Study of Improper Chamfering and Pitting Defects of Spur Gear Faults Using Frequency Domain Technique

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***Abstract-* Spur Gears are the most widely used power transmission elements in various industries and other major industries. It is necessary to have the gears in good conditions so that the machinery runs in good conditions i.e. the gears should be free from any defects. The fault detections becomes an important tools to diagnose the faults. There are various techniques which are used for this purpose. Vibrations analysis, Acoustic Signal analysis, Wear debris analysis etc. are the methods employed to know the health of the gears. In this paper a study is done to analyse the gear faults using frequency domain technique of vibration signals obtained from spur gear in a two stage spur gear box setup.**

Keywords: Spur Gear, Vibration Analysis, Acoustic Signal Analysis, Wear Debris Analysis

1. INTRODUCTION

Gears are commonly used to transmit rotational motion between machinery shafts. When gears of different types and sizes are combined, they can change the rate of rotation, the direction of the axis of rotation, and change rotary motion to linear motion. Spur Gears are the most widely used power transmission elements in various industries and other major industries. It is necessary to have the gears in good conditions so that the machinery runs in good conditions i.e. the gears should be free from any defects. The fault detections becomes an important tools to diagnose the faults. There are various techniques which are used for the purpose of detection and diagnosis of faults. Vibrations analysis, Acoustic Signal analysis, Wear debris analysis etc. are the methods employed to know the health of the gears [1]. In this paper a study is done to analyse the gear faults using frequency domain technique of vibration signals obtained from spur gear in a two stage spur gear box setup. First the healthy gear in mounted on the input shaft and vibration signals are captured at various speeds in time domain and then this time domain signals are converted into frequency domain signals using MATLAB software. After converting the amplitude of the signals are obtained. After this process the healthy gear is removed from the input shaft and a gear with fault is mounted on the shaft. Vibration signals are then captured at varied speed and then this signals are converted into frequency domain signals and amplitudes are obtained and are compared with the healthy gear amplitudes. This process is repeated for all type of faults. The faults considered for the work are improper chamfering, pitting and tooth breakage. Figure 1 shows the experimental setup used for the study.

