Analysis of flank and root crack in the spur gear using vibration signal technique for single stage gear box

[1]Vijay Karma, [2]Manoj Kumar Dwivedi

[1]Assistant Professor, [2] PG scholar,
[1]Department of Mechanical Engineering,
[1]Institute of Engineering and Technology, Indore, India

***Abstract* - Gearing is one of the most important elements in the mechanical power transmission systems and plays a very important role during the transmission of the power between the two shaft .The research approaches is based on gear defects or faults in power transmission system can be found out by processing of their vibration signals. This study deals with the analysis of the spur gear crack defects. A single stage spur gearbox is used as an experimental set up and the vibration signals are recorded with the help of a piezoelectric from gearbox at faulty condition. Vibration signals are processed using MATLAB software and defect such as tooth crack are 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.**

***Key Words* - Vibration signal processing, tooth crack, time domain signal, frequency domain signal.**

I. INTRODUCTION

Spur gear is most commonly used in modern mechanical engineering applications to transmit the power between two shafts. Gear failure generally occur 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 domain analysis

The time domain method is to analyze the amplitude and phase information of the vibration time signal to detect the fault of gear box. It is particularly useful in analyzing impulsive signals from bearing and gear defects with non-steady and short transient impulses. The vibration signal is applied to the scope vertical input. The vertical axis on the graph scaled in amplitude. The horizontal axis on the graph scaled in time, such as seconds or milliseconds [3].

Frequency domain analysis

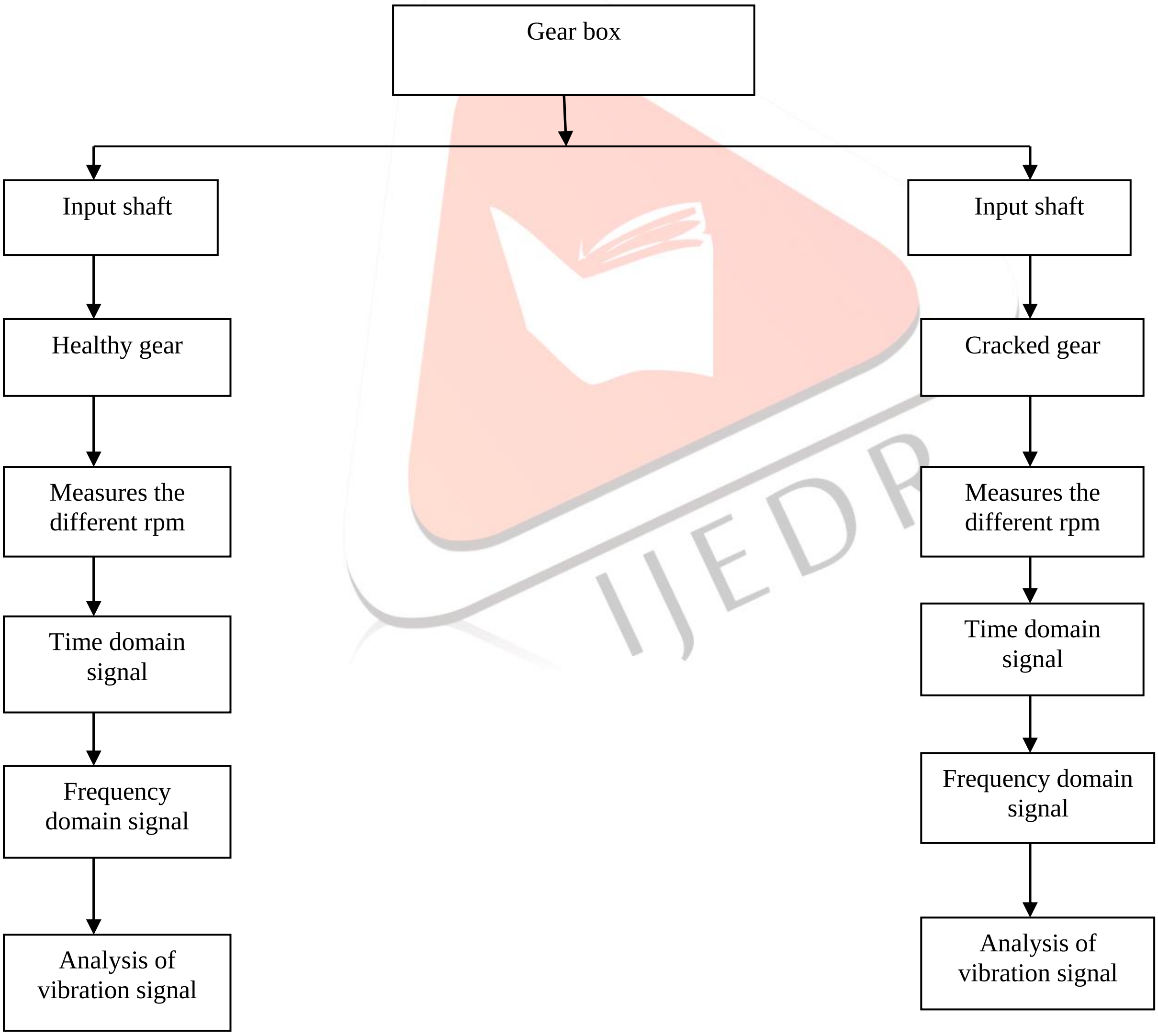
The frequency domain methods include Fast Fourier Transform (FFT), Hilbert Transform Method and Power Cepstrum Analysis, etc. Frequency domain is the most popular approach for the diagnosis of gear faults. Frequency domain techniques convert time domain vibration signals into discrete frequency components using a Fast Fourier Transform (FFT) [4]. The Fast Fourier Transform of time domain signal into frequency domain is shown in fig. 1.0. The frequency domain completely defines the vibration. Frequency domain analysis not only detects the faults in rotating machinery but also indicates the cause of the defect [2].

