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Cepstrum Method for Detecting Inner Race Ball Bearing Fault on Industrial Fans

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Abstract

One of the important machine in the industries was fan industry. Fan used on the Heating process, Ventilation, Air Conditioning system and cooling process. Bearing in the fan, had an important role to sustain blade shaft or any other shaft in that machine. The fault that occur in bearing will have the impact for fan performance. Thus, we needed monitoring's method that can identify bearing condition. One of the monitoring's method that can be used is vibration base method with characteristic vibration analisys. As we know, fan industry had a complex machine component that generates many harmonic and side band families. The purpose of this study was to detect bearing inner race fault on the fan industry with cepstrum analisys. This study used prototype fan industry to collect vibration data and used MATLAB software to process the data. Two bearing were use in this research, normal bearing and inner race fault bearing from ASB 6209 with single row bearing's type. Based on the research, spectrum analysis showed peak at frequency 54,68 Hz that refers to Ball Pass Frequency Inner Race Fault (BPFI) frequency. The peak was hard to identify because many high amplitude from another component frequency, amplitude from harmonic families and amplitude from frequency noise. However, in cepstrum analysis, quefrency from BPFI clearly to identify at peak 0,0201 s because cepstrum can interpret that complexs harmonic in one rahmonik peak at cepstrum.

Keywords*: bearing, BPFI, fan industry, frequency, vibration analysis, quefrency*

1. Introduction

Fan is a rotary machine that is widely used by industry. Fan is a device or machine that is used to produce a flow at a certain fluid that has several common components including blades, casings, shafts, bearings and electric motors (1). Industrial fans have several functions depending on the type of fan itself, which is used in the HVAC system, in the combustion and cooling processes, transport, air dryers and so on. One component of the fan that has an important role in the work process is the bearing. Damage to this component can cause a significant decrease in the performance of the fan or even the fan may not work. Termination of work from this fan will certainly cause problems in the production process in an industry. Therefore, we need a monitoring method that can determine the condition of the fan bearings. One such method is based on vibration signals. The vibration analysis method has several types of analysis in its completion, two of which are spectrum and cepstrum analysis.

Research using spectrum analysis was carried out by (2) on a ball bearing testrig centrifugal pump. Spectrum analysis can identify bearing defects in a variety of experiments. However, in some other variations the amplitude of the bearing defect frequency is almost the same as the other frequency amplitude, making the detection process difficult. Spectrum analysis has also been applied by (3) on detection of damage to inner, outer and rolling elements. Spectrum graphs can show the amplitude of BPFI, BPFO and BSF but there is still a high amplitude of other frequencies that is quite a lot. The spectrum method successfully observes conditions after and before maintenance on an exhaust fan performed by (4). Large changes in amplitude are clearly visible on the spectrum graph. Kamiel. BP (1) detects bearing damage to a fan by using envelope and spectrum analysis. Envelope analysis can identify the peak damage frequency quite well. However, in the analysis of the spectrum amplitude of the frequency defect is potentially covered by the amplitude of another frequency.

Satyam (5) detects bearing damage to the compressor using cepstrum and spectrum analysis. Cepstrum analysis can identify peak damage frequency more easily when compared to spectrum. Cepstrum analysis application to detect gear damage has been done by (6) and (7). Cepstrum analysis can sort out periodic and non periodic vibrations which will improve the quality of diagnostic damage. Detection of damage to the bearing using cepstrum analysis has been successfully carried out by (8). The peak of the bearing damage quefrency is clearly seen on the cepstrum graph.

Several studies that have been carried out using spectrum and cepstrum analysis show that both methods of analysis can be used to detect damage to a machine component. However, in terms of detecting damage to machines that have a lot of high frequency, harmonic and sideband spectrum analysis in some conditions is less able to detect damage properly. That is because the amplitude of the damage frequency is covered by the high amplitude of the other frequencies, the harmonic family, the sideband and also noise. The *cepstrum* method is a method that can be used to detect damage accurately especially to detect damage to engine components that produce *harmonics* and *sidebands* complex. Therefore, the cepstrum method was examined in this study to detect track defects in ball bearings in a prototype fan industry.

