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Fault Analysis Of Two Stage Gearbox Using Acoustic Emission Signal: Effect Of Spalling

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Abstract
Fault detection and diagnosis of gear transmission systems have attracted considerable attention in recent years, due to the need to decrease the downtime on production machinery and to reduce the extent of the secondary damage caused by failures. This paper deals with fault diagnosis of a two stage spur gearbox having pitting defect in driver gear using Wavelet analysis through MATLAB software. For this an experimental setup is fabricated. The Acoustic signals are captured from the experiments and the burst in the Acoustic signal is focused in the analysis and the energy dissipation of the faulty gear is found out.

Keywords: Gears, Fault Diagnostic, MATLAB, Acoustic emission, Wavelet Analysis, Energy dissipated.

Introduction

Acoustic Emission is a tool to detect the faults in rotating machine parts as bearings, gears etc. According to fault Different acoustic emission signals are generated they can measure by different techniques and we can analyze the health of that part. Acoustic emission techniques will be used in order to make a diagnosis of gearbox faults. This paper aims to illustrate the application of acoustic emission monitoring for gear faults detection. [7]

The chosen machine elements for analysis are *gearboxes*, an important part of almost all machines that use some kind of transmission of power from one shaft to another. When gears mesh the acoustic signals may contain amplitude and energy dissipation, which can be caused by a broad variety of fault. For example a gear meshing with an eccentric gear may cause amplitude modulation and the speed fluctuations caused by a gear meshing with a gear with a local fault may cause acoustic signals. Since acoustic signals frequencies are caused by certain faults of machine components including gear, bearing, and shaft, the detection of the acoustic signal is very useful to detect gearbox fault.[7]

“Wavelet Analysis” technique is very accurate method for acoustic emission analysis in gearbox fault detection and therefore, this method is chosen to be the main scope of this project work.

The technique focuses on the high-frequency zone of the spectrum. Using a high-pass filter (allowing high frequencies, but blocking lower ones), the analyzer focuses on the high-frequency data content.[8]

Literature Review

- Maynard &Kenneth P. [1] both carried out an investigation work on the utilization of amplitude & phase maps of the wavelet transform to detect localized gear defect in gear trains. It was found that the phase map displays distinctive features for data measured on a test rig with a cracked gear tooth present.

- Singh A. Houser [3] carried out investigation to compare the effectiveness of different diagnostic methods to detect gear teeth cracks from experimentally measured data, it was concluded that the application of the wavelet transform to the raw measured signals is sensitive to the presence of gear tooth cracks.

- K.H Pedersen [7] previously carried out a thesis work on condition monitoring of gear failures with acoustic Emission. He utilized data taken from earlier experiments to investigate the use of acoustic emission for

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tool conditions monitoring of gears. The aim was seeing how and where the points were growing in amplitude level as the gear running time progressed. He concluded that the results obtained from test confirm that the acoustic emission method for condition monitoring of gear is good.

- Mitchell Lebold & others [8] discussed various methods used for the diagnosis of the gear box. They focused towards features that are used for the detection of gear faults. The features are categorized into five different groups based on their preprocessing needs. They provide an overview of the preprocessing flow and where each of the features is calculated in the processing scheme.

Wavelet Analysis

Wavelet analysis performs a decomposition of the measured acoustic emission signals into a weighted set of scaled wavelet functions. A primary advantage of the wavelet method lies in the fact that it is naturally multiresolution and scalable in applications making it possible for a single decomposition to efficiently provide reconstruction at a variety of sizes and resolution. Wavelet analysis can perform through the use of the wavelet toolbox which is a collection of functions that was built on the Mat lab technical computing environment R.L.Reuben[2]. The toolbox aids with the provisions of tools for the analysis and synthesis of signals and also statistical application through the use of wavelet and wavelet packets within the framework of MATLAB. It provides two categories of tools:

1. Command line functions known as M-files, &
2. The graphical interactive tools.

A number of basis functions are used as the mother wavelet for wavelet transformation. The mother wavelet determines not only the characteristics of the resulting wavelet transform but also produces all wavelet function used in the transformation through translation & scaling.