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

Flow chart



II. METHODOLOGY

The details procedure is explain in flow chart. First take time domain vibration signal of healthy gear at different rpm (i.e. 200rpm, 400rpm, 600rpm, 800rpm, and 1000rpm) and different load (i.e. 2kg, 3kg, and 4kg) by using MATLAB programmed and then this signal are convert into frequency domain vibration signal by using FFT programmed. Now a crack is produced in the gear having 32 teeth. Signal of time domain is analyzed at different loading condition with respect to different rpm. Load of

3kg, 4kg and 5 kg are applied at 200, 400, 600, 800 and 1000 rpm. With the help of time domain signal we convert the time domain signal in frequency domain signal and next the vibration signals of defected gear is having root crack and flank crack.

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 is applied 3kg.

Time domain vibration signal of healthy gear for 3kg load

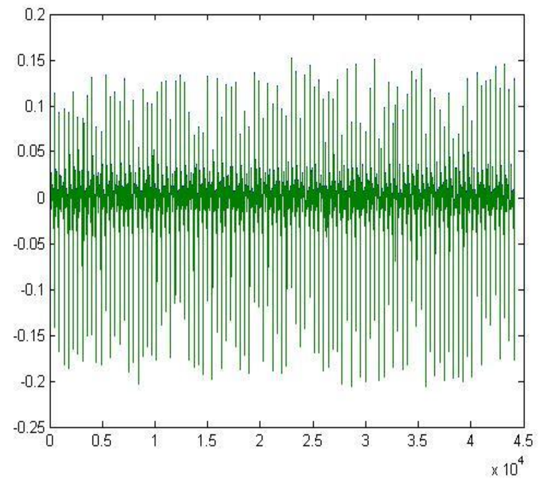


Fig. 1.0 Time Domain Vibration signal of healthy Gearbox at 200 rpm

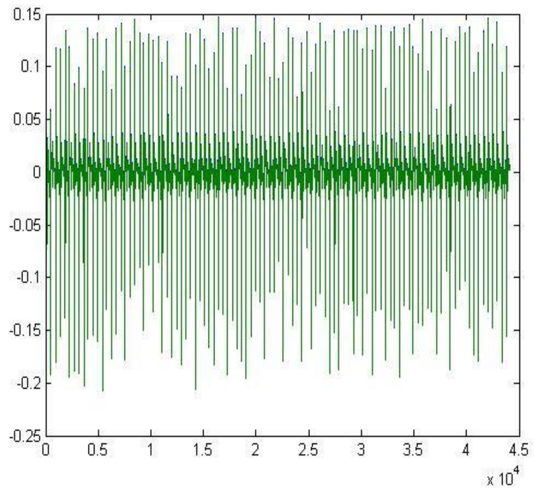


Fig. 2.0 Time Domain Vibration signal of healthy Gearbox at 400 rpm

Similarly plot the time domain vibration signal for healthy gear at 600 rpm, 800 rpm, and 1000rpm, when 3kg load is applied. Also similarly plot time domain signal when 4kg and 5kg load is applied and shaft runs at 200 rpm, 400rpm, 600rpm, 800rpm, and 1000 rpm.

Frequency domain signal of healthy gear for 3kg load

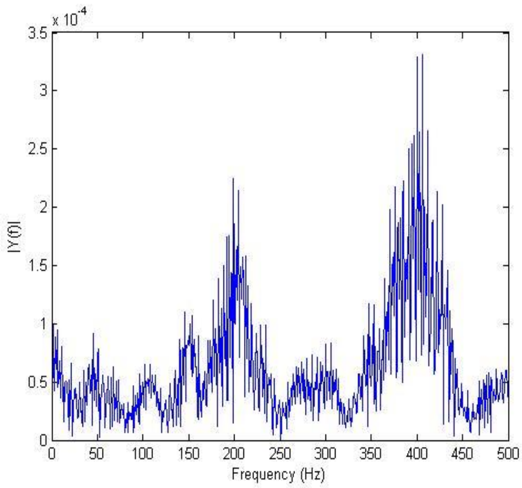


Fig. 3.0 frequency Domain Vibration signal of healthy Gearbox at 200 rpm

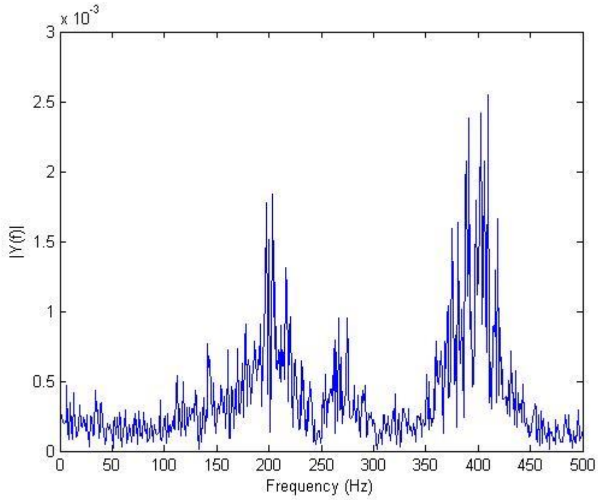


Fig. 4.0 frequency Domain Vibration signal of healthy Gearbox at 400 rpm

Similarly plot the frequency domain vibration signal for healthy gear at 600 rpm, 800 rpm, and 1000rpm, when 3kg load is applied. Also similarly plot frequency domain vibration signal when 4kg and 5kg load is applied and shaft runs at 200 rpm, 400rpm, 600rpm, 800rpm, and 1000 rpm.

Analysis of vibration signal of defected gear

Crack defect: When crack on root and flank portion of gear tooth and load applied is 3 kg.