2. METHODS

This study uses two conditions, namely bearings in normal conditions and bearings in defect conditions in the inner track. The bearing will be attached and a vibration signal taken on a test equipment in figure 1.

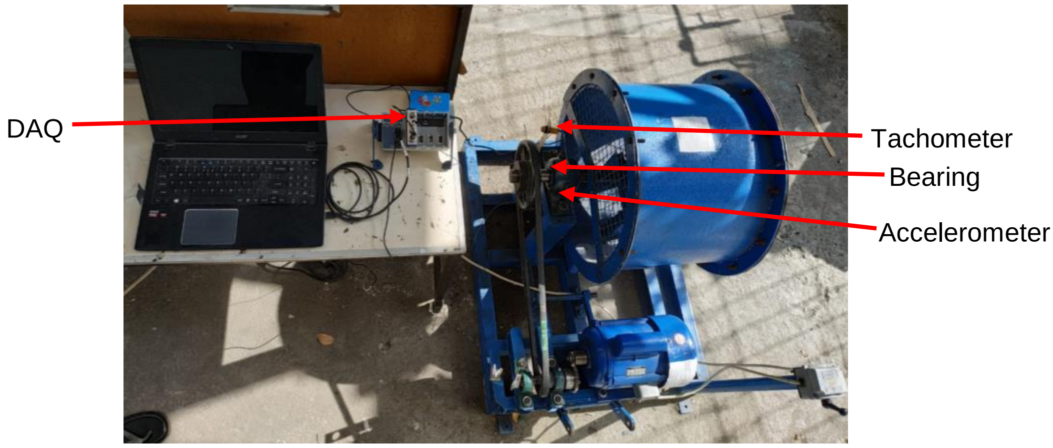


Figure 1. Test Rig Prototype Fan Industri

Bearing is intentionally damaged using the EDM (Electrical Discharge Machine) method with a depth of 1.4 mm deformation and a width of 0.4 mm deformation . In this study the bearings used are single row ball bearings from ASB 6209 shown in Figure 2.

(a) (b)

Figure 2. (a) Normal Bearing, (b) Inner race fault bearing

This study using accelerometer sensors for record vibration signals placed on the bearing housing. Pulse tachometer sensors fired at the pulleys are used to measure the rotational speed of the shaft. Data Acquisition Module (DAQ) from National Instrument which is used to transmit vibration signals from accelerometer sensors and pulse signals from tachometer sensors to laptops or computers with MATLAB software installed from Mathwork. The software is used for data acquisition, data signal processing and vibration signal data analysis. The sampling rate used in this study was 17066 Hz. The vibration recording process is carried out for 10 seconds each file. A data set contains 20 data files which in this study took 10 data sets of normal bearings and internal path defects. The data collection scheme on the test equipment can be seen in Figure 3.

