Research Paper Engineering

Fault Diagnosis of Single Stage Spur Gear Box Using Demodulation Technique: Effect of Pitting

* Mr. Vijay Karma ** Mr. Himanshu Borade

* Assistant Professor, Mechanical Engineering Department, Institute of Engineering & Technology, DAVV University, Indore

** Student, M.E. (Design &Thermal Engineering) Mechanical Engineering Department, Institute of Engineering & Technology, DAVV University, Indore

ABSTRACT

The aim of this paper is to identify and find out the frequency of defect in single stage spur gear box. To perform this work, an experimental set-up is fabricated. The vibration signals are captured from the experiments and the burst in the vibration signal is focused in the analysis. The demodulation technique is used for identification of faults using Matlab Software. A defect of gear named pitting is created on Driver gear and signal is captured of healthy and defected gear. With the help of demodulation technique the defected frequency of the gear is determined.

Keywords : Gears, Fault Diagnostic, Vibration Analysis, Demodulation, Power spectral density.

1. Introduction

A machine in standard condition has a certain vibration signature. Fault development changes that signature in a way that can be related to the fault. This has given rise to the term ‘mechanical signature analysis’. Even in good condition, machines generate vibrations. Many such vibrations are directly linked to periodic events in the machine’s operation, such as rotating shafts, meshing gear teeth, rotating electric fields, and so on [1] . The frequency with which such events repeat often gives a direct indication of the source and thus many powerful diagnostic techniques are based on frequency analysis [5-7]. Due to the rotating nature, the signature of localized faults of the gear teeth, such as deformation, breakage, and fracture, generally represents as periodic transient impulses. The signature is a phenomenon of high frequency (corresponding to meshing frequency or structure resonance frequency) being modulated by a certain fault characteristic frequency (according to the rotating speed of gear shafts). The fault frequency can be identified by demodulating impulsive vibrations and performing spectral analysis. Enveloping technique is a typical demodulation tool, which displays effective results in fault diagnosis [2]. To achieve a good demodulation result, a pre-processing filter should be first required with the proper band as prior information under varying operating conditions.

2. Demodulation Technique.

a. Demodulation principle

Envelope analysis, alias amplitude demodulation, dates back the dawn of radio communication. In AM transmission, the information signal is amplitude modulated onto the carrier, which in turn is transmitted via the antenna. The purpose of the carrier is only to carry the information and facilitate the transmission. The receiver tunes in on the carrier frequency and demodulates the signal to retrieve the information signal. The demodulation is band pass filtering around the carrier frequency followed by detection; that is, the creation of the envelope of the filtered signal, which is now the information signal that originally modulated the carrier [3]. How does this relate to identification of local faults in rotating machinery? As previously mentioned, the local fault is manifested by the harmonics of the impact frequency. The response signal is the harmonics weighted by the transmission path, so the obvious frequency range in which to look for the harmonics is where the harmonics are predominant, which is around the structural resonances where the harmonics are amplified.

b. Narrowband demodulation

In narrowband (NB) demodulation techniques, as the name implies the idea is to select an interesting frequency band for further analysis instead of analyzing the whole frequency-domain. This is performed by plotting the spectrum and selects the frequency band in frequency-domain. Hence, one is performing filtering of the DFT of the signal instead of filtering the signal in time-domain. The faulty gear generates the impulse with low amplitude level every time in meshing. This low-level impulse has an amplitude-modulating effect on the vibration signal which is visible as high amplitude signal burst in time domain. The modulation effect spreads over a wide frequency range because of the short duration of impulse. Envelope analysis is a practical approach for investigation of such signals, where amplitude modulation presents in characteristic frequencies of the system. The envelope detection technique focuses on a narrow band range in the specified frequency band, which is useful for detecting the low-level impulses that are below the noise level in the normal spectrum [4]. Low pass filtering and FFT based Hilbert transform are the most commonly known methods for envelope detection. However, the FFT based Hilbert transform has advantage for its high speed and so, suitable for real time envelope detection.

3. Experimentation

In the present work, the experiments are conducted on a gear mesh assembly fabricated for the purpose as shown in Fig. 3.1. The gearbox used in the setup is an automotive gearbox of Maruti 800 car. The driver gear is having 35 teeth, mounted on driver shaft coupled with a single phase 50 Hz DC motor (make: Crompton_, power rating 0.5 HP). The driver shaft is supported on two ball bearings 6303z. The gear on the driven shaft is having 32 teeth and also supported between two ball bearings 6204z. Other end of the driven shaft has provisions to apply load. A Piezoelectric type accelerometer is mounted on the case closer to matting gears. The vibration signal is captured with the help of a PC using Matlab software. The operating frequency was set at 1800 RPM (30 Hz) and verified with an optical tachometer.

ISSN - 2250-1991

Figure 3.1 Experimental test -rig.

