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Effect of Speed and Torque on Statistical Parameters in Tapered Bearing Fault Detection

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***Abstract*—**The effect of the rotational speed and axial torque on the diagnostics of tapered rolling element bearing defects was investigated. The accelerometer was mounted on the bearing housing and connected to Sound and Vibration Analyzer (SVAN 958) and was used to measure the accelerations from the bearing housing. The data obtained from the bearing was processed to detect damage of the bearing using statistical tools and the results were subsequently analyzed to see if bearing damage had been captured. From this study it can be seen that damage is more evident when the bearing is loaded. Also, at the incipient stage of damage the crest factor and kurtosis values are high but as time progresses the crest factors and kurtosis values decrease whereas the peak and RMS values are low at the incipient stage but increase with damage.

***Keywords*—**crest factor, damage detection, kurtosis, RMS, tapered roller bearing.

I. Introduction

ROLLING element bearings are a universal component in equipment. Hence they have received great concern in the field of condition monitoring [1]. Rolling element bearings are manufactured by assembling different parts. These are the rolling elements, the outer race and the inner race, which are in contact under heavy dynamic loads and relatively high speeds. The Hertzian contact stresses between the rolling elements and the rings are one of the basic mechanisms that initiates a localized defect. When a rolling element strikes a localized defect an impulse occurs and this excites the resonances of the structure. The vibration signature of a damaged bearing consists of exponentially decaying ringing. The impulses will occur with a period determined by the location of the defect, the geometry of the bearing and the type of the bearing load [2].

Many techniques for condition monitoring of rolling element bearings exist [3, 4, 5, 6, 7, 8, 9, 10, 11, 12]. Vibration and acoustic measurements techniques are used most often [13]. They considered the detection of both localized and distributed categories of bearing defect. An explanation for the vibration and noise generation in bearings was given. Vibration measurement in both time and frequency domains along with signal processing techniques such as the high-frequency resonance technique were covered. Other acoustic measurement techniques such as sound pressure, sound intensity and acoustic emission were reviewed including recent trends in research on the detection of defects in bearings, such as the wavelet transform method and automated data processing.

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II. Methodology

The vibration data obtained are analyzed and different statistical parameters such as peak, root mean square (RMS), crest factor (Cf) and kurtosis are assessed with regard to their effectiveness in the detection of bearing condition.

The damage was introduced to the outer race of the tapered roller bearing. The statistical parameters were computed for speed ranging from 500 rpm to 1200 rpm for the no torque scenario. For the torque scenario the statistical parameters were computed for 200 rpm to 1200 rpm. The time domain properties for a discrete vibration signal x can be written as follows:

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

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

$$CrestFactor = \frac{peak}{RMS} \tag{3}$$

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

The study evaluated bearing damage using accelerometers mounted on the bearing housing and connected to Sound and Vibration Analyzer (SVAN 958) (see figure 1). Damage was introduced to the tapered roller bearing on the outer race and tested in the laboratory. The accelerometer was used to measure the radial accelerations from the bearing housing and a sample acceleration-time response is as shown in figure 2.

The data obtained was then processed using MATLAB based software. The statistical approach was used in the processing and analysis of the data for damage detection and assessment of the bearing. The peak, RMS, crest factor, kurtosis values were used in the statistical approach. The effects of speed and torque loads were also investigated.

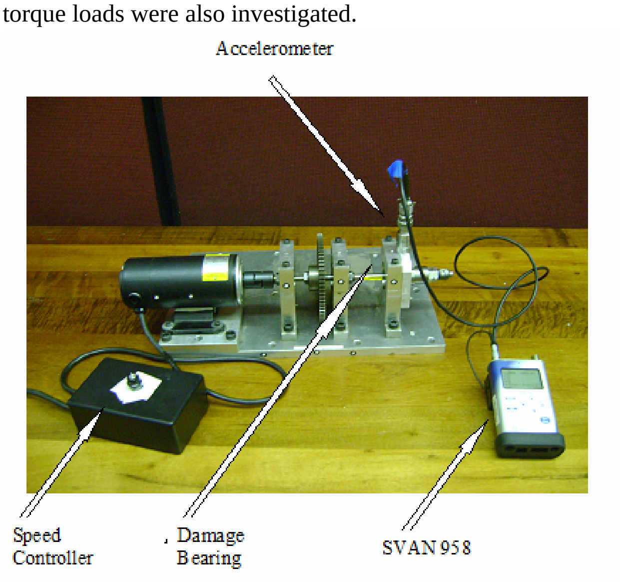

Fig. 1 Bearing set-up with accelerometers and SVAN 958

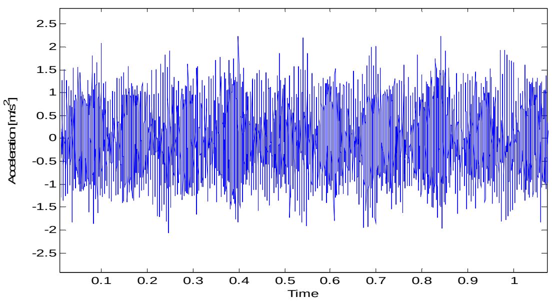

Fig. 2 Time data from Accelerometer with SVAN 958

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 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 [14]:

III. Analysis of Results

The bearing set-up was run for about five minutes at each speed in RPM and the data recorded and the subsequently the statistical parameters were computed using Matlab based programs. It is found that at earlier stages or speeds the Crest factor and kurtosis was high. However, with increasing time the crest factors and kurtosis were reducing in magnitude whereas the peak and RMS values kept increasing. This shows that the bearing has been damaged and was beginning to flatten out at the advanced stage of damage. However, comparing the current RMS values to the baseline RMS values it could be seen that the bearing has deteriorated with usage. It was discovered that the RMS depended on runtime and not the speed of the machine. With increase in run time and speed (RPM), the peak and RMS values increased whereas the crest factor and kurtosis decreased. Load had the effect of increasing the magnitude of the statistical parameters. When there was no load at about 0 Nm) the values of the statistical parameters indicated damage but the magnitude was low as shown in figure 3. When there was a load of about 1 Nm the values of the statistical parameters increased in magnitude thereby indicating damage more as shown in figure 4. From figure 3 it can be seen that the peak and RMS values increase with increasing speed for the no load scenario. The same thing applies when the bearing is loaded axially with a torque of 1 Nm. It can be seen in figure 4 that once again the peak and RMS values increase with increasing speed. The only difference being that the magnitude of the peak and RMS values in the loaded case is higher than in the non loaded case. However, it can be seen in figure 3 that both the crest factor and kurtosis decrease in value with increasing speed for the no load scenario. Again it can be seen that both values, ie the crest factor and kurtosis still decrease in value with increasing speed when a torque of 1 Nm is applied to the bearing axially. Again the only difference being that the magnitude of the crest factor and the kurtosis in the loaded case is higher than in the non loaded case.

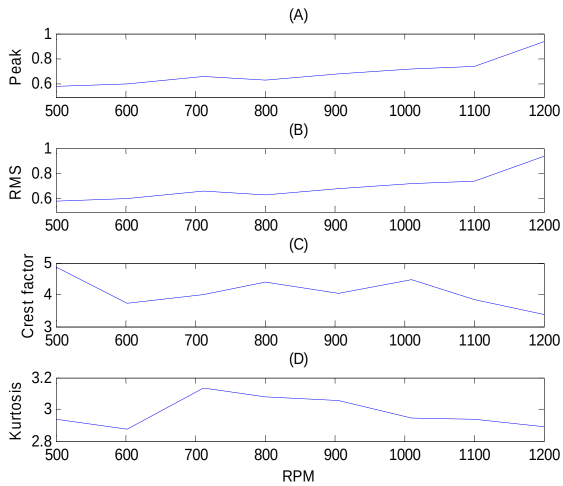

Fig. 3 Statistical parameters for the acceleration response at a load of about 0 Nm: (a) Peak (b) RMS; (c)crest factor; (d) kurtosis

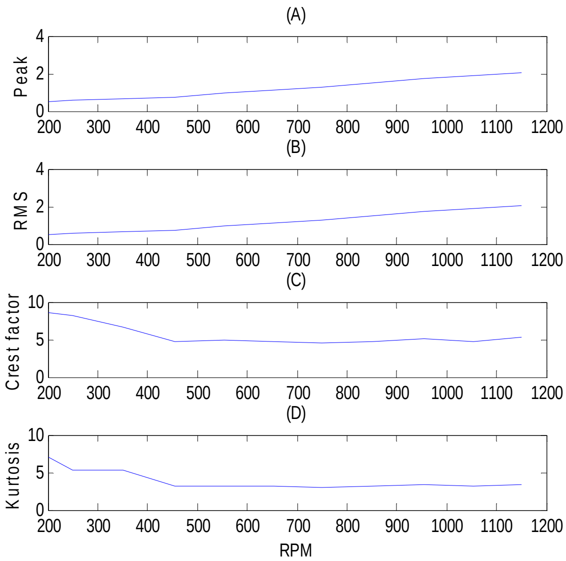

Fig. 4 Statistical parameters for the acceleration response at a load of about 1 Nm: (a) Peak (b) RMS; (c)crest factor; (d) kurtosis

IV. Conclusions

The bearing set-up was run for about five minutes at each speed in RPM and the data recorded and it was found that at earlier stages or speeds the crest factor and kurtosis were high. However, with increasing time the crest factors and kurtosis were reducing in magnitude whereas the peak and RMS values kept increasing. This showed that the bearing has been damaged and was beginning to flatten out at the advanced stage of damage. However, comparing the current RMS values to the baseline RMS values it could be seen that the bearing had deteriorated with usage. It was discovered that the RMS depended on runtime and not the speed of the machine. With increase in run time and speed (RPM), the peak and RMS values increased whereas the crest factor and kurtosis decreased. Load had the effect of increasing the magnitude of the statistical parameters. When there was no load at about 0 Nm) the values of the statistical parameters indicated damage but the magnitude was low. When there was a load of about 1 Nm the values of the statistical parameters increased in magnitude thereby indicating damage more.

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