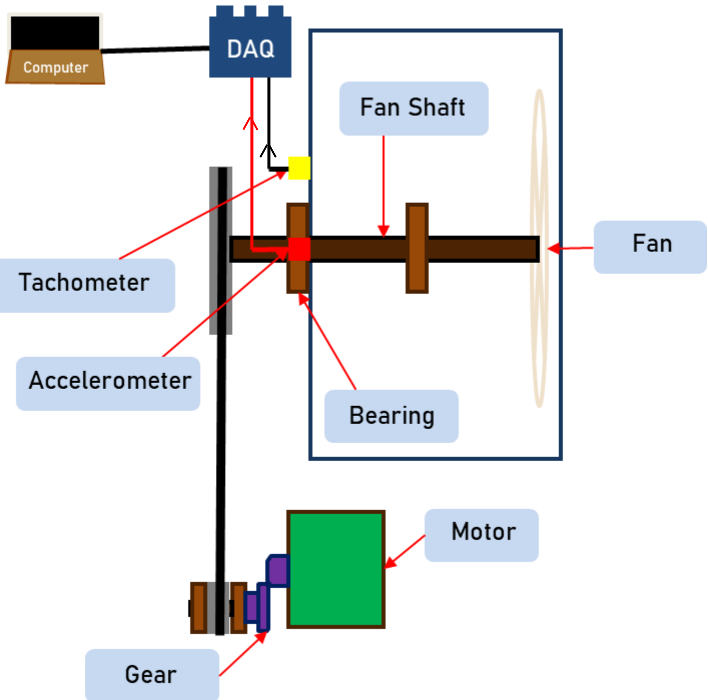


Figure 3 Data Collect Scheme

Process of recording the vibration starts from the preparation of installing the data acquisition tool on the test equipment. After the electric motor is turned on, the data retrieval script in the MATLAB software on the computer is run, then the accelerometer sensor will automatically pick up the vibration data and the tachometer sensor will pick up the pulse speed data.

Inner track defects that occur in the bearing have a large frequency of its own. The frequency that appears is influenced by the dimensions of the bearings and the mechanical conditions of the machine which can be seen in Figure 4.

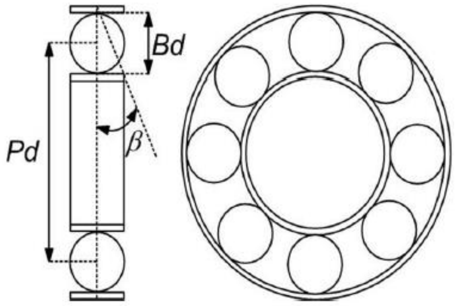


Figure 4. Bearing Dimension

The equation used to calculate the magnitude of frequency generated by the defect in the path that occurs is as follows:

$$\text{BPFI} = \frac{\text{Nb}}{2} \times fr \times \left(1 + \frac{\text{Bd}}{\text{Pd}} \text{ x} \cos \propto\right)$$

Which :

Nb = Number of balls

Fr = Frequency of relative rotation of the inner and outer trajectories (Hz),

Bd = Ball diameter (mm)

Pd = Pitch Diameter (mm) and

α = Contact angle degrees.

3. Result and Discussion

3.1 Plot Time Domain

Normal time domain bearing graph is shown in Figure 5 and the time domain graph of bearing defect in the path is shown in Figure 6. One parameter that clearly shows the difference is the high value of the vibration amplitude that occurs. In the time domain of normal bearing the amplitude height ranges from 2.5 - 3 mV while in the time domain the bearing defect height is amplitude ranging from 10-13 mV. The increase in the value of the amplitude indicates a problem with the machine. However, in the graph it is difficult to do the process of identifying which components are the source of the problem of increasing the amplitude.