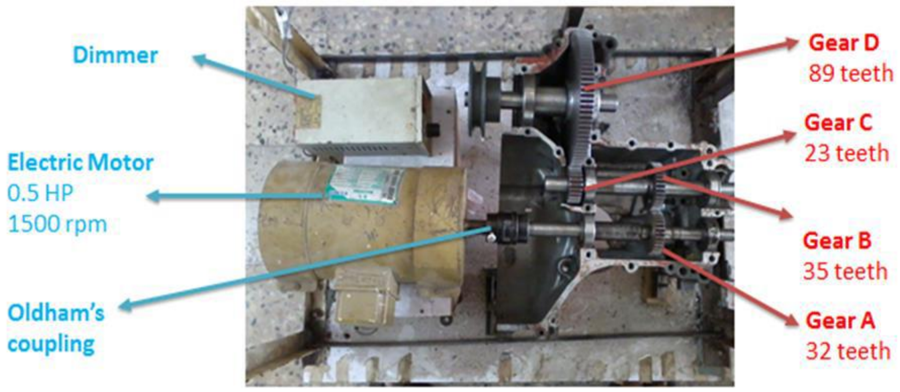


Figure 1: Experimental Setup

2. LITERATURE REVIEW

Amit et al [2] presented a review of vibration analysis techniques for gearbox diagnostics. Widely used techniques for gearbox diagnostics are Time Domain Analysis (Time Waveform Analysis, Peak, RMS, Crest Factor, Kurtosis, etc.) Frequency Domain Analysis (Fast Fourier Transformation, Spectral Analysis, Demodulation, Hilbert Transform, Cepstrum Analysis etc.). Shawki et al [3] presented the use of vibration analysis in the detection, quantification, and advancement monitoring of fault incurred by wind turbine gearbox components. VimalSaxena et al [4] concluded with a brief discussion on current practices of PDM methodologies such as vibration analysis and Acoustic Emission analysis. Randall [5] discussed the different requirements for detecting and diagnosing faults. Patidar et al [6] summarized the recent research and developments in the vibration analysis techniques for diagnosis of rolling element bearing faults. They concluded that the time domain techniques only can indicate the fault(s) present in the bearing but it can't identify the location. Kobra et al [7] investigated the correlation between vibration analysis and fault diagnosis of tractor gearbox. They used the conventional techniques for fault signals diagnosis including power spectra in time domain or frequency domain. Praneeth et al [8] presented an application of Laplace wavelet kurtosis for processing vibration signal to detect faults in gears. Noureddine et al [9] shows that the fault diagnosis of a system can be performed by observing the evolution of the power spectrum of the vibration signal. M. Khazaee et al [10] presented an advanced non-parametric approach for signal processing such as wavelets, Fast Fourier Transform (FFT) and short time Fourier transform (STFT). Jiri Tuma [11] discussed the assessment of noise and vibration sources, measurement methods, and diagnostics. Hongyuet al [12] explained various vibration feature extraction techniques for fault diagnosis of rotating machinery in time domain, frequency domain and time-frequency domain. Ahmad et al [13] used two newest fault detection methods, the resonance demodulation technique (R.D) and the instantaneous power spectrum technique (IPS) for gear box fault diagnostic. Gao Hongbinet al [14] proposed a method of enveloping that provides the theoretical basis for preventing and monitoring turbine's faults. Tsaoet al [15] used a new method to overcome the traditional envelope method for the selection of the resonant frequency band. The proposed method combined the empirical mode decomposition (EMD) and the envelope analysis to detect the fault of the rolling bearing.

3. DIAGNOSIS OF FAULTS

The following faults are considered for the experimental work to record the vibration signals.

Improper Chamfering (defect1) - This defect is introduced by chamfering the teeth on both the sides of the gear on the lathe machine. Figure 2 shows this defect.

Pitting (defect2) - This defect is introduced by drilling in the gaps between the teeth. Figure 3 shows this defect.

First the healthy gear in mounted on the input shaft and vibration signals are captured at various speeds in time domain and then this time domain signals are converted into frequency domain signals using MATLAB software. After converting the amplitude of the signals are obtained. After this process the healthy gear is removed from the input shaft and a gear with fault is mounted on the shaft. Vibration signals are then captured at varied speed and then this signals are converted into frequency domain signals and amplitudes are obtained and are compared with the healthy gear amplitudes. This process is repeated for all type of faults. A DC Motor, which is connected to the gearbox, is run at various speed i.e. 400, 500, and 600 rpm to rotate the input shaft. A dimmer is used for controlling the speed of the motor. The experimental set up has three shaft, driving gear mounted on input shaft has 32 teeth, two gears mounted on intermediate shaft have 35 teeth and 23 teeth, and driven gear mounted on third shaft has 89 teeth. Optical Tachometer is used to measure the speed of shaft. The vibration signal from the experimental setup is collected by accelerometer placed near the bearing. The sampling rate is 1000 Hz. The data is collected for time span of five second. For vibration data collection, an approximate method is introduced in which data from the piezoelectric transducer is captured through microphone port of PC, and analyzed with the help of software utility MATLAB

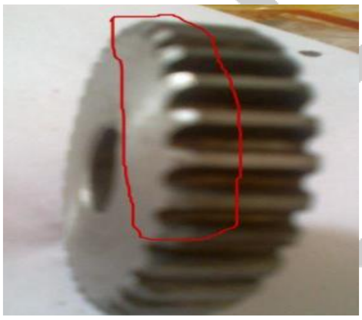


Figure 2: Improper Chamfer Defect

Figure 3: Pitting Defect

3.1 ANALYSIS OF IMPROPER CHAMFERING DEFECT (DEFECT1)

The time domain vibration signals for both perfect working condition and chamfering fault condition at 400, 500 and 600 rpm speed without loading are taken and shown in figures from 4 to 9.