Wavelet families are classified as follows

1. Haar
2. Daubechies
3. Coiflet
4. Symlet
5. Meyer
6. Morlet
7. Maxflat
8. Mexican Hat

Experimentation

In the project work, the two stage gear box has been selected for the experimental work. The experimental test rig with controlled operating conditions was set up to conduct a series of tests using spur gears. Medium carbon steel spur gears were used in the tests, to drive a dynamometer. A photograph of the experimental set-up is shown in Fig.1. The power is given to the input shaft with the help of a single phase 50 Hz DC motor. The AE signal is captured for different RPM (300:50:500) with the help of a PC using Matlab software. The speed (rpm) of the DC Motor is controlled by Dimmer/Speed Controller having a maximum capacity up to 1 H.P or maximum 4 Amp current. The Dimmer varies the speed in terms of percentage. The operating frequency was verified with an optical tachometer.

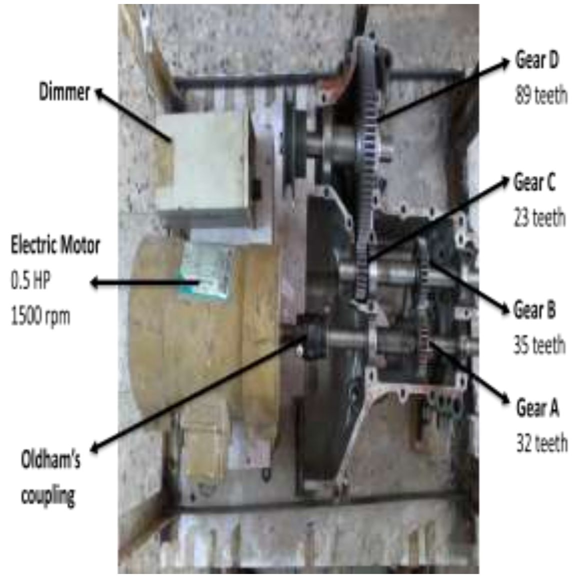

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Figure 1: Experimental Set-Up

Figure 2: Spalling Defect in Gear

The experiment is carried out in two phases without loading. In the first phase, the healthy gears are mounted and the corresponding Acoustic signal is captured. A sample data of one second duration and its power spectral density (PSD) spectrum are shown in Figure 3 and 4, respectively. In the second phase, the driver gear was replaced with a gear with Spalling defect. As can be seen from Figure 2, the defects have been introduced on the first tooth. As earlier, the Acoustic signal is captured and a sample data of one second duration along with its PSD spectrum are shown in Figure 11 & 12, respectively.

Results and discussion

The Figure 3 shows the signals in time domain and frequency domain, when the gear is fault free or healthy. The Time domain signal is converted into frequency domain with the help of FFT of the signal. At different rpm the energy dissipated by the healthy gear may be analyze by wave menu tool of MATLAB toolbox as shown in figure 5,6,7,8 & 9.