The experiment is carried out in two phases without loading. In the first phase, the healthy gears are mounted and the corresponding vibration signal is captured. A sample data of one second duration and its power spectral density (PSD) spectrum are shown in Fig. 4.1 and 4.2, respectively. In the second phase, the driven gear was replaced with a gear with Pitting defect. As can be seen from Fig. 3.2, the defects have been introduced on the first, second and third tooth. As earlier, the vibration signal is captured and a sample data of one second duration along with its PSD spectrum are shown in Fig. 4.3 &

Figure 3.2 Pitting Defects in Gear

4. Results & Discussion

The Figure 4.1 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.

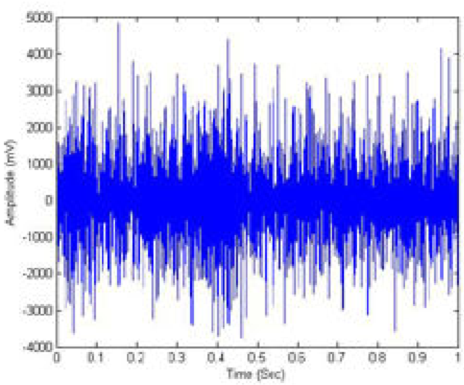

Figure 4.1 Vibration signal in time domain of Healthy gear

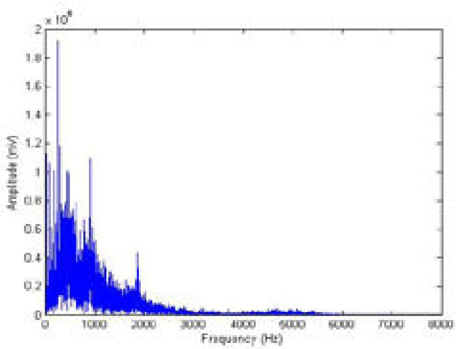

Figure 4.2 Vibration signal in frequency domain of Healthy gear

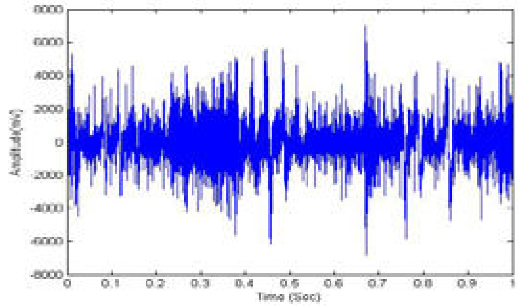

Figure 4.3 Vibration signal in time domain of faulty gear (Pitting defect)

As the Fault is introduced in driven gear, the vibration signals are changed as shown in fig.4.4. It is clear from the figure 4.4 that the amplitude is higher at the frequency nearly 5000 Hz.

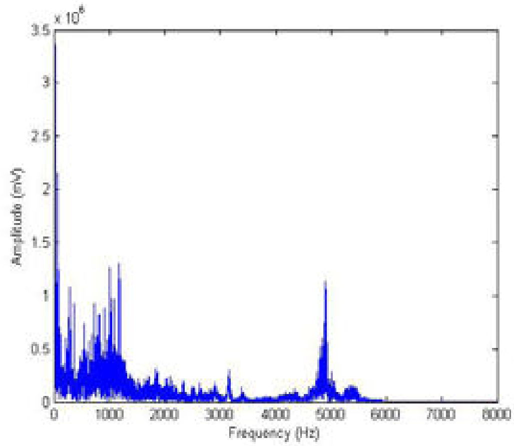

Figure 4.4 Vibration signal in frequency domain of faulty gear

From the spectrum in fig. 4.4, one can observe that the vibration bursts due to the defect in the gear tooth generates 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.

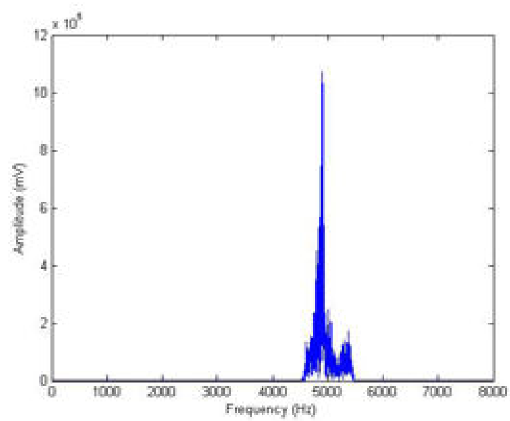

Figure 4.5 shows the filtered frequency plot.

Figure 4.5 Filtered signal in frequency domain of faulty gear

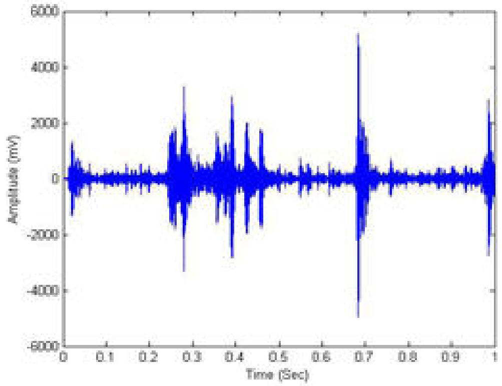

Figure 4.6 Filtered signal in time domain of faulty gear

After filtering the signal, the frequency component is converted into time component through Inverse Fast Fourier Transform (IFFT). This is shown in Figure 4.6.

