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Fault Identification and Diagnosis of Helical Gear Pair by Experimental Vibration Analysis

Pravin Gawali
Student, Department of Mechanical Engineering, Suman Ramesh Tulsiani Technical Campus, Pune, India

***Abstract*: Now-a-days it is becoming more essential and reliable to predict the performance of gear box without dissembling the gear box. It is possible to predict the fault and fault conditions in case of any rotary machinery by using vibration analysis with the help of FFT analyzer and its accessories. In this paper, the similar kind of experimental setup is prepared and the vibration analysis is carried out at different speeds to analyze the behavior of time waveform and FFT spectrum for three different fault conditions. The helical gear pair of gear box is taken and the faults are created on gear and the vibration behavior is observed for different speeds like 300, 600 and 900 RPM and four different position of accelerometer. The three fault conditions are single tooth damaged gear; double teeth damaged gear and wear gear. Also some of the numerical technique like RMS value is used for comparing the behavior of faulty gear with respect to healthy gear.**

***Keywords*: Helical Gear pairs, FFT Analyzer, Vibration Analysis.**

1. Introduction

As the gears are power transmitting elements, certain faults are getting created in the gears. The faults like tooth damage, wear, pitting, chipping are getting created in the gears due to various reasons like excess loading, large friction and fatigue loading, etc. Also some of the faults like backlash, eccentricity, run out and alignment error are caused during assembling and manufacturing of gear. The faults will create the noise and vibrations during its working condition. These parameters can be used to identify the fault condition as each and every fault condition creates a different vibration spectrum. So it becomes necessary to identify the fault conditions in gear box by using proper vibration analysis technique.

2. Literature review

1. Dr. S.B. Kivade: The aim of this research, on the basis of experimental results is to evaluate and compare detection and diagnostic capabilities of some of vibration signal processing techniques.
2. G. Dalpiaz: Results considered in this paper, the power spectrum is practically insensitive to the crack evolution. The presented results show that the WT of the raw signals is practically insensitive to cracks, while the sensitivity of the WT of TSA signals is quite satisfactory.
3. Amit Aherwar: The first purpose is to separate the gearbox related signal from other components and to minimize the noise that may mask the gearbox signal, especially in the early stages of the fault.
4. Zhixiong Li: The independent component analysis (ICA) has been introduced into the mechanical fault diagnosis. The ICA is very useful for the gear fault detection, but limited work has been done to address the issue of coupled faults isolation.
5. S. S. Ajanallkar: In practice all gears contain teeth manufacturing errors, such as errors due to the gear cutting process, deviation in the mesh angle, deviations from the involutes profile, surface roughness of the gears; oscillations on the sliding velocity, where during the transmission of power there will be rolling and slipping in the point of contact and also oscillation may occur because of stick-slip effects.
6. D. A. Shinde: The aim of this paper is to improve reliability, safety & productivity of gearbox using different non-destructive inspection methodologies and processing acquired waveforms with advance signal processing techniques.
7. Amar Pawar: The condition monitoring of a lab-scale, two stage, gearbox using different non-destructive inspection methodologies and the processing of the acquired waveforms with advanced signal processing techniques.
8. V. S. Panwar: It is well known that the most important components in gear vibration spectra are the gear meshing frequency (GMF) and its harmonics, together with side bands due to modulation phenomena.

3. Methodology

The methodology used for fault identification and for observing the behavior of various faults is as given:

- Conducting experimental vibration analysis for healthy gear pair and faulty gear pair for four different positions and three speeds (300, 600 and 900RPM) by using accelerometer and FFT analyzer.
- Comparing the vibration analysis results by using the RMS value of vibration parameters for all the gear pair.

Observing and comparing the time domain vibration signatures.
Faults in Gear
For our experimentation we select three types of faults as

1) Single tooth damage

2) Double teeth damage and
3) Wear

Method used for analyzing the given signatures:

Time Domain Analysis:

The time domain methods try to analyze the amplitude and phase information of the vibration time signal to detect the fault of gear rotor bearing system. The time domain is perceptive that feels natural, and provides physical insight into the vibration. It is particularly useful in analyzing impulsive signals from bearing and gear defects with non-steady and short transient impulses.

