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Time Domain Analysis of Sound Signals for Bearing Damage Identification

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Abstract—**Time domain analysis requires less computational time compared to the frequency domain. Analysis is performed directly on the signal without any conversion at all. This paper describes high-frequency signal analysis on sound produced by rotated bearing. Three bearing conditions - normal, damaged, and badly damaged - was chosen to obtain the characteristics of high frequency sound. From the entire spectrum of the recorded sound, the higher frequency range looks very different for the three conditions bearing. Phisically, more damage rotated bearing, the disturbance sound heard more loudly. Bearings were rotated at various rpm, from low to high, to ensure the similarities and differences in characteristics. Average energy and standard deviation were calculated as bearing damage indication.**

Keywords— bearing; damage identification; sound signal; time domain.

I. Introduction

The previous research have been done to identify the bearing signal vibration. To discover a comprehensive vibration signal around the bearing, the five accelerometers/sensors have been implemented with different angle [1]. The five location of sensors were to cover in the top of casing-axial, upper bearing-radial, lower bearing-transverse, lower bearing-radial and lower bearing-axial. Each sensor is equipped with five channels digitizer which is operated in 51.2 kHz sampling rate with rotating in 1125 rpm (18.75 Hz). The implementation of piezoelectric-type acoustic emission sensors was also implemented [2]. The sensor can be operated in the frequency ranging of 100-1000 kHz glued tightly on the bearing housing. The bearing was rotated in 600, 1500 and 3000 rpm. The sampling data rate was recorded at 4 MHz for each simulated damage conditions. The harmonics of the stator current in permanent magnet synchronous motor was observed to recognize bearing damage [3]. This motor could rotate at a high speed of 1500, 3000, and 6000 rpm. The two simulation models for demonstrating the damage condition performed were by presenting 0.5% and 1% of the nominal variation torque in the machinery system.
The accuracy of the observations bearing damage using acoustic emission sensor combined with the piezoelectric type accelerometer for retrieve vibration data has been compared [4]. On the other hand, a critical study comparing the vibration signal retrieval techniques and the induction motor stator currents has also been discussed [5]. Signal processing methods can be used to determine bearing damage in [6]. Sound signal also have beed proved as bearing damage indicator as well in [7].

The main data to be acquired is the only sound signal of vibration. Therefore, to acquire the sound signal vibration due to the damage bearing without any sensor implementation is the main concerned in this paper. Sound signals are recorded from bearings with the same environment without any physical contact between the bearing and the sensor. The recorded sound signals are then filtered to get its high frequencies. Using time domain techniques, the sound signal characteristics between the normal and damage signal bearing was observed. In this technique the origin signal of rolling bearing is not necessary to be taken into account neither.

II. METHOD

Three test bearings were selected based on the conditions: normal, damaged, and badly damaged, each of 6205 2RS type. Damaged levels were known from rotatiton difficulties. Tested bearings displayed in Figure 1. The sound was recorded within 1 cm from the bearing put in the testing rig as seen in Figure 2.

Fig.1. Normal, Damaged, and Badly Damaged Tested Bearings

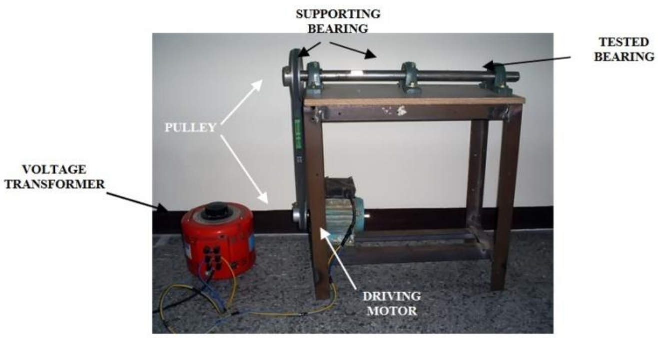


Fig.2. Bearing Damage Test Rig.

Axle rotation speed was set by changing the supply voltage of the ac motor using voltage transformer in 1465, 1590, 1670, and 1740 rpm. Then, sound signal was recorded in WAV format, 8 bit data. Sampled in 44.1 kHz rate and 60 seconds duration.

Figure 3 shows the procedure of the sound signal processing. Sound signals were filtered to get data at high frequencies only. Then analyzed the differences in average power and standard deviation.

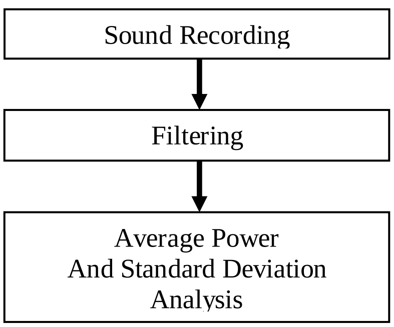


Fig.3. Sound Signal Processing Procedure.

