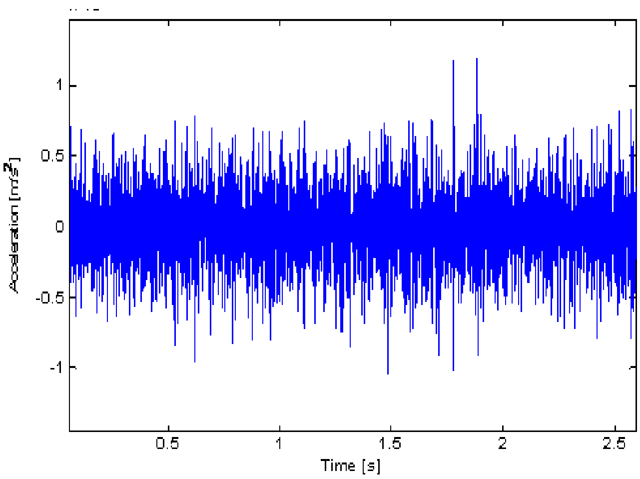

Fig. 3. Time data from Accelerometer with SVAN 958

ISBN: 978-988-19251-5-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

TABLE I
STATISTICAL PARAMETERS FROM THE ACCELEROMETER WITH SVAN 958 DATA

Speed (RPM)	Peak (m/s^2)	RMS (m/s^2)	Crest factor	Kurtosis
409	2.2000	0.5979	3.5331	2.8863
501	2.8410	0.5827	4.8757	2.9348
603	2.2398	0.6000	3.7334	2.8724
712	2.6240	0.6576	3.9902	3.1354
800	2.7540	0.6291	4.3778	3.0777
906	2.7392	0.6787	4.0360	3.0512
1011	3.2146	0.7197	4.4663	2.9425
1100	2.8398	0.7361	3.8577	2.9367
1200	3.1380	0.9342	3.3588	2.8930

TABLE II
STATISTICAL PARAMETERS FROM THE LASER VIBROMETER DATA

Speed (RPM)	Peak (m/s^2)	RMS (m/s^2)	Crest factor	Kurtosis
409	2.9600	0.7296	4.061	4.1384
501	4.5437	0.7872	5.7717	5.0398
603	3.721	0.8222	4.5258	4.0581
712	5.9797	1.0571	5.6566	4.3226
800	5.3756	1.4199	3.7860	3.6736
906	7.7169	1.7161	4.4966	4.3951
1011	6.9757	1.7836	3.911	3.4461
1100	6.9277	2.0422	3.3923	2.5473
1200	7.4121	1.9461	3.8086	2.9289

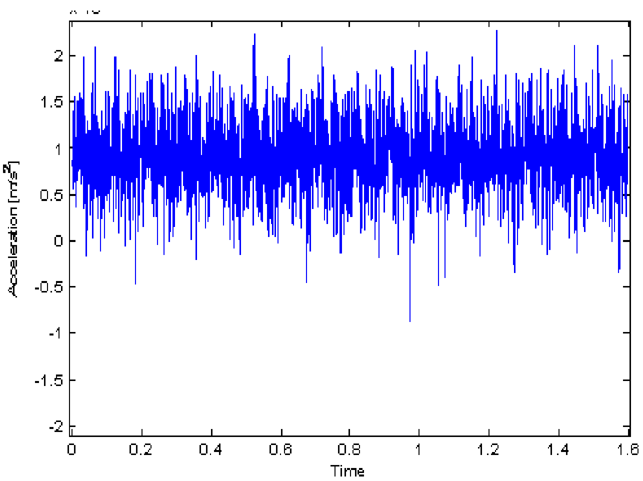

Fig. 4. Time data from Accelerometer with laser

TABLE III
STATISTICAL PARAMETERS FROM THE ACCELEROMETER WITH SVAN 958 DATA

Speed (RPM)	Crest factor	Kurtosis
409	12.99926	30.25565
501	15.52402	41.76753
603	17.50851	29.21811
712	29.45939	27.46495
800	15.63127	16.22115
906	10.24329	30.57723
1011	14.19841	14.61362
1100	13.71931	15.28677
1200	11.81011	1.225716

IV. DISCUSSION

It has been shown that it is possible to use the laser vibrometer which is a non contact method (see figure 2) to obtain the time domain vibration signal just as using accelerometers which is a contact method (see figure 2). The advantage of the contact method is that mass is not added to the system by placing accelerometers on the system as such the dynamics of the system is not altered. However, if the mass of the accelerometer is small in relative terms to the object being measured the effect would be negligible.

The data obtained from the accelerometers which was attached to the SVAN 958 for the contact method was processed using MATLAB based software to obtain the statistical parameters such as the peak, RMS, crest factor and kurtosis which are tabulated as shown in table 1. It can be seen that the kurtosis is about 3 which shows the bearing is not yet damaged. This does not however tell us how close to being damaged the bearing is. Similarly, the data obtained from the laser vibrometer which uses a laser beam was equally processed and the statistical parameters such as the peak, RMS, crest factor and kurtosis were obtained and tabulated as shown in table 2. However, it can be seen that the kurtosis is about 4 and 5 which shows the bearing is damaged as we would expect. Hence in this study the laser vibrometer was able to detect damage better than the accelerometer.

The values obtained for the accelerometers measurements were consistently higher than those for the laser vibrometer measurements as can be seen in table 1 and 2. The accelerometer is more sensitive to vibration from the bearing casing as the magnitude of the peak and RMS values are in the order of mm whereas the measurement from the laser vibrometer are in the order of nm. However, the crest factor and kurtosis values from the laser vibrometer measurements were higher than the values from the accelerometer. This indicates that the laser vibrometer is able to pick up incipient damage earlier than the accelerometers. The percentage difference between the statistical parameters of crest factor and kurtosis is shown in table 3. This shows that the laser vibrometer was more sensitive to damage than the accelerometers.

V. CONCLUSIONS

The data obtained by using the contact and non contact methods in measuring bearing vibration was processed to detect damage of the bearing using the different methods and the results compared thereby showing the most effective approach to damage detection of bearings.

The percentage difference between the statistical parameters of crest factor and kurtosis is shown in table 3. Comparing the results obtained from the two methodologies it can be seen that the values obtained by the use of laser vibrometer are consistently higher than that of the accelerometers as can be seen in the percentage difference in table 3. This shows that the laser vibrometer was more sensitive to damage than the accelerometers. In places where high sensitivity is extremely important it recommended that laser vibrometer be used.

REFERENCES

[1] H. Qiu, J. Lee, J. Lin and G. Yu, "Robust performance degradation assessment methods for enhanced rolling element bearing prognostics", in *Advanced Engineering Informatics*, vol. 17, pp. 127–140, 2003.

[2] R.B.W. Heng and M.J.M. Nor, "Statistical Analysis of Sound and Vibration Signals for Monitoring Rolling Element Bearing Condition" in *Applied Acoustics*, vol. 53, No. 1-3, pp. 21 l-226, 1998.

[3] D. Dyer and R.M. Stewart, "Detection of rolling element bearing damage by statistical vibration analysis", *Design Engineering Technical Conference of ASME, Chicago III*, September 20-30, 1977.

[4] P.J. Dempsey, J.M. Certo, R.F. Handschuh and F. Dimofte, "Hybrid bearing prognostic test rig", *NASA TM-2005-213597*, 2005.

ISBN: 978-988-19251-5-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)