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FAULT DIAGNOSIS OF SINGLE STAGE SPUR GEARBOX USING NARROW BAND DEMODULATION TECHNIQUE: EFFECT OF SPALLING

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ABSTRACT

Fault detection and diagnosis of gear transmission systems have attracted considerable attention in recent years, due to the need to decrease the downtime on production machinery and to reduce the extent of the secondary damage caused by failures. This paper deals with fault diagnosis of a spur gearbox having spalling defect in driver gear using narrow band demodulation technique through MATLAB software. For this an experimental setup is fabricated. 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.

KEYWORDS: Gears, Fault Diagnostic, MATLAB, Narrow Band Demodulation, Power Spectral Density

INTRODUCTION

Vibration signals measured from a gearbox are complex multi component signals; generated by tooth meshing, gear shaft rotation, gearbox resonance vibration signatures; however, because the measured vibration signals are often disturbed by uncertain impulses and random noises [1], it is essential to employ some signal processing techniques in the fault diagnosis to attenuate the effects of disturbances and ensure that more accurate gear fault features can be extracted.

In most of gear fault diagnosis systems, the demodulation technique is often used for the purpose of fault detection and diagnosis. When a gear has a local fault, the vibration signal of the gearbox may contain amplitude and phase modulations that are periodic with the rotation frequency of the gear. This is known as modulation, since modulating frequencies are caused by certain faults of machine components including gear, bearing, and shaft, the detection of the modulating signal is very useful to detect gearbox fault.

The modulation of the meshing frequency, as a result of faulty teeth, generates sidebands, which are frequency components equally spaced around a centre frequency. The centre frequency called the carrier frequency is the gear mesh frequency or the resonant frequency of an accelerometer [2]. The process of restoring the modulating signal that is mixed with a carrier signal is called demodulation.

LITERATURE REVIEW

Amit Aherwar, Md. Saifullah Khalid [3] has been presented a brief review of some current vibration based techniques used for condition monitoring in geared transmission systems. Hongyu Yang, Joseph Mathew and Lin Ma [5] explained various vibration feature extraction techniques for fault diagnosis of rotating machinery in time domain, frequency domain and time-frequency domain. Frequency domain features are generally more consistent in the detection of damage than time domain parameters. Wenyi Wang [6] deduced a very effective method of the resonance demodulation technique for early detection of gear tooth cracks. The proposed scheme focuses on the fact that gear tooth crack will produce vibration impacts that would excite the structural resonances when the cracked tooth is engaged. Ahmad Ghasemloonia & Siamak Esmaeel Zadeh [7] used two newest fault detection methods, the resonance demodulation technique (R.D), and the instantaneous power spectrum technique (IPS) for gear box fault diagnostic. Fengxing Zhou & Baokang Yan [8] effectively used demodulated resonance technique in fault diagnosis of high speed line rolling mill synchromesh gears.

Conclusion for Literature Review

- After a brief analysis of some current vibration based techniques used for condition monitoring in geared transmission systems [3-5] and it is conclude that frequency domain features are generally more consistent in the detection of damage than time domain parameters [5], so any fault diagnosis method which is based on frequency domain can be selected for project work.
- It is also conclude that the envelope analysis and Power Spectrum Density techniques have shown a better representation for fault identification. The Hilbert Transform and PSD techniques are suitable for multiple point defect diagnostics for condition monitoring [3]. Also Resonance Demodulation is a recent technique that can be used for early detection of gear tooth crack [6] but can be effectively used at the early stages of fault generation [7].
- It can be conclude for the above literature review that the envelope analysis or demodulation analysis is most suitable and common for diagnosing the bearing faults and can also be used for the detection of gear faults also.

NARROW BAND DEMODULATION TECHNIQUE

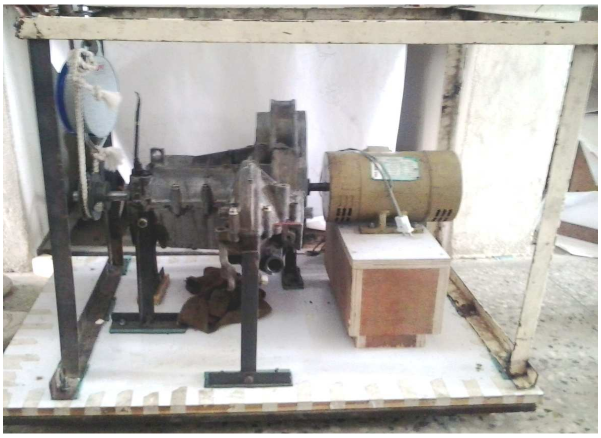

Figure 1: Experimental Set-Up

In narrowband (NB) demodulation techniques, as the name implies the idea is to select an interesting frequency band for further analysis instead of analyzing the whole frequency-domain. This is performed by plotting the spectrum and selects the frequency band in frequency-domain. Hence, one is performing filtering of the DFT of the signal instead of filtering the signal in time-domain. The faulty gear generates the impulse with low amplitude level every time in meshing. This low-level impulse has an amplitude-modulating effect on the vibration signal which is visible as high amplitude signal burst in time domain. The modulation effect spreads over a wide frequency range because of the short duration of impulse. Envelope analysis is a practical approach for investigation of such signals, where amplitude modulation presents in characteristic frequencies of the system. The envelope detection technique focuses on a narrow band range in the specified frequency band, which is useful for detecting the low-level impulses that are below the noise level in the [9]. Low pass filtering and FFT based Hilbert transform are the most commonly known methods for envelope detection. However, the normal spectrum FFT based Hilbert transform has advantage for its high speed and so, suitable for real time envelope detection.

