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COMPARATIVE ANALYSIS OF HEALTHY AND CRACKED SPUR GEAR USING VIBRATION SIGNAL IN SINGLE STAGE GEAR BOX

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ABSTRACT
In gearbox, load fluctuations on the gearbox and gear defects are two major problem of vibration. This paper deals with the analysis of a healthy gear and faulty spur gearbox having crack defect on multiple teeth at different angle on driving gear using frequency domain technique through MATLAB software. The vibration signals are captured from the experiments and the burst in the vibration signal is focused in the analysis and the frequency of the faulty gear is found out. The analyses are done on gear under varying speeds at different loading conditions.

KEYWORDS: vibration signal processing, tooth crack, time domain signal, frequency domain signal.

INTRODUCTION
Spur gear is most commonly used in modern mechanical engineering applications to transmit the power between two shafts. Gear failure generally occurs due to excessive applied load, improper lubrication, manufacturing error and installation problem. When gear has a fault the gear box produced a vibration signal, this vibration signal contain amplitude and phase modulation that are periodic form [1]. The vibration analysis has become highly important in fault gearing in gearing systems. The role of the vibration monitoring to detect the fault in gearing system and gives an early warning and indicate that the schedule shutdown to prevent the system failure[3]. In this paper the author has studied the vibration signal during the running condition of gear box by using time domain signal and frequency domain signal and detects the fault in the spur gear in single stage gear box.

TIME FREQUENCY TECHNIQUE
Time Frequency analysis is the technique in which both frequency and time domains are studied to represent a signal processing. Instead of the conventional method of studying a 1-dimensional analysis and some transform, time frequency analysis studies a 2-dimensional signal whose function is a 2-dimensional real plane. The most basic form of time–frequency analysis is the short-time Fourier transform (STFT), but more sophisticated techniques have been developed, notably wavelets. The Short Time Fourier Transform of a signal *x(t)* using a window function *g(t)* is defined as follows[2]

$$STFT(f,s)=\int_{-\infty}^{\infty}x(t)g(t-s)e^{-j2\pi ft}dt$$

FREQUENCY DOMAIN TECHNIQUE
Frequency domain is the domain for analysis of mathematical functions or signals with respect to frequency, rather than time. To analyze the frequency distribution of vibration waveforms it is necessary to transform the time domain signal into frequency domain. Fourier transform is used to process the vibration signals obtained from time domain into the frequency domain in the form of Fast Fourier Transform [FFT]. If a discrete time signal x (t) represents a sampled periodic function with period T, the Fourier series expansion of x (t) can be obtained from the Fourier integral.

$$X(f) = \frac{1}{T}\int_{-T/2}^{T/2} x(t)e^{-i2\pi ft}dt$$

Where, f represents discrete equally spaced frequencies being multiples of the reciprocal of the period T.

LITERATURE SURVEY

Lelia.nacib, komi midzodzi [1] this paper proposes how to detect faults in gearbox of helicopter by registration signals during flight, with spectrum analysis and cepstrum analysis. Analyzed results show that the proposed method is effective to extract modulating signal and help to detect the early gear fault. For helicopter safety, early gear fault detection is important to prevent system break down and accident.

A.A. Mohamed, R. Neilson, P. MacConnell, N. C. Renton and W. Deans [2].This paper describes experimental tests to examine the vibration characteristics in two different types of cracks in a long rotor shaft, a notch cut to varying depths and actual crack growth from a pre-crack. The approach was to set up experimental apparatus, develop a vibration detection system, and maximize the dynamic range. Fatigue crack initiation and propagation in a pre-cracked high carbon steel shaft was experimentally evaluated and monitored using a vibration based condition health monitoring method.

L.S.Dhamande , A.C.Pawar and V.J Suryawanshia [3]. In this research paper the various types of defects can be created on gear tooth such as one corner defect, two corner defect, three corner defect, Missing tooth, inadequate lubrication, wear formation etc. By comparing Signals of defective condition with healthy (ok) condition through FFT analyser in which, analysis is carried out with the signal to trace the sidebands of the high frequencies of vibration. The validation is done successfully by taking input signal from FFT analyser to MATLAB program. It is for calculating effective statistical parameters in defective condition for time & frequency domain analysis. The actual position in angle of rotation for one tooth missing in gearbox is also investigated by using MATLAB program.