Now the envelope of this filtered time signal is created. The envelope of filtered signal as shown in

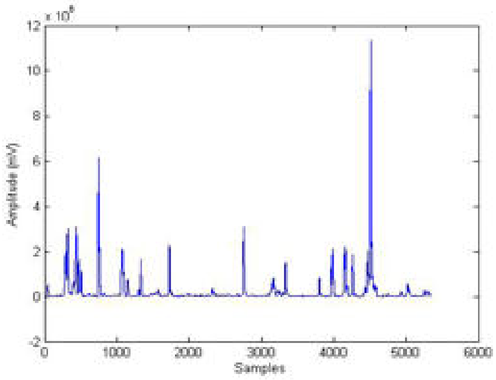

Figure 4.7 Enveloping of the filtered signal

After enveloping, Fast Fourier Transform of signal has been done i.e. the time domain signal is converted into frequency domain.

It is clear from figure 4.8, that the second harmonic of the defective fault occurs at 27Hz frequency, therefore the frequency of the defect is 13.5 Hz.

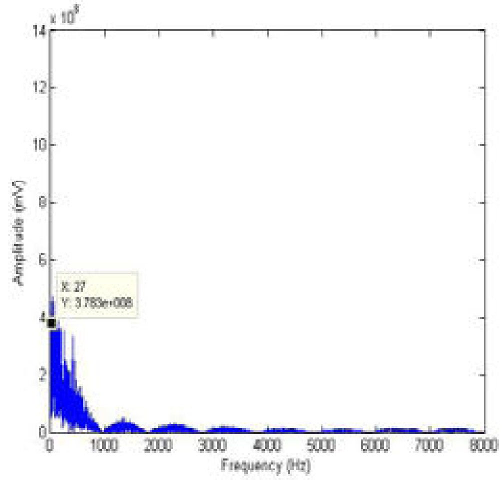

Figure 4.8 Spectrum of defect

Results and Conclusions

The frequency of the pitting defect was found to be 13.5 Hz. In this paper, the experimental analysis presented here re-establishes the fact that demodulation is the most suitable fault diagnostic technique to identify the defect in gears.

Acknowledgement

The work is supported by the Mechanical Engineering Department, Institute of Engineering and Technology Devi Ahilya University, Indore. Kind help from Assistant Professor Vijay Karma is acknowledged.

REFERENCES

[1] Robert Bond Randall. Vibration-based condition monitoring: industrial, aerospace, and automotive applications. Wiley, Chichester, West Sussex, U.K., 2011. | [2] D. N. Brown, "Envelope analysis detects bearing faults before major damage occurs," Pulp and Paper, vol. 63, pp. 113-117, 1989. | [3] Hans Konstantin-Hansen and Henrik Herlufsen,"Envelope and Cepstrum analyses for Machinery fault identification", Sound & Vibration/May 2010, Bruel and kjaer, Naerum, Denmark. | [4] Ruqiang Yan, Robert X. Gao, Multi-scale enveloping spectrogram for vibration analysis in bearing defect diagnosis, Tribology International 42 (2009) 293–302. | [5] Amit Aherwar & Md. Saifullah Khalid, "Vibration analysis techniques for gearbox diagnostics: A Review", International Journal of Advanced Engineering Technology, IJAET/Vol.III/ Issue II/April-June, 2012/04-12. | [6] Lebold, M.; McClintic, K.; Campbell, R.; Byington, C.; Maynard, K., "Review of Vibration Analysis Methods for Gearbox Diagnostics and Prognostics", Proceedings of the 54th Meeting of the Society for Machinery Failure Prevention Technology, Virginia Beach, VA, May 1-4, 2000, p. 623-634. | [7] Hongyu Yang, Joseph Mathew and Lin Ma, "Vibration Feature Extraction Techniques for Fault Diagnosis of Rotating Machinery-A Literature Survey", School of Mechanical Manufacturing and Medical Engineering, QUT, Brisbane, QLD 4001, Australia. | [8] Weni Wang "Early detection of gear tooth cracking using the resonance demodulation technique". Journal of Mechanical Systems and Signal Processing (2001) 15(5), 887-903. | [9] James I. Taylor. The Vibration Analysis Handbook. | [10] Sanjay Sharma, Signal and Systems (with Matlab Programs), Katson Books, fifth edition 2005. | [11] Digital Signal Processing Using MATLAB for Students and Researchers, First Edition. John W. Leis. © 2011 John Wiley & Sons, Inc. Published 2011 by John Wiley & Sons, Inc |