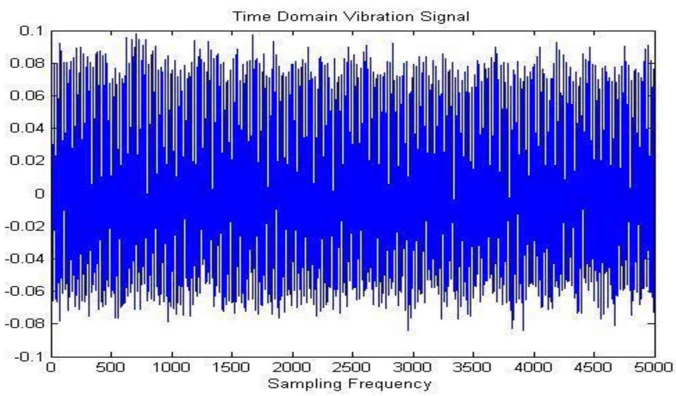


Figure 4: Signal of Healthy Gear at 400 rpm

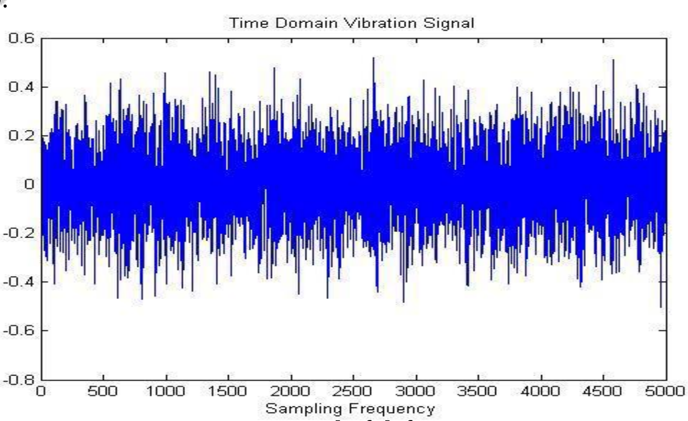


Figure 7: Signal of defect1 Gear at 400 rpm

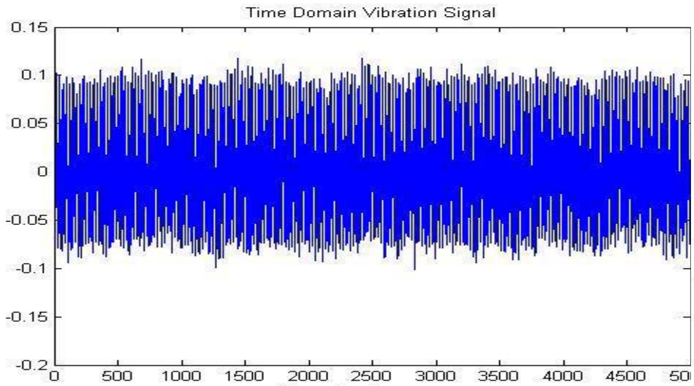


Figure 5: Signal of Healthy Gear at 500 rpm

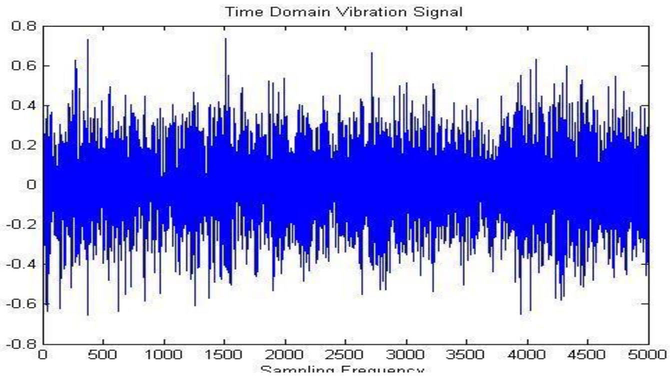


Figure 8: Signal of defect1 Gear at 500 rpm

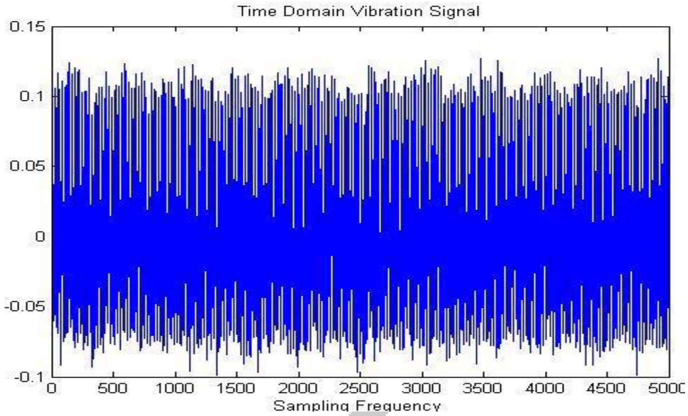


Figure 6: Signal of Healthy Gear at 600 rpm

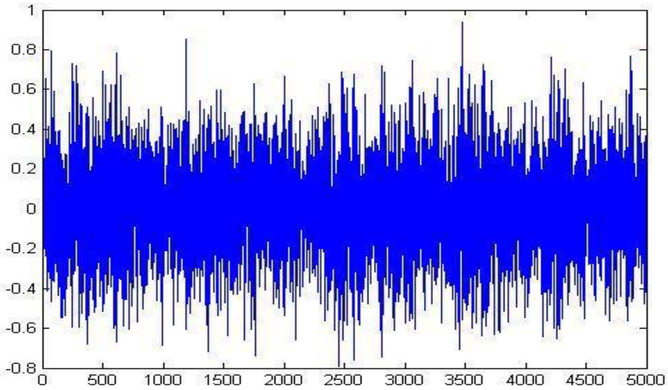


Figure 9: Signal of defect1 Gear at 600 rpm

The time domain vibration signals of both healthy gear and gear with chamfering fault are converted into frequency domain with the help of FFT. Figure 10 to 15 shows the frequency domain signals of healthy and faulted (improper chamfering) gear. Table 1 represent the vibration amplitude of healthy and defect1 gear at 400, 500 and 600 rpm.