Vimal Saxena,Nilendu Kar Chowdhury,S. Devendiran[4] in this paper Fault signals of gearboxes or rolling-element bearings are non-stationary. It was clearly stated that vibration signature analysis and acoustic emission are two very efficient techniques for early fault detection. Vibration signature analysis is used for detect major defects whereas acoustic analysis is used to detect very minute cracks occurring in the gear box. The importance of wavelet transformation has also been mentioned which is now a day‟s widely used for feature extraction as waves associated to the gear boxes are non stationary nature.

EXPERIMENTAL SETUP

The experimental setup used for the data collection is shown in the figure. It consists of motor, input shaft, Oldham coupling, output shaft, bearing and pulley. The input shaft contains a gear of 32 teeth and the output shaft contains a gear having 35 teeth. A dimmer is used for varying the speed of input shaft. The collected data from gear box is processed in matlab software for signal processing. The vibration signal recorded is from gear box at 200 rpm, 400 rpm, 600rpm, 800 rpm and 1000 rpm.

Fig.1.0 experimental setup

METHODOLOGY

1) First crack on gear tooth
2) Second crack 180 degree
3) Third crack 90 degree
4) Fourth crack 270 degree

First we give the crack on root and flank portion of the spur gear tooth and then180 degree,90degree and then 270 degree from first crack having 32 teeth, which is mounted on the input shaft and measures the RPM of input shaft with the help of tachometer. The vibration signal from the setup is collected by piezoelectric transducer placed near bearing, this vibration signal is time domain signal, with the help of dimmer change the speed of the motor and measures 5 different rpm i.e. 200, 400, 600, 800 and 1000 rpm by using the tachometer. Simultaneously different load is also applied i.e. 3kg , 4kg, 5kg and take time domain signal by using the matlab programme and this time domain signal convert into frequency domain vibration signal by using FFT matlab programme.

ANALYSIS OF VIBRATION SIGNAL OF HEALTHY GEAR

The FFT have been recorded for healthy gear condition at different speed and different load which is applied on gear box.

Healthy gear: When gear runs at 200 rpm, 400 rpm, 600 rpm, 800 rpm, and 1000 rpm. And load applied is 3kg.

Time domain vibration signal and frequency domain vibration signal of healthy gear at 3kg load