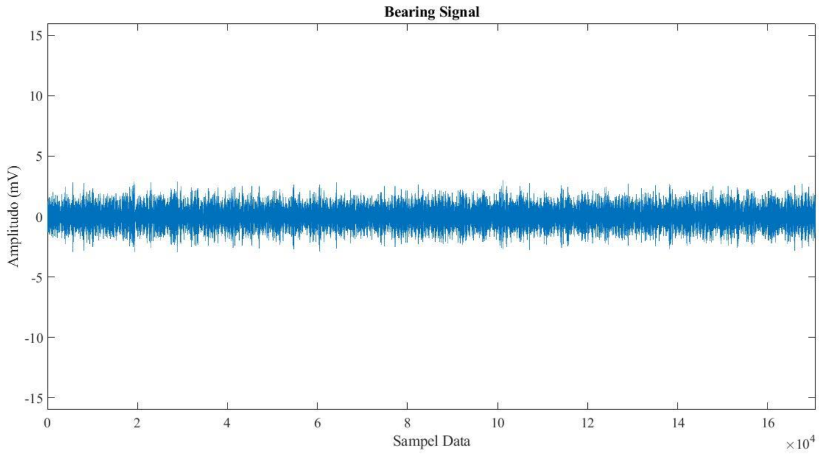


Figure 5. Plot Time Domain Normal bearing

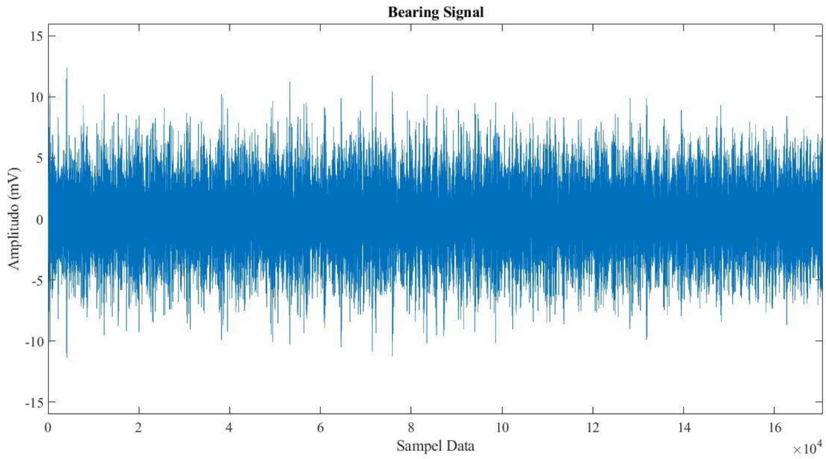


Figure 6. Plot Time Domain Fault Bearing

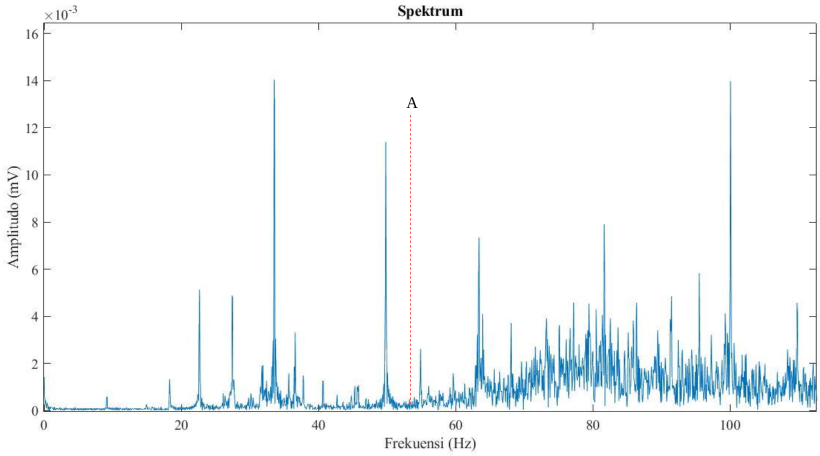
3.2 Plot Spectrum Analysis and Cepstrum Analysis

Single row ball bearing dimensions of ASB type 6209 have the dimensions shown in table 1 that are used to calculate the magnitude of the frequency value of the inner ball pass frequency race fault (BPFI).

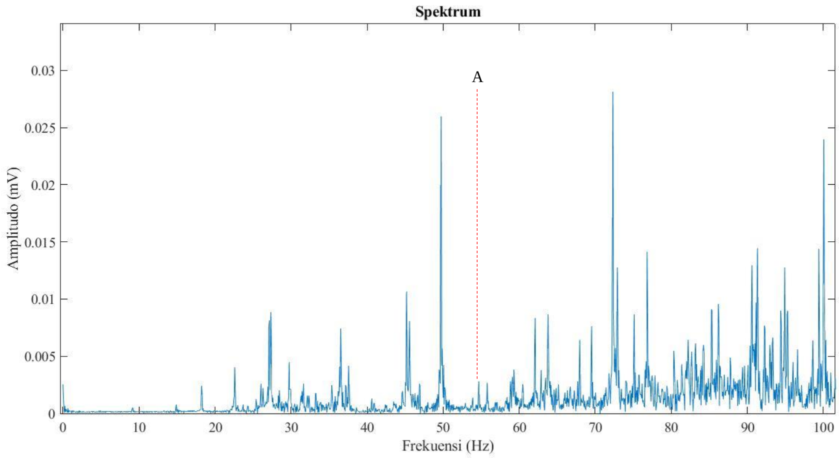
Table 1. BPFI Frequency

Nb	**10**
Fr (Hz)	9,114
Bd (mm)	13
Pd (mm)	65
$\propto$*(^{o})*	0^{o}
BPFI *(Hz)*	54,68

