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Analysis of Spur Gear Faults using Frequency Domain Technique

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Abstract

In power transmission systems such as lathe machine, automobile gearbox, and watch etc, gears are used to transmit motion without slipping (Definite motion). Any variation arising due to falults/defects in gears results in loss of power. Gear defect or faults in power transmission system can be found out by processing of their vibration signals. This paper deals with the analysis of the spur gear defect. A two stage spur gearbox is used as an experimental set up and the vibration signals are recorded with the help of accelerometer from gearbox at healthy as well as faulty condition. Vibration signals are processed using MATLAB software and tooth breakage defect is considered as a gear fault. In this paper, recorded vibration signals, which are in time domain, are converted into frequency domain by using fast fourier transform (FFT). Compairision of these frequency spectrum at healthy and faulty condition of gearbox reflects the symptoms of tooth breakage defect on frequency spectrum.

Keywords: Spur Gear, Fault Diagnosis, Vibration signature, MATLAB, Fast Fourier Transform

Introduction

The elements in various mechanical power transmission systems have a specific pattern of vibration that depends on the construction and condition of the machine. Any variation in vibration pattern indicates the initiation of fault in machine. The main purpose of vibration analysis is to identify condition of gearbox, to distinguish the good and faulty gear and to identify the defective component [1]. Variation in transmitted force is one of the most important mechanism responsible for the vibration. [2]. Various vibration analysis tchniques are Time Domain Techniques, Frequency Domain Technique, Time Frequency Analysis and Envelope Analysis [3]. The frequency domain methods include Fast Fourier Transform (FFT), Hilbert Transform Method and Power Cepstrum Analysis, etc [1]. Vibration analysis of mechanical system can be based on an on-line computer monitoring system. The type of analysis to be applied depends on the type of fault/defect, and therefore it is an important crieteria to investigate the cause of faults in the vibration signal.[4]. In these paper the authors have anaylised the effect of tooth breakage on the vibration signal with the help of MATLAB software. The signals are taken from experimental setup consisting of two stage spur gear system (fig. 2.0). The vibration signals are analysed using fast fourier transform (FFT), a frequency domain technique. The technique is described in below sections.

Frequency domain technique

The vibration signals, recorded from mechanical power transmission system with the help of an accelerometer, are in time domain. But it is hard to detect clear symptoms of any defect in the gear from only the time domain, especially if the defect is at an early stage [5**]**. Frequency domain is the most popular approach for the diagnosis of gear faults. Frequency domain techniques convert time-domain vibration signals into discrete frequency components using a fast fourier transform (FFT). The fast fourier transform of time domain signal into frequency domain is shown in fig. 1.0. This is a method of taking a real world, time varying signal and splitting it into components, each with an amplitude, a phase and a frequency [6]. Frequency domain does not carry any information that is not in the time domain. The frequency domain is simply another way of looking at signal information. The main advantage of frequency-domain analysis over time-domain analysis is that the repetitive nature of the vibration signals is clearly displaced as peaks in the frequency spectrum and it has ability to easily detect the certain frequency components of interest [3].

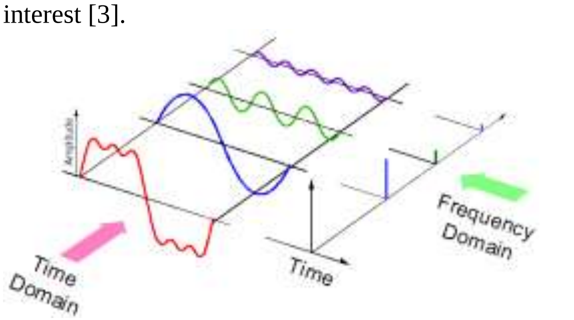

Fig.1.0 Fourier transformation of time domain signal to frequency domain[7]

Fast fourier transform (FFT)

The Fast Fourier Transform (FFT) is a class of special algorithms which implement the discrete Fourier transform with considerable savings in computational time. the FFT is not a different transform from the DFT, but rather just a means of computing the DFT with a considerable reduction in the number of calculations required[1].
The discrete Fourier Transform is defined as

$$\mathrm{x(k)} = \sum_{n=0}^{n-1} \mathrm{x(n)} e^{-j2\pi nk/N}$$

Here:
X : the frequency domain representation of time series signal ‘x’.
K : the ‘k’ frequency component ; k = 0, 1, 2,…. N-1.
N : the total number of samples in signal ‘x’.
x : the time series signal.
n : the n’th sample (in the time domain).
J : the imaginary unit [8].