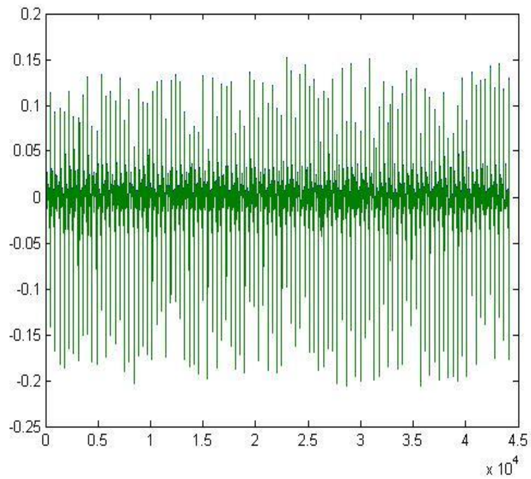

Fig.1.0 Time domain Vibration signal of healthy gear at 200rpm

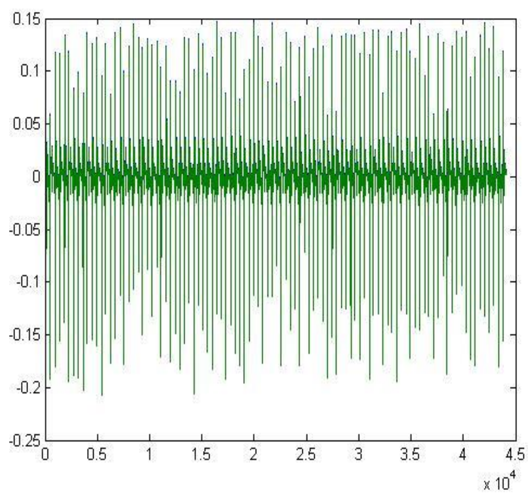

Fig.2.0 Time domain Vibration signal of healthy gear at 400rpm

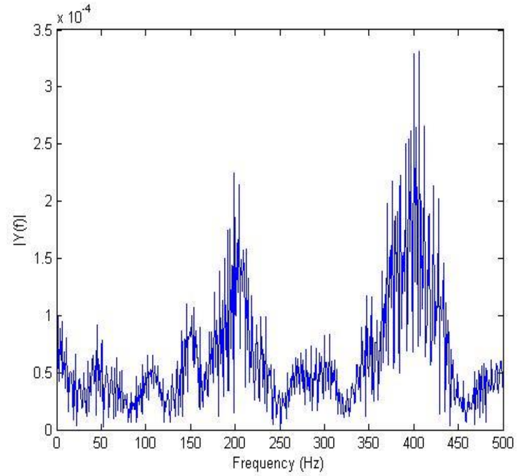

Fig.3.0 Frequency domain Vibration signal of healthy gear at 200rpm

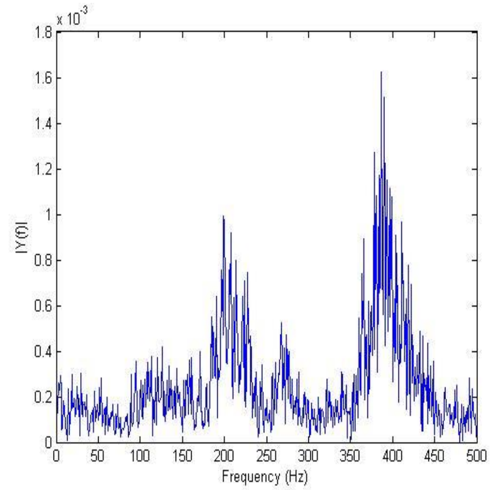

Fig.4.0 Frequency domain Vibration signal of healthy gear at 400rpm

Crack Defect: When crack on root and flank portion of gear tooth 180 degree to the first crack and load applied is 3 kg.

Frequency domain vibration signal, when spur gear runs at 200 rpm , 400 rpm , 600 rpm , 800 rpm , and 1000 rpm.

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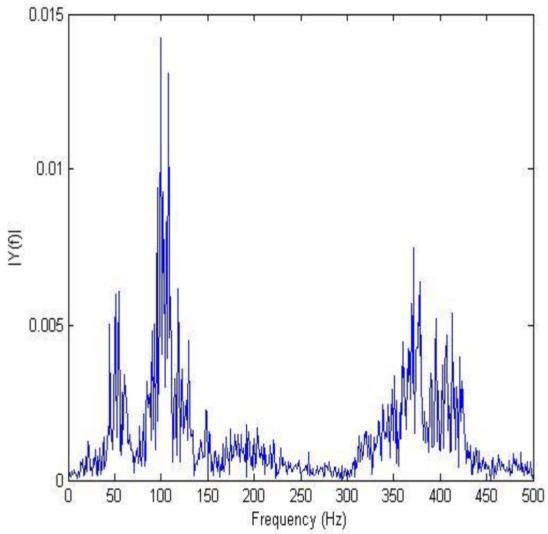

Fig.5.0 Frequency domain Vibration signal of defective gear at 200rpm

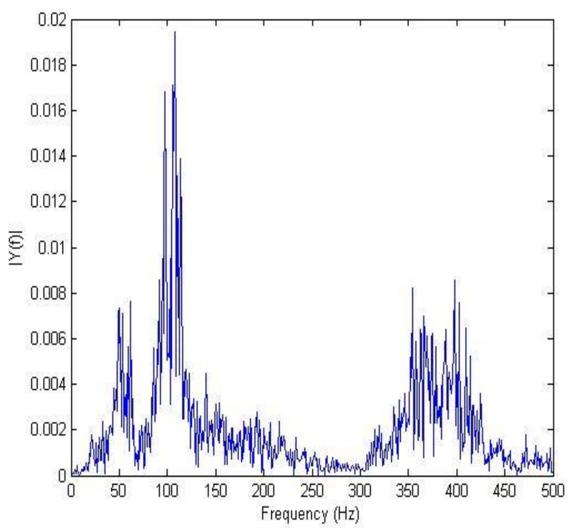

Fig.6.0 Frequency domain Vibration signal of defective gear at 400rpm

Crack Defect: When crack on root and flank portion of gear tooth 90 degree to the first crack and load applied is 3 kg.

Frequency domain vibration signal, when spur gear runs at 200 rpm , 400 rpm , 600 rpm , 800 rpm , and 1000 rpm.