Figure 7 (a) and (b) are plots of spectrum analysis. The amplitude that appears at the BPFI frequency is shown by the symbol letter A. In the normal high amplitude spectrum bearing graph that appears at the BPFI frequency is not observed because there is no impact on the bearing due to defects that occur in the inner path so that the amplitude of the frequency does not appear. While on the spectrum chart of bearing defects in the inner path, amplitude appears at a frequency of 54.69 Hz which is identified as the frequency of BPFI. However, the peak of the amplitude is quite difficult to observe because many amplitudes are higher than other frequencies. These high amplitudes can potentially cover the frequency amplitude of this BPFI, thus causing errors in the detection process. The amplitude is derived from the frequency of other components, namely the fan shaft, gear shaft, blade and also the noise from the external system. Difficulties in the process of detecting damage are also experienced in studies using gears conducted by [9]. On the spectrum graph, gearmesh frequency is difficult to observe due to the operation of other parameters such as workload.



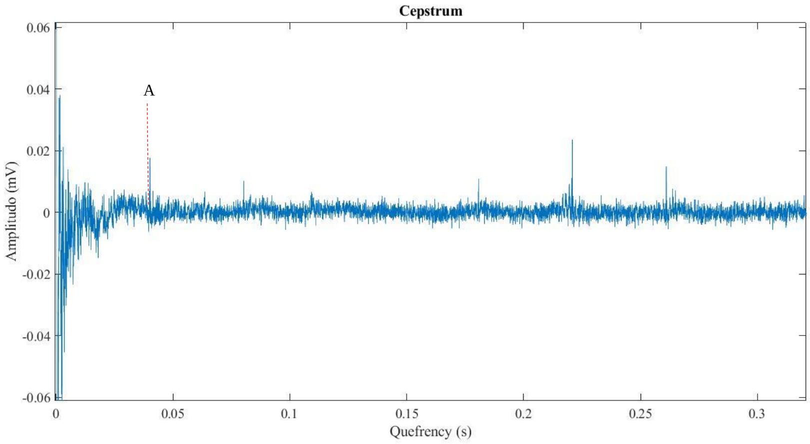
(a)



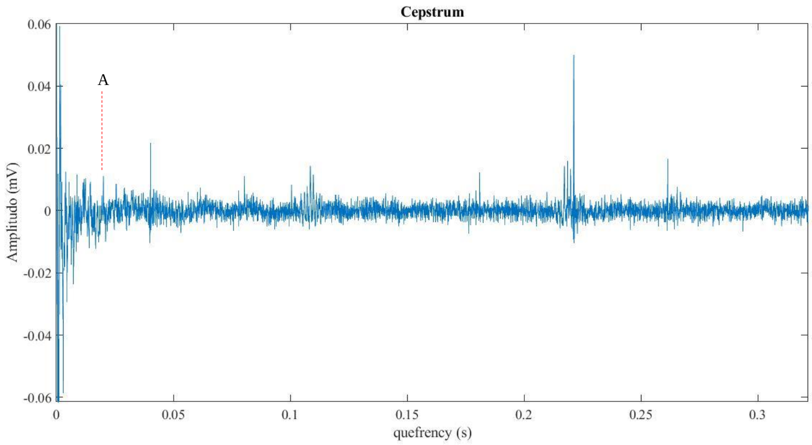
(b)

Figure 7. (a) spectrum of normal bearing dan (b) spectrum of inner race fault bearing