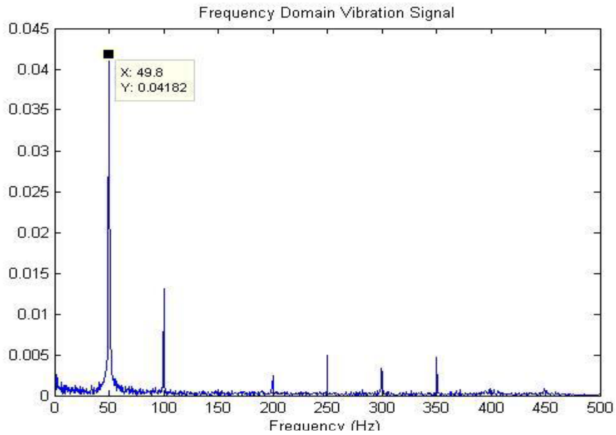


Figure 10: Signal of Healthy Gear at 400 rpm

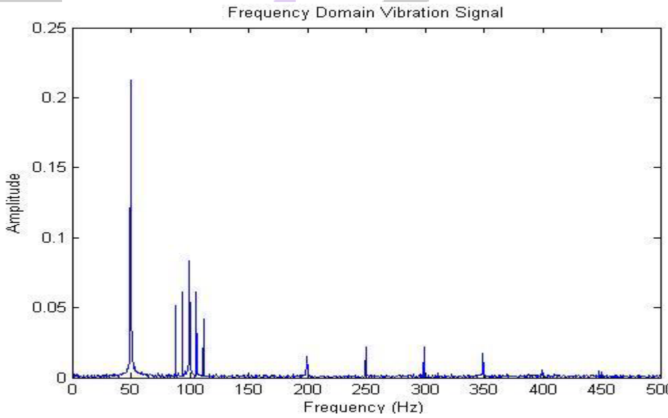


Figure 13: Signal of defect1 Gear at 400 rpm

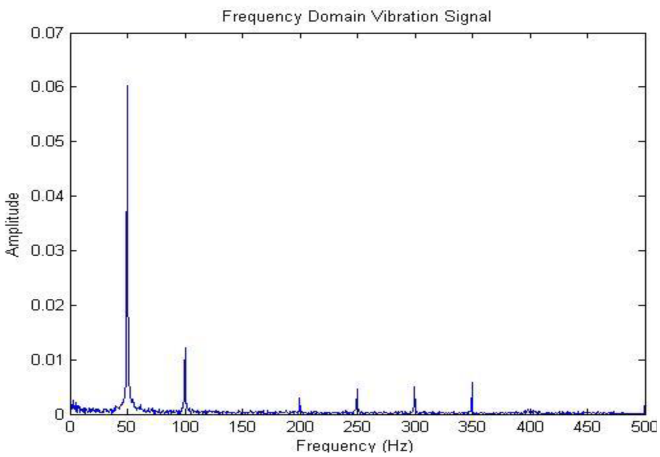


Figure 11: Signal of Healthy Gear at 500 rpm

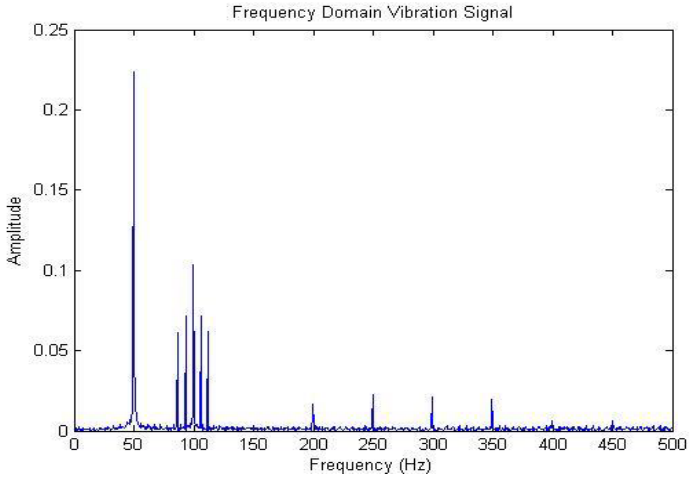


Figure 14: Signal of defect1 Gear at 500 rpm

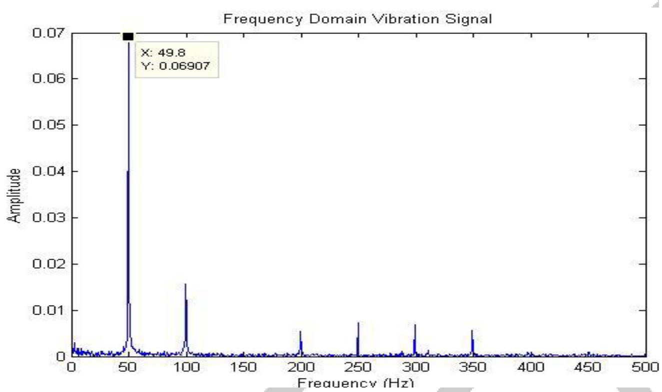


Figure 12: Signal of Healthy Gear at 600 rpm

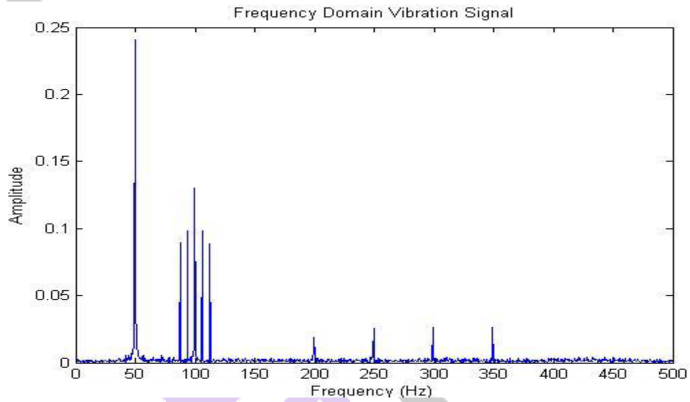


Figure 15: Signal of defect1 Gear at 600 rpm

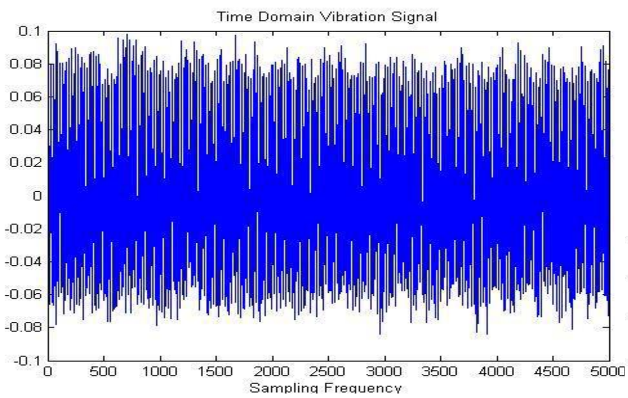
Table 1:Vibration Amplitude of Healthy Gear vs Improper Chamfering Gear at Varied Speed

SPEED	CONDITION	1X	2X	3X	4X	5X	6X
400 RPM	Healthy	0.04182	0.01305	0.002479	0.00498	0.003375	0.004642
	Faulty	0.2122	0.08353	0.01506	0.02185	0.02185	0.01724
500 RPM	Healthy	0.06023	0.01211	0.003001	0.003001	0.00498	0.005898
	Faulty	0.2237	0.1033	0.0167	0.02297	0.02102	0.01978
600 RPM	Healthy	0.06907	0.01569	0.005524	0.007302	0.006798	0.005662
	Faulty	0.2324	0.1208	0.01291	0.1962	0.02349	0.2363

From FFT spectrum of healthy gear and gear with Chamfering fault, it is clearly observe that the effect of chamfering fault appears in frequency domain vibration signal as Sidebands of 2nd harmonics and that the amplitudes of harmonics in case of gear with chamfering fault are more than the amplitude of harmonics of healthy gearbox.

3.2 ANALYSIS OF PITTING DEFECT (DEFECT2)

The time domain vibration signals for both healthy and pitting fault condition at 400, 500 and 600 rpm speed without loading are taken and shown in figure 16 to 21 respectively.