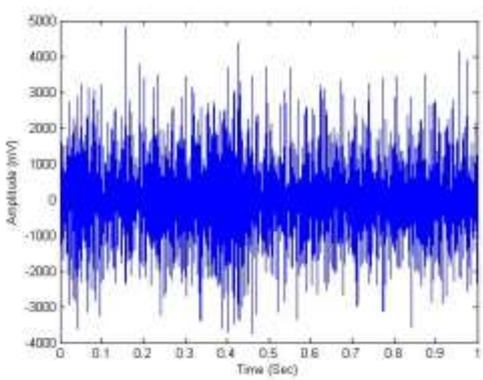

Figure 3: Acoustic Signal in Time Domain of Healthy Gear

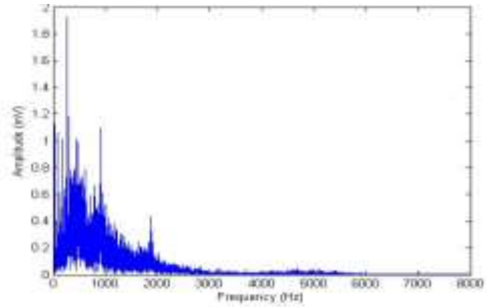

Figure 4: Acoustic Signal in Frequency Domain of Healthy Gear

Figure 5: ***Spectrum of Healthy gear at 300 rpm***

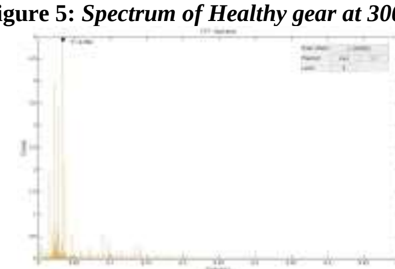

Figure 6: ***Spectrum of Healthy gear at 350 rpm***

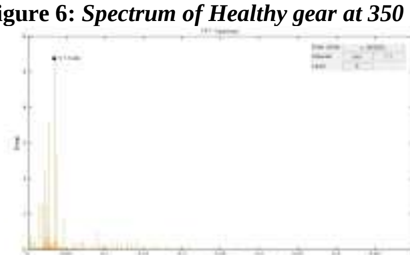

Figure 7: ***Spectrum of Healthy gear at 400 rpm***

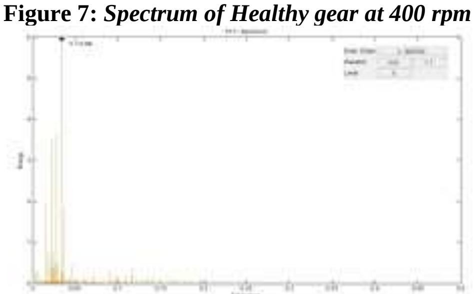

Figure 8: ***Spectrum of Healthy gear at 450 rpm***

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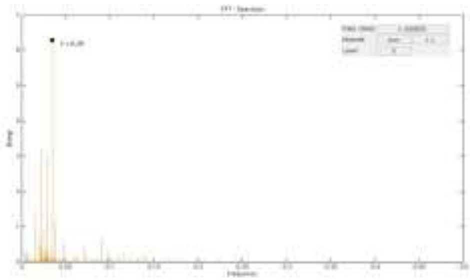

Figure 9: ***Spectrum of Healthy gear at 500 rpm***

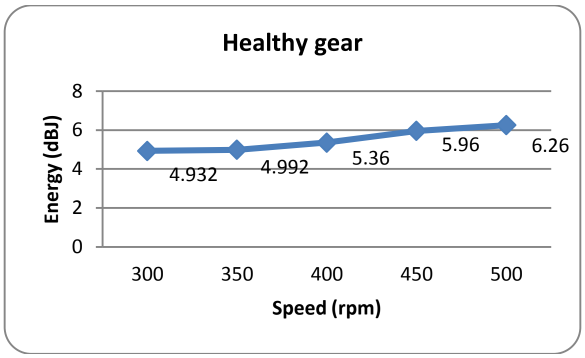

Figure 10: ***Energy dissipated by Healthy gear***

As the Fault is introduced in driven gear, the acoustic signals are changed for different rpm as shown in figure 12. It is clear from the figure 12 that the Energy dissipated is higher at the frequency nearly 5.2 kHz. From the spectrum in figure 1, one can observe that the acoustic bursts due to the defect in the gear tooth generate high frequency components (in the range of 4.5–5.5 kHz). The defect is identified in the spectrum as high intensity stripes. Therefore a frequency band range between 4.5 kHz to 5.5 kHz is selected by applying the filtering of the signal as shown in figure 13. After filtering the signal, at different rpm the energy dissipated by the defective gear may be analyzed by wave menu tool of MATLAB toolbox as shown in figure 14,15,16,17 & 18.

