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Fault diagnosis of massey ferguson gearbox using power spectral density

K.Heidarbeigi[*], Hojat Ahmadi, M. Omid and A. Tabatabaeefar

Department of Power and Agricultural Machinery Engineering, Faculty of Bio-system Engineering, University of Tehran.

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Many vibration environments are not related to a specific driving frequency and may have input from multiple sources which may not be harmonically related. Examples may be excited from turbulent flow as in air flow over a wing or past a car body, or acoustic input from jet engine exhaust, wheels running over a road, etc. With these types of vibration, it may be more accurated, or interested to analyze and tested using random vibration. Unlike sinusoidal vibration, acceleration, velocity and displacement are not directly related by any specific frequency. Of primary concern in random testing is the complete spectral content of the vibration being measured or generated. Most random vibration testing is conducted using Gaussian random suppositions for both measurement and specification purposes. With Gaussian assumptions, there is no definable maximum amplitude, and the amplitude levels are measured in RMS (root-mean-squared) values. In this study, were calculated RMS and Power Spectral Density (PSD) of Massey Ferguson gearbox in different situation. The calculated G_{rms} and PSD for different faults were done. The results showed the different PSD vs. frequency, that with calculating PSD to find some fault and diagnosis of gearbox.

Key words: condition monitoring, fault diagnosis, fibration, gearbox, power spectral density

Introduction

Many vibration environments are not related to a specific driving frequency and may have input from multiple sources which may not be harmonically related.

Machine condition monitoring has long been accepted as one of the most effective and cost-efficient approaches to avoid catastrophic failures of machines. It has been known for many years that the mechanical integrity of a

[*]Corresponding author: K.Heidarbeigi; e-mail: kobra.heidarbeigi@gmail.com

machine can be evaluated by detailed analysis of the vibratory motion (Eisenmann, 1998).

Materials and methods

Experimentation and testing

The test rig used for the experimentation was a gearbox. The experimental setup to collect dataset consists of Massey Ferguson gearbox, an electrical motor with two independent variable speeds that drive the system, a triaxial accelerometer (X-Viber, VMI is manufacturer) and four shock absorbers under the base of test-bed. Test-bed was designed to install gearbox, electric motor and four shock absorbers under bases to cancel out vibrations. All vibration signals were collected from the experimental testing of gearbox using the accelerometer which was mounted on the outer surface of the bearing case of input shaft of the gearbox. For each configuration different fault conditions were tested that were medium-worn, broken teeth of gear. The signals from the accelerometer were recorded in a portable condition monitoring signal analyzer.

Power spectral density

In physics, the signal is usually a wave, such as an electromagnetic wave, random vibration, or an acoustic wave. The spectral density of the wave, when multiplied by an appropriate factor, gives the power that carried by the wave, per unit frequency. This is known as the **power spectral density** (PSD) of the signal. The units of power spectral density are commonly expressed in watts per hertz (W/Hz) or watts per nanometer (W/nm) (for a measurement versus wavelength instead of frequency). Although it is not necessary to assign physical dimensions to the signal or its argument, in the following discussion the used terms assumes that the signal varies in time. The energy spectral density describes how the energy (or variance) of a signal or a time series is distributed with frequency. If $f(t)$ is a finite-energy signal, the spectral density $\Phi(\omega)$ of the signal is the square of the magnitude of the continuous Fourier transform of the signal (energy is taken as the integral of the square of a signal). The above definitions of energy spectral density require that the Fourier transforms of the signals exist, that the signals are square-integrable or square-sum able. An often more useful alternative is the **power spectral density** (PSD), which describes how the power of a signal or time series is distributed with frequency. The power can be the actual physical power, or more often, for convenience with abstract signals, can be defined as the squared value of the signal, that is, as the actual power if the signal was a voltage applied to a 1-ohm load. This instantaneous power (the mean or expected value of which is the average power) is then given by:

$$P = s(t)^2 \ .$$

Since a signal with nonzero average power is not square integrable, the Fourier transforms do not exist in this case. Fortunately, the **Wiener–hinchin theorem** provides a simple alternative. The PSD is the Fourier transform of the **autocorrelation function**, $R(\tau)$, of the signal if the signal can be treated as a stationary random process. This results in the formula:

$$S(f) = \int_{-\infty}^{\infty} R(\tau)\, e^{-2\,\pi\, i\, f\, \tau}\, d\tau.$$

The power of the signal in a given frequency band can be calculated by integrating over positive and negative frequencies:

$$P = \int_{F_1}^{F_2} S(f)\, df + \int_{-F_2}^{-F_1} S(f)\, df.$$

The power spectral density of a signal exists if and only if the signal is a wide-sense **stationary process**. If the signal is not stationary, then the autocorrelation function must be a function of two variables, so no PSD exists, but similar techniques may be used to estimate a time-varying spectral density.