III. RESULT AND DISCUSSION

Bearing sound recordings and their spectra can be seen in Figure 4. This study focuses on the frequency of about 10 kHz (8.5 kHz - 12 kHz) are shaded green in Figure 4.

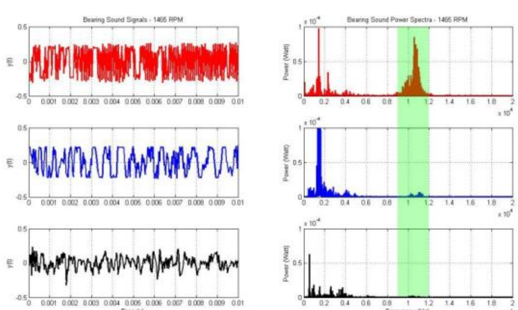


Fig.4. Sound Signals and Power Spectra.

Recorded voice signals were filtered using a band pass filter with the specifications: N = 100, Fst1 = 8.2 kHz, Fp1 = 8.5 kHz, Fp2 = 12 kHz, 12.3 kHz = Fst2. Signal filtering results are shown in Figure 5. Only the frequencies of 8.5kHz to 12 kHz remaining.

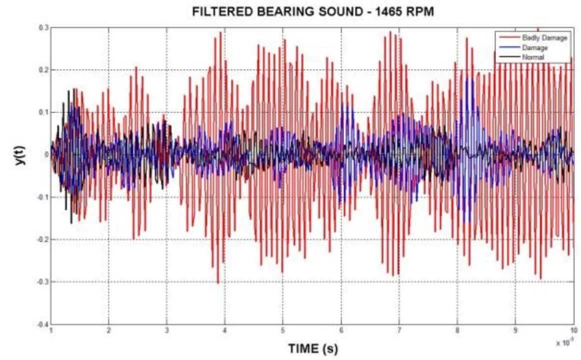


Fig.5. Filtered Bearing Sounds.

Characteristics of each signal can be found using statistical techniques. The average power and standard deviation are the most meaningful value that shows it. The equation to find those values are shown in Equation 1 and Equation 2.

$$P_{av} = \frac{1}{n}\sum_{i=1}^{n} |x_i|^2 \quad (1)$$

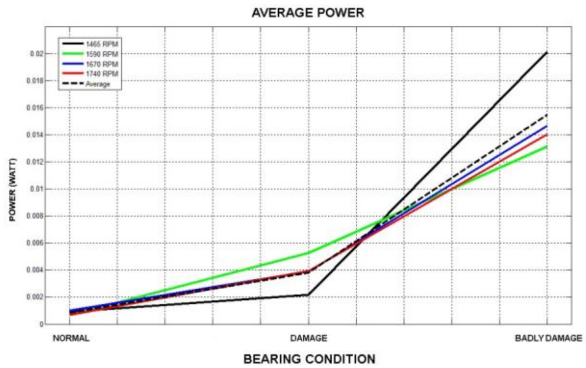
$$s = \quad \text{where} \quad (2)$$

The results of the calculation of average power and standard deviation are shown in Table 1.

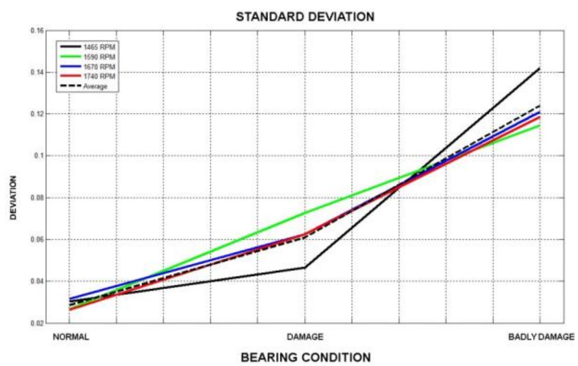
Table 1. Results of Sound Signal Analysis.

No	Condition	Average Power			
		1465	1590	1670	1740
1	Normal	9.23e-04	7.04e-04	0.00100	6.88e-04
2	Damage	0.00215	0.00528	0.00388	0.00391
3	Badly Damage	0.02015	0.01314	0.01464	0.01402
		Standard Deviation			
1	Normal	0.03038	0.03038	0.03038	0.03038
2	Damage	0.04644	0.04644	0.04644	0.04644
3	Badly Damage	0.14197	0.11464	0.12103	0.11845

Figure 6.a and Figure 6.b also present the result in the graphical form.



(a)



(b)

Fig.6. Average Power and Standard Deviation

IV. CONCLUSIONS

Time domain analysis can be used as a fast way to investigate the bearing conditions. Bearing damage level can be determined based on the characteristics of the high frequency sound. Greater average power and standard deviation indicate that the bearing getting damaged.

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