Experimental Set- Up

The experimental set up is shown in fig. 2.0. It consists of a motor, compound (two stage reduction) gear box. The input shaft of gearbox is connected to 0.5 HP, 1500 rpm electric motor through Oldham’s coupling. All drive shafts are supported at its ends with antifriction bearings. A dimmer is used to vary the speed of electric motor and speed of motor or input shaft is measured with the help of tachometer. The vibration data is collected from the drive end bearing of gear box using the accelerometer. The collected vibration data are processed in MATLAB software for signal processing.
The vibration signals from a healthy gear are collected at a shaft speed of 400, 500 and 600 rpm. Tooth breakage Fault is induced in an intermediate shaft gear and the vibration readings are taken.

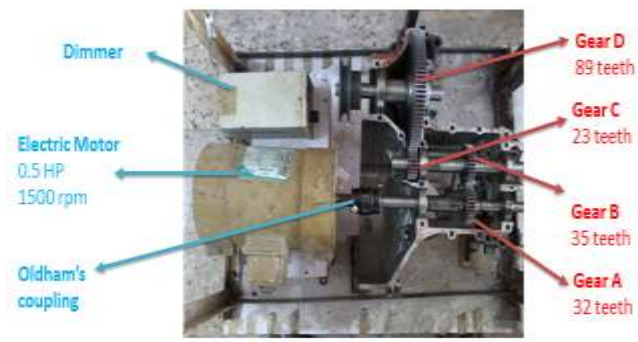

Fig. 2.0 Experimental set- up

Tooth Breakage Defect

When two gears meshes with each other to transmit a load, the teeth of each gear are under bending action due to periodic effect of the load, fatigue crack may occur near the tooth base resulting in ultimate failure of the tooth[9]. Tooth breakage fault is shown in Fig. 3.0

Fig. 3.0 Tooth breakage fault

Observations

Vibration signals at speed 400 rpm

The time domain vibration signals for both perfect working condition and Breakage fault condition at 400 rpm speed without loading are taken and shown in figure 4.0 and figure 5.0 respectively.

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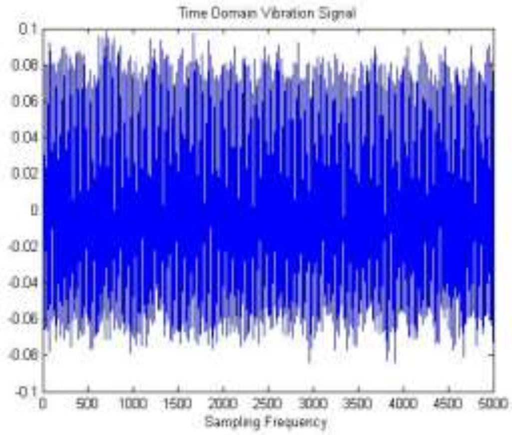

Fig. 4.0 Time Domain Vibration signal of Healthy Gearbox

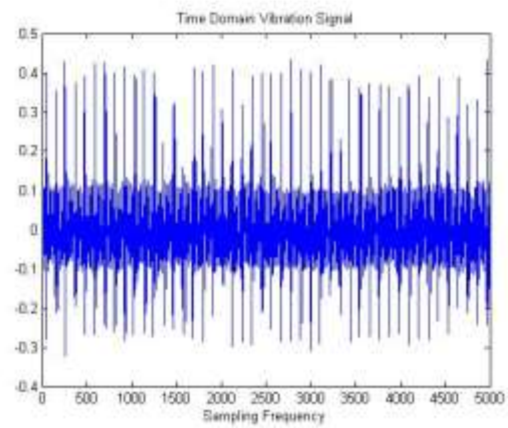

Fig. 5.0 Time Domain Vibration Signal of Faulty Gearbox with breakage fault

The time domain vibration signals of both healthy gear and gear with breakage fault are converted into frequency domain with the help of FFT. Which is shown in figure 6.0 and figure 7.0 respectively.