Results and discussion

Result showed frequency spectrum of gearbox. The largest acceleration value of broken gear was occurred at gearbox speed and its value was about 0.09 g and for worn gear was occurred at the same frequency and its value was 0.03g as seen in figs 1, 2 and 3.

The frequency spectrum of healthy gearbox was showed. The largest acceleration value of healthy condition was occurred at 15 Hz and its value was about 0.018 g.

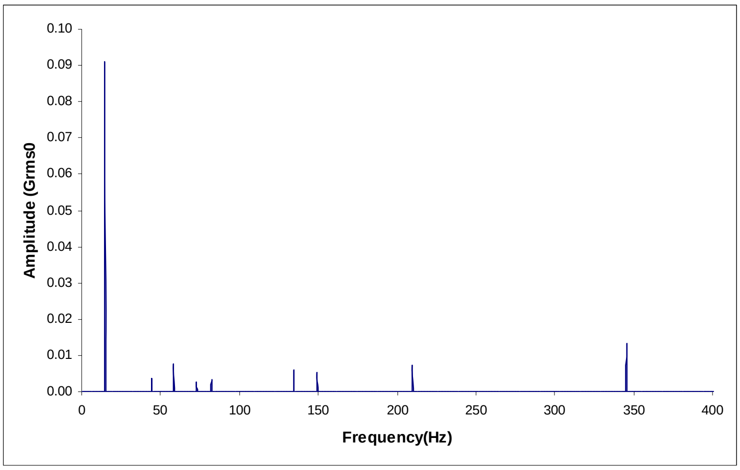

Fig. 1. Frequency spectrum of broken gear (800 rpm).

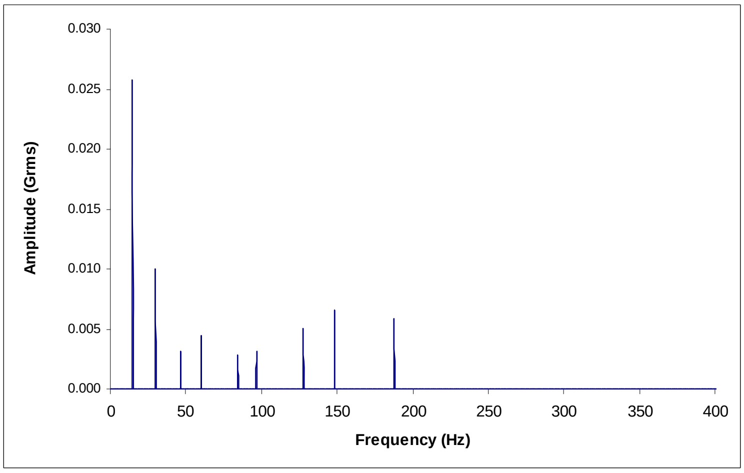

Fig. 2. Frequency spectrum of worn gear (800 rpm).

The results showed that area under Power Spectral Density carves were indicated a problem. The more area below Power Spectral Density curve showed the deeper fault. The power spectral density of gearbox in different situation was showed in fig. 4.

The results showed that different faults were showed different ASD vs. frequency. The results showed that with calculating PSD that could find some fault and diagnosis of gearbox.