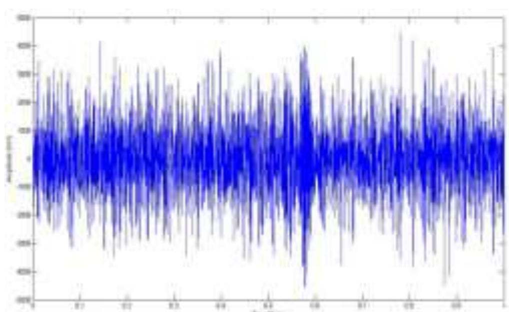

Figure 11: Acoustic Signal in Time Domain of Faulty Gear

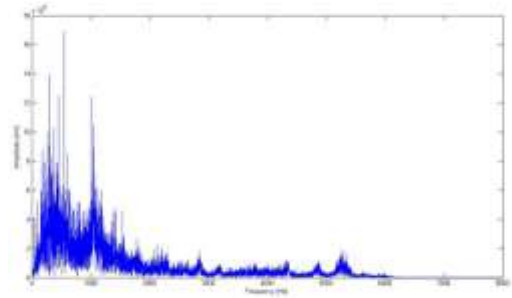

Figure 12: Acoustic Signal in Frequency Domain of Faulty Gear

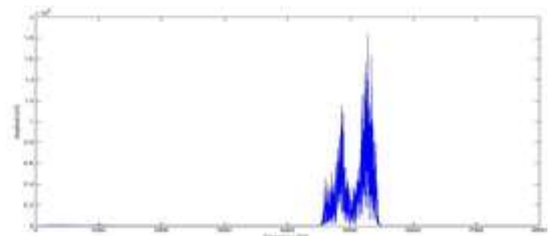

Figure 13: Filtered Signal in Frequency Domain of Faulty Gear

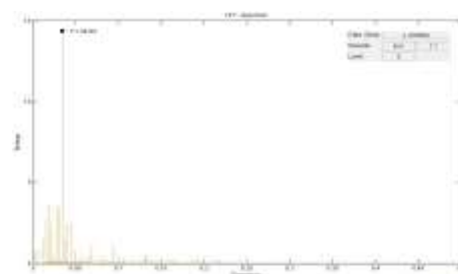

Figure 14: ***Spectrum of defective*** **gear** ***At 300rpm***

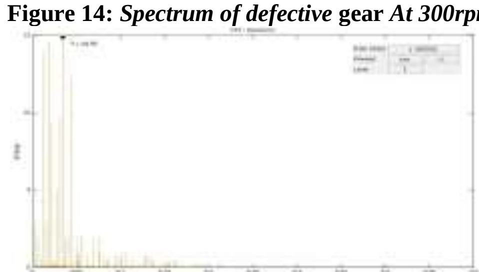

Figure 15: ***Spectrum of defective*** **gear** ***At 350rpm***

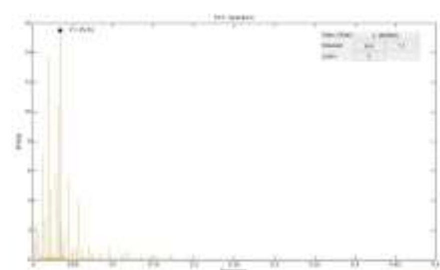

Figure 16: ***Spectrum of defective*** **gear** ***At 400rpm***

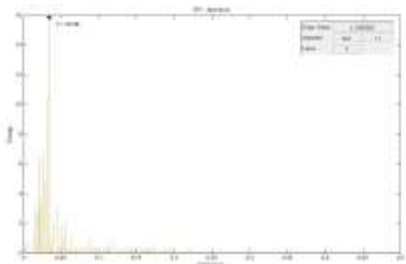

Figure 17: ***Spectrum of defective* gear *At 450rpm***

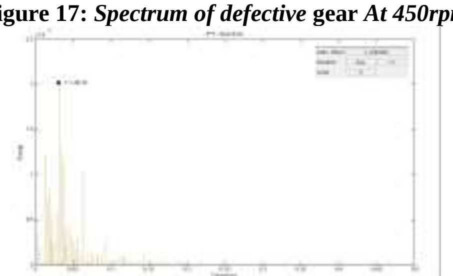

Figure 18: ***Spectrum of defective* gear *At 500rpm***

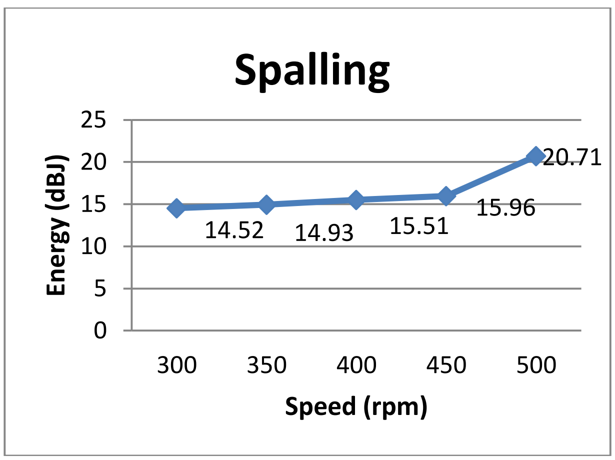

Figure 19: ***Energy dissipated by defective gear***

By comparing figure10 & figure 19 we can easily see that energy dissipation of healthy gear for different rpm is 4.93-6.26 dBJ and due to defect energy dissipation of defective gear is varies from 14.52- 20.71 dBJ.

Conclusion

The energy dissipation of the Spalling defect was found to be 14.52- 20.71 dBJ. Experimental work was carried out with the intention to use wavelet technique to show how the energy dissipation varies for different faults due to severe; we can detect the fault but cannot predict the fault on the basis of signature.

Acknowledgements

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