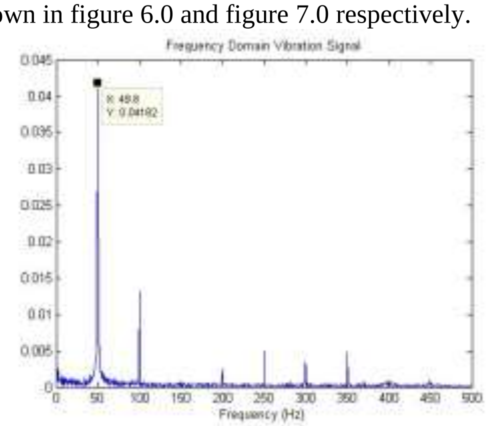

Fig. 6.0 Frequency Domain Vibration Signal of Healthy Gearbox

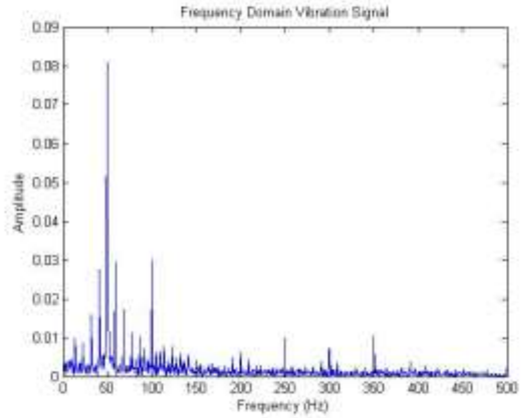

Fig.7.0 Frequency Domain Vibration Signal of Gearbox with Breakage Fault

Vibration signals at speed 500 rpm

The time domain vibration signals for both perfect working condition and Breakage fault condition at 500 rpm speed without loading are shown in figure 8.0 and figure 9.0 respectively.

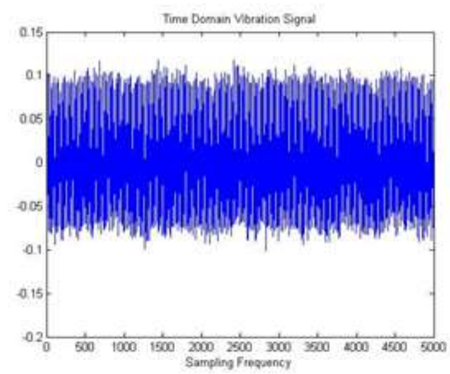

Fig. 8.0 Time Domain Vibration signal of Healthy Gearbox

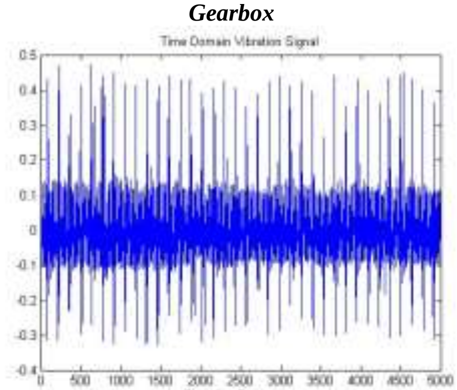

Fig. 9.0 Time Domain Vibration Signal of Gearbox With Breakage Fault

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The time domain vibration signals of both healthy gear and gear with breakage fault are converted into frequency domain with the help of FFT. Which is shown in figure 10.0 and figure 11.0 respectively

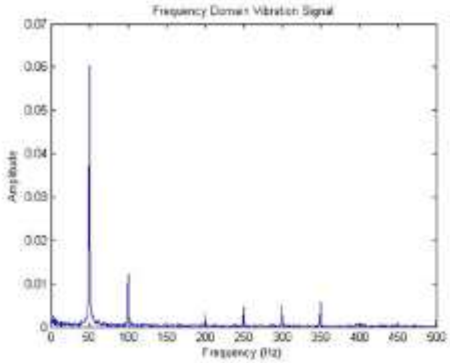

Fig.10.0 Frequency Domain Vibration Signal of Healthy Gearbox

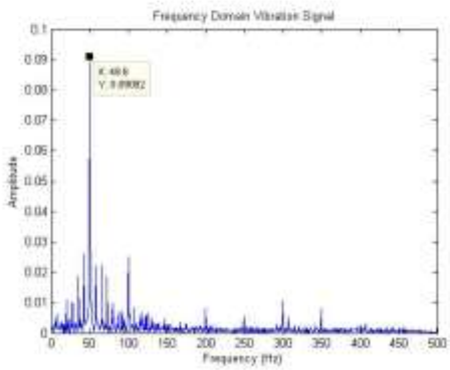

Fig. 11.0 Frequency Domain Vibration Signal of Gearbox with Breakage Fault

Vibration signals at speed 600 rpm

The time domain vibration signals for both perfect working condition and Breakage fault condition at 600 rpm speed without loading are shown in figure 12.0 and figure 13.0 respectively.