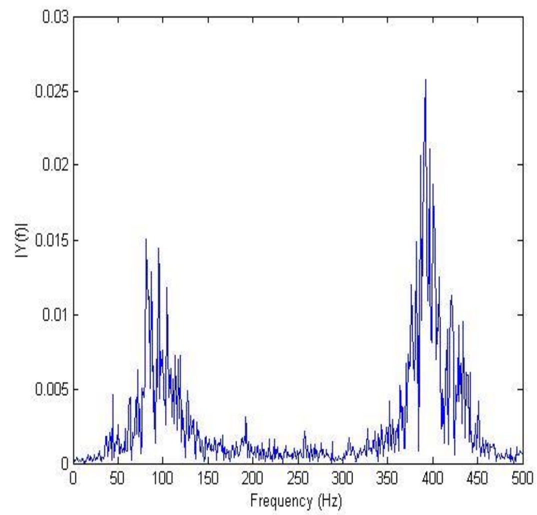

Fig.7.0 Frequency domain Vibration signal of defective gear at 200rpm

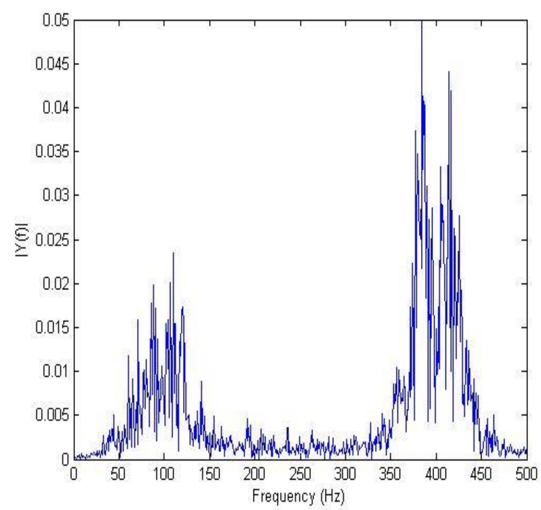

Fig.8.0 Frequency domain Vibration signal of defective gear at 400rpm

Similarly plot the time domain signal and frequency domain signal for all load and all rpm for healthy gear and defected gear.

Crack Defect: When crack on root and flank portion of gear tooth 270 degree to the first crack and load applied is 3kg.

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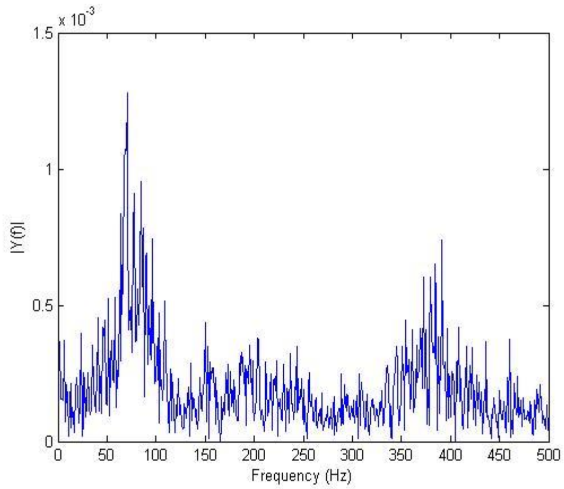


Fig.9.0 Frequency domain Vibration signal of defective gear at 200rpm

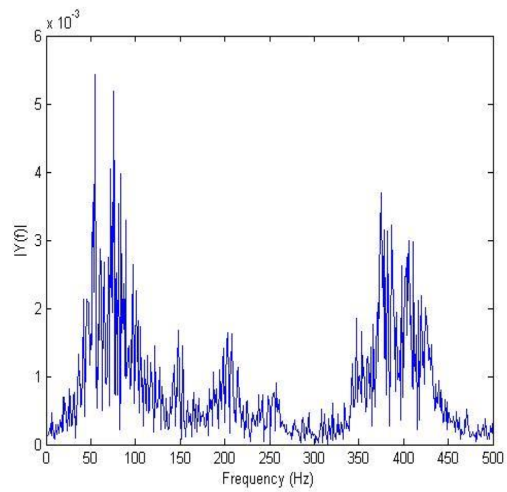


Fig.10.0 Frequency domain Vibration signal of defective gear at 400rpm

Comparative analysis of healthy gear and defected gear (crack1, crack 2, crack3)