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

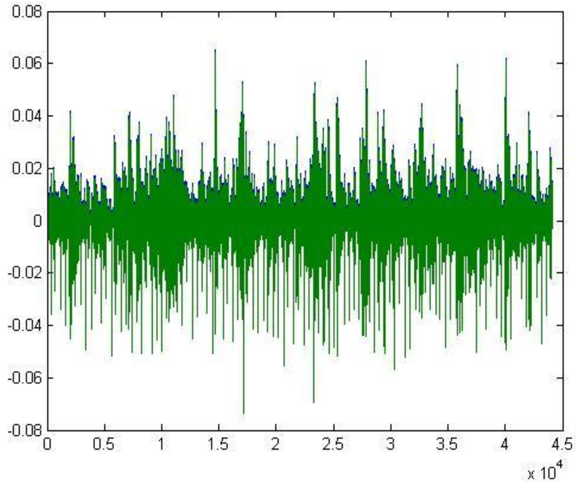


Fig. 5.0 Time Domain Vibration signal of defected Gearbox at 200 rpm

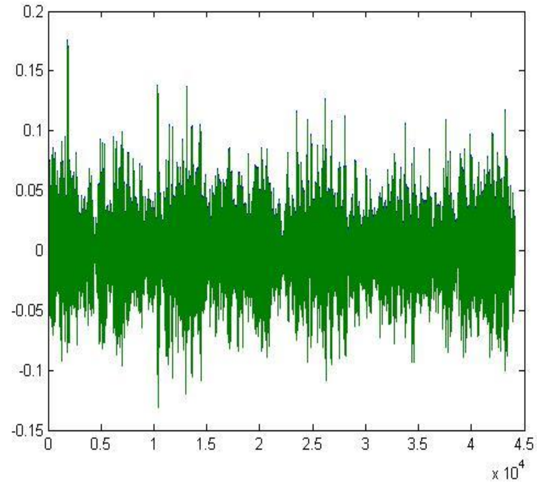


Fig. 6.0 Time Domain Vibration signal of defected Gearbox at 400 rpm

Similarly plot the time domain vibration signal for defected gear at 600 rpm, 800 rpm, and 1000rpm, when 3kg load is applied. Also similarly plot time domain signal when 4kg and 5kg load is applied and shaft runs at 200 rpm, 400rpm, 600rpm, 800rpm, and 1000 rpm.

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

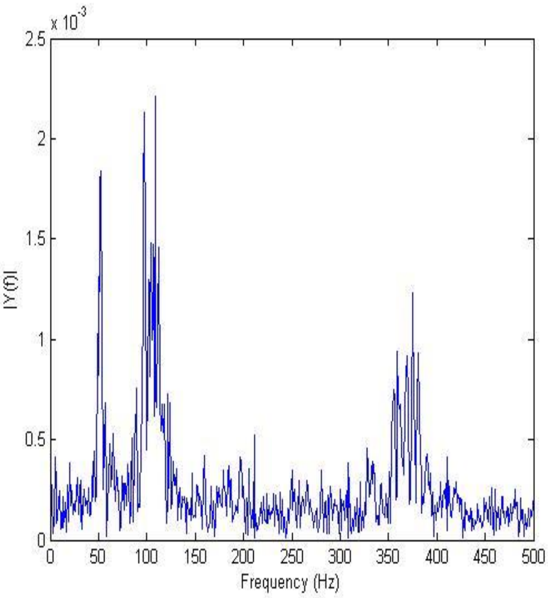


Fig.7.0 frequency Domain Vibration signal of defected Gearbox at 200 rpm

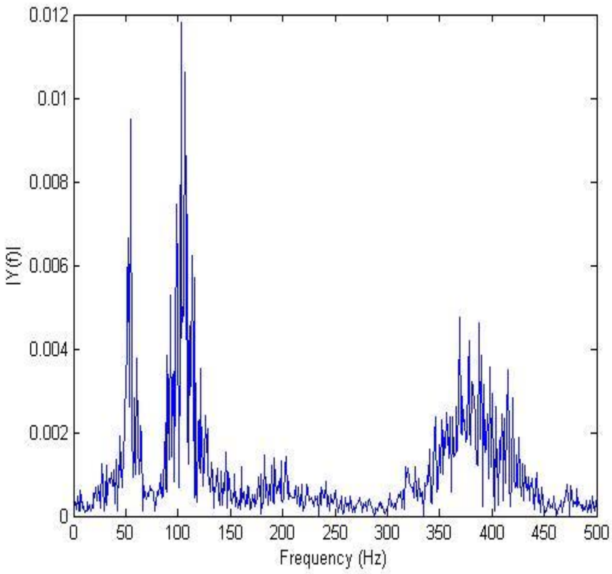


Fig. 8.0 frequency Domain Vibration signal of defected Gearbox at 400 rpm

Similarly plot the frequency domain vibration signal for defected gear at 600 rpm, 800 rpm, and 1000rpm, when 3kg load is applied. Also similarly plot frequency domain vibration signal when 4kg and 5kg load is applied and shaft runs at 200 rpm, 400rpm, 600rpm, 800rpm, and 1000 rpm.