4. Experimental Setup

The experimental setup is prepared to conduct a vibration analysis of healthy and faulty gear pair as shown in figure.

Fig. 1. Experimental setup

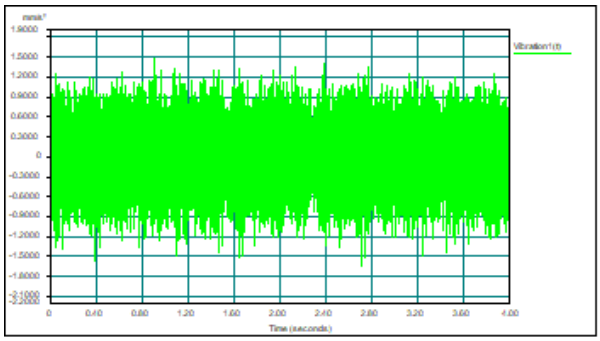
Fig. 2. FFT analyzer with four channels

Fig. 3. Transducer

5. Result

One sample result shown below which is taken with the help of FFT analyzer,

Signal Analysis and Waveform Source in x direction for first position and at a speed of 300 rpm of pinion, the time domain signal is recorded by using accelerometer and FFT analyzer. The maximum amplitude of vibration for this case in X-direction is varying in the range.



Spectral Lines: 6400 Time Capture Points: 16384
Frequency Span:1600
Average Type: Linear
Average Domain: Frequency
Average Number: 100

Comparative graphs for RMS Vs speed for different Accelerometer position.

Graph of RMS vs. Speed for Position 1 (driving end of input shaft)

For first position and at different speeds (300, 600 and 900RPM) of pinion, the time domain signal is recorded by using accelerometer and FFT analyzer for duration of 4 second. The rms values are calculated by using the amplitude on y axis for 16384 readings, step by step calculation are done as firstly square the amplitude values for each reading then calculate the mean of that all values and take the square root of mean. And the rms values are calculated for each speeds and position. The maximum RMS value from the table is for healthy gear pair.

RMS value calculated by using formula

$$\text{Mean} = \frac{\Sigma(y_i)^2}{\text{Total No.of Readings}},$$

$$\text{RMS} = \sqrt{Mean}$$

Graph for RMS Vs Speed for first position as shown below,

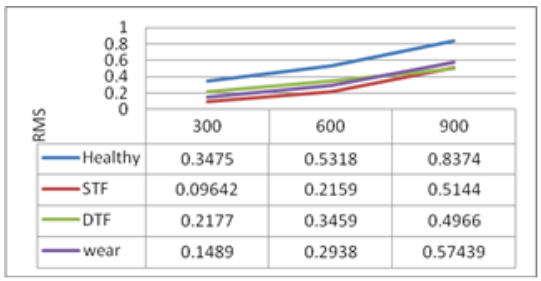


Fig. 5. RMS vs. Speed

6. Conclusion

As per discussion and analysis of results some predictable conclusions are occurs,

A. Amplitude of Peak occurs in faulty gears

The maximum peak of amplitude of vibration signatures occurs in X-direction due to radial force acting in X-direction, the intermediate peak of amplitude of vibration signatures occurs in Z-direction due to tangential force acting in Z-direction. The minimum peak of amplitude of vibration signatures occurs in Y-direction due to axial force acting in Y-direction. As per above discussion we conclude that peak of amplitude occurs in X-direction is favourable.

B. Nature of graphs

The crowded graphs with minimum fluctuations in peak of amplitude of vibration occur in healthy gears. The destructed graphs with maximum fluctuations in peak of amplitude of vibration occur in faulty gears. As per above discussion we conclude that graph for healthy gear is crowded with less fluctuations and destructed graph for faulty gears with higher peak.

As speed of motor increases, amplitude of vibration also increases

C. From graph of RMS vs. Speeds

a) Location of graph of RMS vs. Speeds is on top for healthy gear pair due to greater RMS values.
b) Location of graph of RMS vs. Speeds for double teeth damage gear pair is below the healthy gear pair due to less RMS values than healthy.
c) Location of graph of RMS vs. Speeds for wear teeth gear pair is below the double teeth damage gear pair due to less RMS values.
d) Location of graph of RMS vs. Speeds for single tooth damage gear pair is below the wear teeth gear pair due to less RMS values.

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