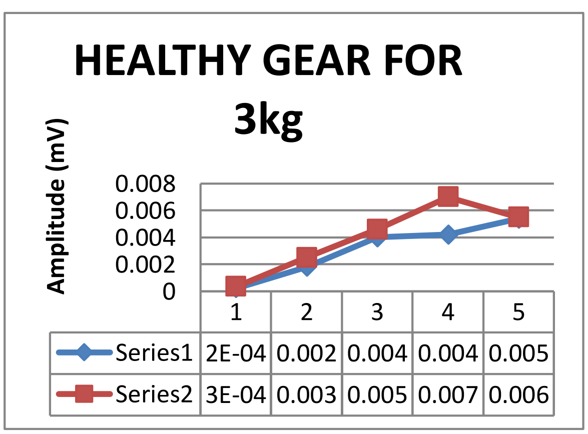


Fig.11.0 Amplitude of healthy gear

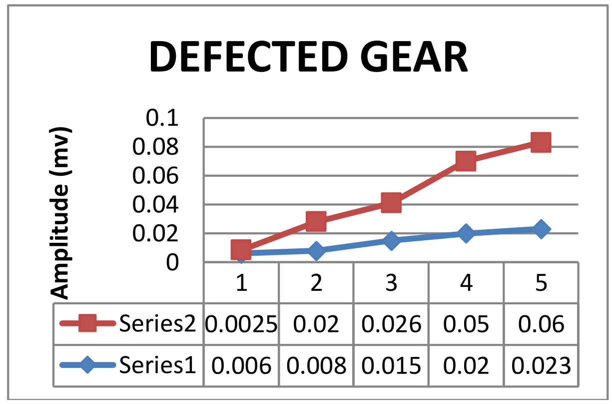


Fig.12.0 Amplitude of defective gear

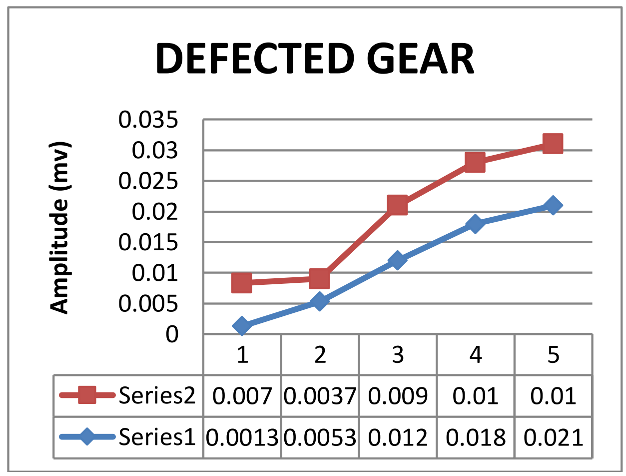
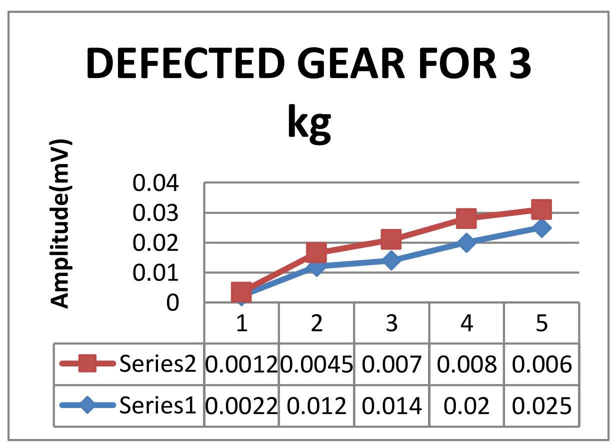


Fig.13.0 Amplitude of defective gear



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CONCLUSION

From the above graph it is observe that amplitude is continuously changing at the frequency of 200 and 400 Hz for healthy gear. And the amplitude of frequency changing at 100 and 380Hz for defective gear when crack on root and flank portion of gear tooth, amplitude of frequency changing at 100 and 400 Hz when crack on root and flank portion of gear tooth from 180 degree to the first crack, amplitude of frequency changing at 80 and 380 Hz when crack 90 degree to the first crack when load is applied 3kg. Similarly the graph is plotted when 4kg and 5kg load is applied. Gearbox vibration signals are usually periodic and noisy. Time frequency domain average technique successfully removes the noise from the signal and captures the dynamic of one period of signals. The presence of fault in any gear of the gearbox give rise to peak in the plot of the time frequency domain average. By using FFT technique it can be predicted that the gear box has some fault but the severity of fault cannot be determined.

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