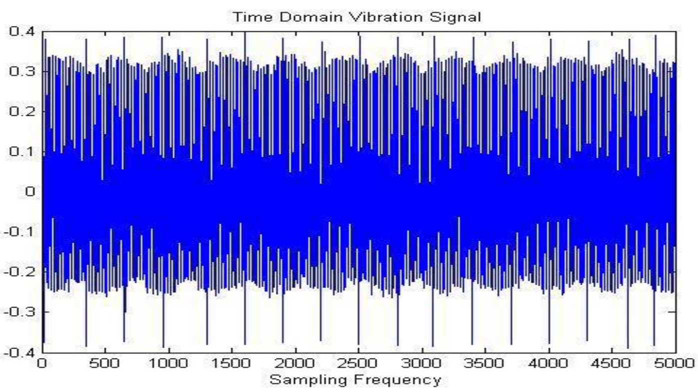
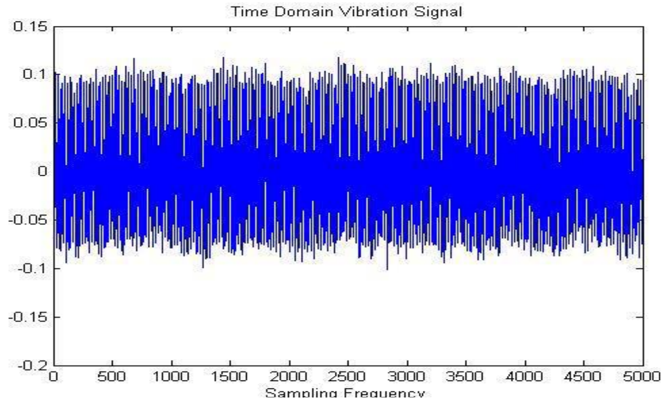


Figure 16: Signal of Healthy Gear at 400 rpm

Figure 19: Signal of defect2 Gear at 400 rpm



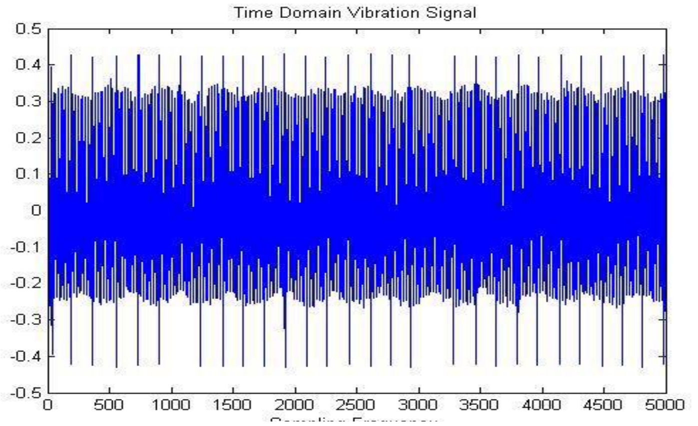
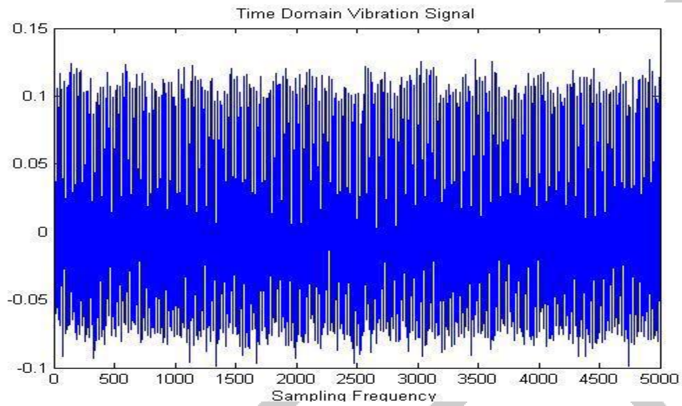