Figures 8 (a) and (b) are consecutive cepstrum analysis plot plots and normal cepstrum bearing graphs plot of cepstrum chart bearing defects in deep trajectories. On the cepstrum graph of normal bearings, the peak of the BPFI frequency is not observed. That is because in the spectrum graph no amplitude appears on the BPFI frequency and also the harmonics. The absence of a peak at the BPFI quefrency is also caused by the absence of defects or damage to the bearings. In contrast to the plot of the cepstrum analysis chart of bearing defects in the inner track. The peak of the inner path defect quefrency appears at the 0.0201 s frequency which is identified as the frequency of BPFI. As investigated by [10], this cepstrum analysis improves and improves the quality of diagnoses of damage to a complex machine component. This can be seen in the cepstrum graph of the defective bearing, the peak of the BPFI quefrency is clearly seen when compared to the peak frequency of the BPFI on the spectrum graph. In the cepstrum graph, high amplitude of other frequencies including several harmonic families of gear shafts, fan shafts and blades do not appear so as to facilitate the process of detecting and analyzing the condition of an engine component. From the cepstrum chart, small changes in the condition of a machine can be easily identified and then action can be taken as needed.



(a)



(b)

Figure 8. (a) Plot cepstrum analysis of normal bearing dan (b) Plot cepstrum analysis of inner race fault bearing

results of the plot of the cepstrum graph improve the quality of the fault diagnosis as described by (7) which detects damage to a gearbox can be applied to ball bearings in a fan industry. From the cepstrum graph the peak quefrency of defects in the inner track defects in single row ball bearings from ASB can be identified quite easily. This is in line with research conducted by (8). The peak frequency of the SKF bearing defects in the gearbox is clearly visible on the cepstrum graph. Cepstrum analysis can detect damage to complex engine components in this case is bearings.

4. CONCLUSION

In the time domain graph plot, it is found that the machine has a problem or damage seen from the increase in the value of the amplitude. However, it is difficult to know which component is damaged. Spectrum analysis can identify components that have problems seen from the amplitude generated from component frequencies. However, in this case, spectrum analysis is less effective in detecting defects in the bearing defects in the bearing caused by the high amplitude and harmonic generated by the fan machine industry, making the detection process difficult. The high amplitude of the harmonic family, the frequency of other components and noise can be solved by cepstrum analysis in this case. Track defects in ball bearings in the fan industry can be detected properly and easily using cepstrum analysis because cepstrum can interpret several harmonic families that disrupt the detection process into a peak on the cepstrum graph.

REFERENCES

Journal:

1. Kamiel, B. P., Nuh, A. M., & Sudarisman.. Pengembangan Metode Deteksi Cacat Bantalan Berbasis Analisis Envelope pada Prototipe Fan Industri. Jurnal Material dan Proses Manufaktur. (2018); 27-34.
2. Kamiel, B. P., Mulyani, & Sunardi.. Deteksi Cacat Bantalan Bola Pada Pompa Sentrifugal Menggunakan Spektrum Getaran. Jurnal Ilmiah Semesta Teknika. (2017); 204-215.
3. Wahyudi, T., Soeharsono., & Eddy, N. Mendeteksi Kerusakan Bantalan Menggunakan Sinyal Vibrasi. Jurnal Sinergi. (2016); 123-128.
4. Taplak, H., Kurt, E., & Parlak, M. Fault Diagnosis For Exhaust Fan Using Experimental Predictive Maintenance Method. International Journal of Acoustics and Vibration. (2016); 274-280.
5. Satyam, M., Rao, V. S., & Devy, C. G. Cepstrum Analysis – An Advance Technique in Vibration Analysis of Defect in Rotating Machinery. Defence Science Journal. (1994); 53-60.
6. Morsy, M. E., & Achtenová, G. Envelope Detection and Cepstrum Analysis for Gear Fault Diagnosis – A Comparative Study. MEASUREMENT. (2015); 187-190.
7. Widodo, A., Satrijo, D., & Prahasto, T. Deteksi Kerusakan Roda Gigi dengan Analisis Sinyal Getaran. ROTASI. . (2015); 67-75.
8. Adithya, L. R., & Amoghavarsha, K. P.. Bearing Fault Detection Using Cepstrum Analysis. Trends in Microwave Engineering and Technology Journal. (2018); 1-8.
9. Nacib, L., Pekpe, K. M., & Sakhara, S. (2013). Detecting Gear Tooth Cracks Using Cepstral Analysis in Gearbox of Helicopters. International Journal of Advances in Engineering & Technology, 139-145.