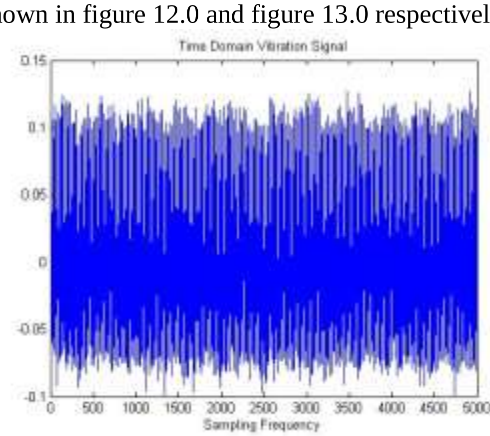

Fig.12.0 Time Domain Vibration signal of Healthy Gearbox

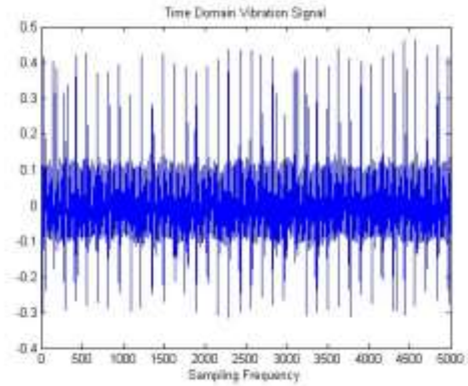

Fig. 13.0 Time Domain Vibration Signal of Gearbox With Breakage Fault

The time domain vibration signals of both healthy gear and gear with breakage fault are converted into frequency domain with the help of FFT. Which is shown in figure 14.0 and figure 15.0 respectively

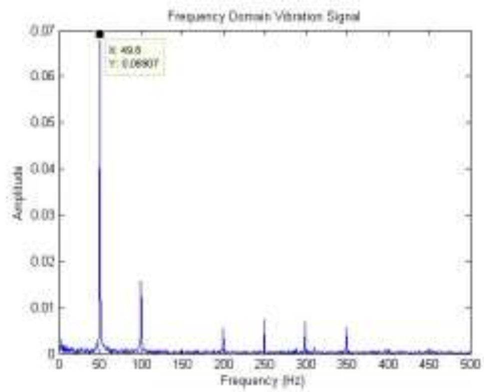

Fig. 14.0 Frequency Domain Vibration Signal of Healthy Gearbox

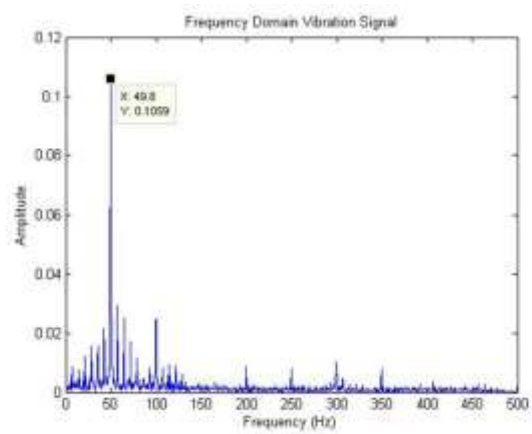

Fig.15.0 Frequency Domain Vibration Signal of Gearbox with Breakage Fault

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Table 1.0 Spectrum Amplitudes of Healthy Gearbox vs Gearbox with Tooth Breakage Fault

Speed	*Condition*	*1X*	*2X*	*3X*	*4X*
400 RPM	Healthy	0.042	0.013	0.002	0.005
	Faulty	0.080	0.029	0.005	0.008
500 RPM	Healthy	0.060	0.012	0.003	0.004
	Faulty	0.091	0.025	0.008	0.005
600 RPM	Healthy	0.069	0.015	0.005	0.007
	Faulty	0.100	0.024	0.009	0.008

Result, Discussion and Conclusions

From FFT spectrum of healthy gear and gear with Breakage fault, it is observed that the effect of gear tooth breakage appears in frequency domain vibration signal as Sidebands of fundamental frequency. Also from Table 1.0, it can be seen that the amplitudes of harmonics in case of gearbox with breakage fault are more than the amplitude of harmonics of healthy gearbox. The presence of tooth breakage fault in any gearbox gives rise to peaks and generates sidebands. From FFT technique it can be predicted that the gear box has some fault but the severity cannot be determined.

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