Figure 17: Signal of Healthy Gear at 500 rpm

Figure 20: Signal of defect2 Gear at 500 rpm



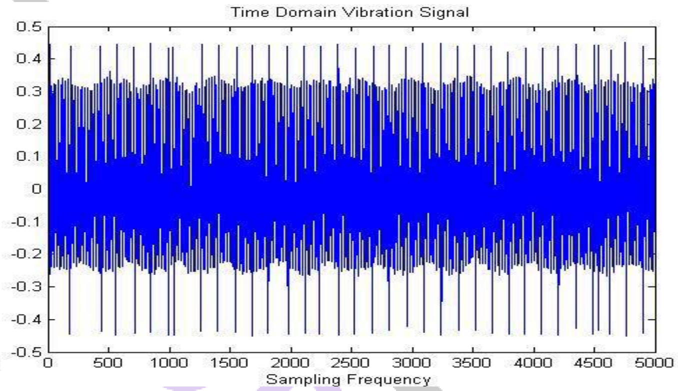
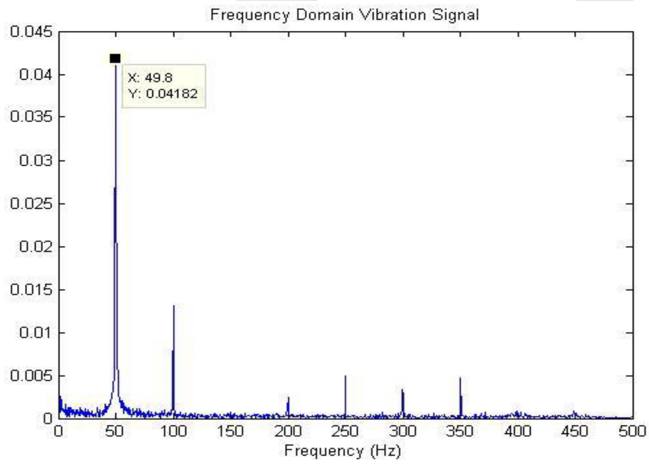


Figure 18: Signal of Healthy Gear at 600 rpm

Figure 21: Signal of defect2 Gear at 600 rpm

The time domain vibration signals of both healthy gear and gear with pitting fault are converted into frequency domain with the help of FFT. Figure 22 to 27 shows the frequency domain signals of healthy and faulted (pitting) gear. Table 2 represent the vibration amplitude of healthy and defect2 gear at 400, 500 and 600 rpm.