TABLE-1 Represent the amplitude and frequency at various rpm and loading condition for healthy gear

Load	RPM	200rpm	400rpm	600 rpm	800rpm	100 rpm
3 kg	Amplitude at frequency 200Hz	0.00023	0.0018	0.004	0.0042	0.0054
	Amplitude at frequency 400Hz	0.00034	0.0025	0.0046	0.007	0.0055
4kg	Amplitude at frequency 200Hz	0.00034	0.0017	0.0045	0.006	0.01
	Amplitude at frequency 400Hz	0.00023	0.001	0.0028	0.0052	0.007
5kg	Amplitude at frequency 200Hz	0.00068	0.0024	0.005	0.0063	0.008
	Amplitude at frequency 400Hz	0.0004	0.0015	0.003	0.005	0.008

TABLE-2 Represent the amplitude and frequency at various rpm and loading condition for defected gear

Load	RPM	200rpm	400rpm	600 rpm	800rpm	100 rpm
3 kg	Amplitude at frequency 100Hz	0.0022	0.012	0.014	0.02	0.025
	Amplitude at frequency 380Hz	0.0012	0.0045	0.007	0.008	0.006
4kg	Amplitude at frequency 100Hz	0.0035	0.008	0.02	0.021	0.023
	Amplitude at frequency 380Hz	0.0015	0.006	0.008	0.01	0.013
5kg	Amplitude at frequency 100Hz	0.013	0.007	0.009	0.012	0.016
	Amplitude at frequency 380Hz	0.0025	0.01	0.012	0.018	0.02

III. Conclusion

When we have used FFT technique the graph is plotted between amplitude versus frequency. Results are drawn when 3kg, 4kg and 5kg load is applied at different rpm i.e.200rpm, 400rpm, 600, 800rpm and 1000 rpm. When gear is in running condition there are number of frequency generated. When we investigated the generated graph and the table we find that there are major changes taking place at 200 Hz and 400 Hz when gear is healthy gear. Similarly the major changes seen at 100 Hz and 380 Hz when crack on root and flank portion of gear tooth. 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 gives 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.

IV. Acknowledgement

The authors are thankful to the director and Head of the Department of Mechanical Engineering of IET DAVV, Indore, India, to provide the necessary facilities for the successfully completion of this work.

V. References

[1] S. Braun (Ed.), Mechanical Signature Analysis – Theory and applications, Academic Press Inc., London, UK, 1986.
[2] B.D. Forrester, Advanced Vibration Analysis Techniques for Fault Detection and Diagnosis in Geared Transmission Systems, Ph.D. Thesis, Swinburne University of Technology, Australia, 1996.
[3] Amit Aherwar, and Md. Saifullah Khalid, Vibration Analysis Techniques For Gearbox Diagnostic: A Review, International Journalof Advanced Engineering Technology, EISSN0976-3945
[4] Dennis H. Shreve, (November 1995), Signal Processing For Effective Vibration Analysis, IRD Mechanalysis, Inc Columbus, Ohio.
[5] www.testrf.com/2010/spectrum-analyzertutorial.
[6] Robert Randall bond, Wiley 2011, "vibration-based condition monitoring: industrial, automotive and aerospace applications ".
[7] A Vallavaraj and C Gnanapriya, Digital Signal Processing, TATA McGraw Hill, 2004.
[8] H. zheng, z. li and x. chen, (2002) gear fault diagnosis based on continuous wavelet transform mechanical systems and signal processing 16(2-3), 447.