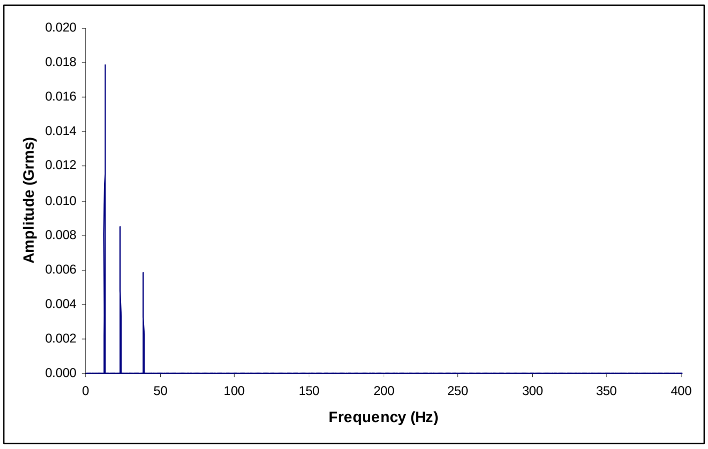

Fig. 3. Frequency spectrum of healthy gear (800 rpm).

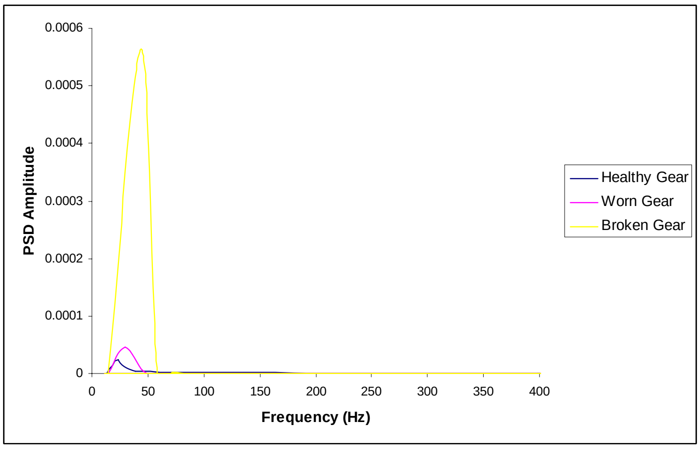

Fig. 4. Power Spectral Density results of gearbox (healthy, wear broken).

Vibration analysis in particular has been used as a predictive maintenance procedure and as a support for machinery maintenance decisions (Barron, 1996; Want *et al*., 1996; Luo *et al*., 2000; Smith, 1989). This was achieved by vibration analysis of gearbox. A series of tests were conducted under the operating hours of electromotor. Vibration data was regularly collected. Power Spectral Density data produced by vibration analysis was compared with previous data. Numerical data produced by Power Spectral Density were compared with Power Spectral Density in healthy gearbox, in order to quantify the effectiveness of the PSD technique (Wowk, 1991). The results from this paper have given more understanding on the dependent roles of vibration condition monitoring and PSD curve in predicting and diagnosing of gearbox faults (Peng *et al*., 2003). RMS and PSD (Power Spectral Density) of gearbox in different situation, G_{rms} and PSD for different faults were calculated. The results showed that different faults were showed different PSD vs. frequency. The results showed that with calculating PSD we could find some fault and diagnosis of gearbox as soon as possible. Results gave more understanding on the dependent roles of vibration analysis and Power Spectral Density carve in predicting and diagnosing of gearbox faults.

Conclusion

Results showed that vibration condition monitoring and Power Spectral Density technique could detect fault diagnosis of gearbox. Vibration analysis and Power Spectral Density could provide quick and reliable information on the condition of the gears. Integration of vibration condition monitoring technique with Power Spectral Density analyze could indicate more understanding about diagnosis of gearbox.

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References

Eisenmann, R.C.Sr. (1998). Machinery Malfunction Diagnosisand Correction, Prentice Hall.

Barron, T. (1996). Engineering Condition Monitoring, Addison Wesley Longman.

Want W.J. and McFadden, P.D. (1996) Application of wavelets to gearbox vibration signals for fault detection. Journal of Sound and Vibration 192: 927–939.

Luo, G.Y., Osypiw, D. and Irle, M. (2000). Real-time condition monitoring by significant and natural frequencies analysis of vibration signal with wavelet filter and autocorrelation enhancement. Journal of Sound and Vibration 236: 413–430.

Smith, J.D. (1989). Vibration Measurement and Analysis, Butterworth & Co. Ltd.

Wowk, V. (1991). Machinery Vibration: Measurement and Analysis, McGraw- Hill Inc.

Peng, Z. and Kessissoglou, N.J. (2003). An integrated approach to fault diagnosis of machinery using wear debris and vibration analysis, Wear.255: 1221–1232.

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