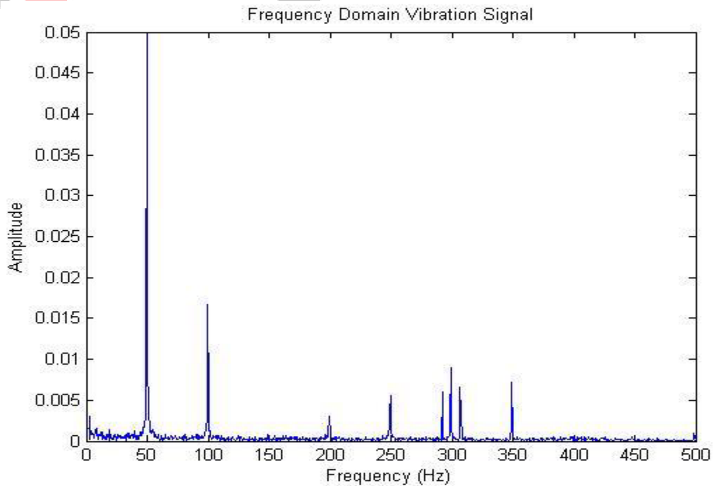


Figure 22: Signal of Healthy Gear at 400 rpm

Figure 25: Signal of defect2 Gear at 400 rpm

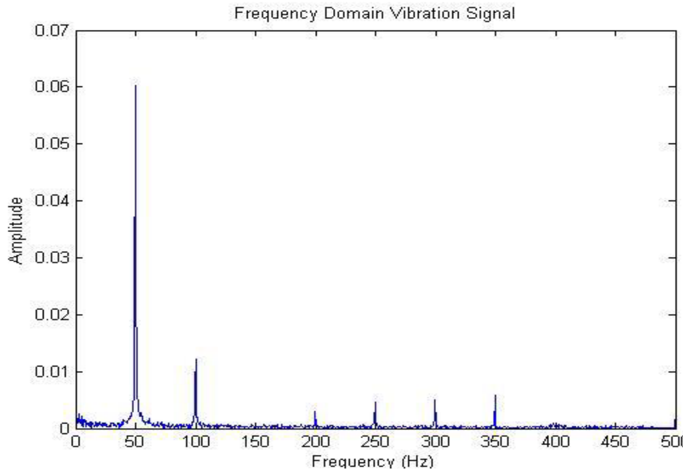


Figure 23: Signal of Healthy Gear at 500 rpm

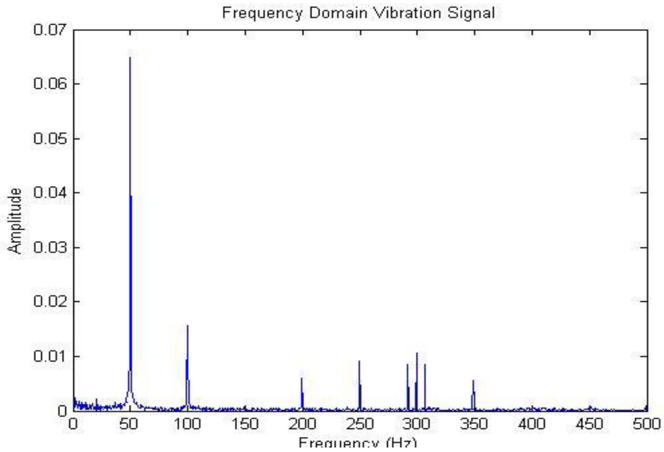


Figure 26: Signal of defect2 Gear at 500 rpm

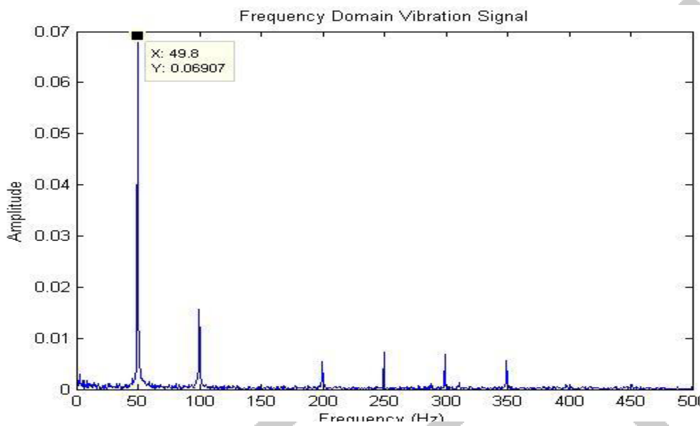


Figure 24: Signal of Healthy Gear at 600 rpm

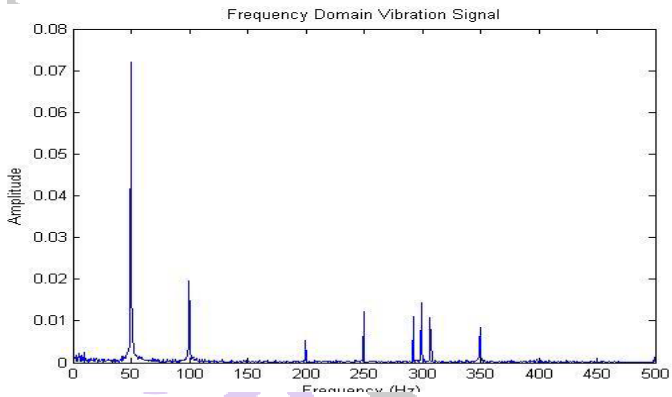


Figure 27: Signal of defect2 Gear at 600 rpm

Table 1:Vibration Amplitude of Healthy Gear vs pitting defect Gear at Varied Speed

SPEED	CONDITION	1X	2X	3X	4X	5X	6X
400 RPM	Healthy	0.04182	0.01305	0.002479	0.00498	0.003375	0.004642
	Faulty	0.04991	0.01668	0.003091	0.005635	0.008964	0.007137
500 RPM	Healthy	0.06023	0.01211	0.003001	0.003001	0.00498	0.005898
	Faulty	0.06485	0.01560	0.006009	0.009059	0.01053	0.005592
600 RPM	Healthy	0.06907	0.01569	0.005524	0.007302	0.006798	0.005662
	Faulty	0.07216	0.01968	0.005361	0.001222	0.01448	0.008374

From the FFT spectrum of healthy gear and gear with Pitting fault, it can clearly be observe that the effect of pitting fault appears in frequency domain vibration signal as Sidebands of 5th harmonics and from Table 2, it can be seen that the amplitudes of harmonics in case of gear with pitting fault are more than the amplitude of harmonics of healthy gear.

4. CONCLUSIONS

Fast Fourier Transformation is a very versatile technique to determine the frequency contents of a signal. From these frequency content the faults can be predicted. The presence of tooth faults such as improper chamfering and pitting in any gear gives rise to peaks and generates sidebands. Thus by using FFT technique it can be predicted that the gear has some fault but the severity cannot be determined.

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