EXPERIMENTATION

In the present work, the experiments are conducted on a gear mesh assembly fabricated for the purpose as shown in Figure 1. The gearbox used in the setup is a gearbox of Maruti 800 car. The driver gear is having 32 teeth, mounted on driver shaft coupled with a single phase 50 Hz DC motor (power rating 0.5 HP). The driver shaft is supported on two ball bearings 6303z. The gear on the driven shaft is having 35 teeth and also supported between two ball bearings 6204z. Other end of the driven shaft has provisions to apply load. A Piezoelectric type accelerometer is mounted on the case closer to matting gears. The vibration signal is captured with the help of a PC using Matlab software. The operating frequency was set at 1800 RPM (30 Hz) and verified with an optical tachometer.

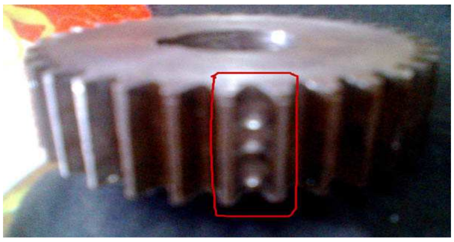

Figure 2: Spalling Defect in Gear

The experiment is carried out in two phases without loading. In the first phase, the healthy gears are mounted and the corresponding vibration signal is captured. A sample data of one second duration and its power spectral density (PSD) spectrum are shown in Figure 3 and 4, respectively. In the second phase, the driver gear was replaced with a gear with Spalling defect. As can be seen from Figure 2, the defects have been introduced on the first tooth. As earlier, the vibration signal is captured and a sample data of one second duration along with its PSD spectrum are shown in Figure 5 & 6, respectively.

RESULTS & DISCUSSIONS

The Figure 3 shows the signals in time domain and frequency domain, when the gear is fault free or healthy. The Time domain signal is converted into frequency domain with the help of FFT of the signal.

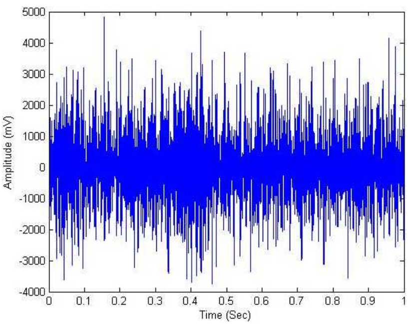

Figure 3: Vibration Signal in Time Domain of Healthy Gear

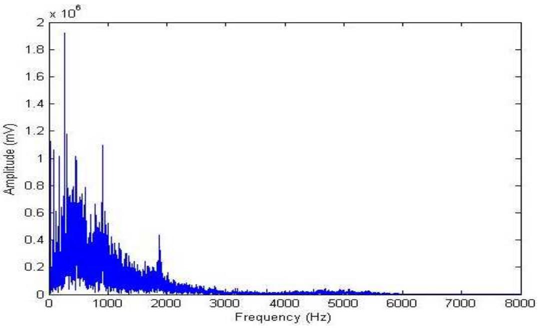

Figure 4: Vibration Signal in Frequency Domain of Healthy Gear

As the Fault is introduced in driven gear, the vibration signals are changed as shown in figure 6. It is clear from the figure 6 that the amplitude is higher at the frequency nearly 5.2 kHz.

From the spectrum in figure 6, one can observe that the vibration bursts due to the defect in the gear tooth generates high frequency components (in the range of 4.5–5.5 kHz). The defect is identified in the spectrum as high intensity stripes. Therefore a frequency band range between 4.5 kHz to 5.5 kHz is selected by applying the filtering of the signal as shown in figure 7

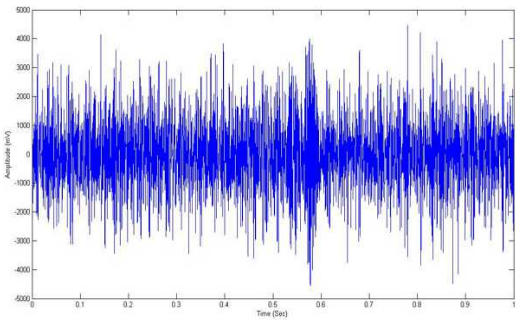

Figure 5: Vibration Signal in Time Domain of Faculty Gear

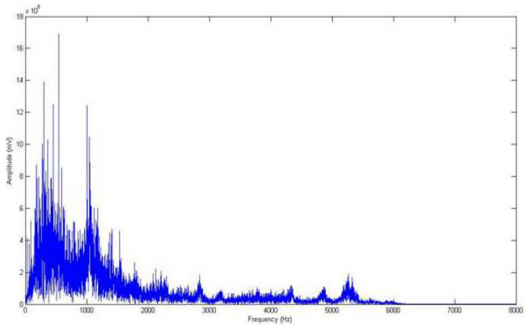

Figure 6: Vibration Signal in Frequency Domain of Faculty Gear

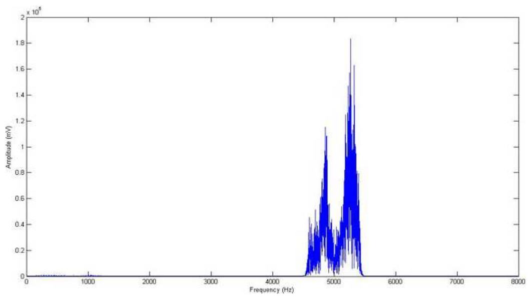

Figure 7: Filtered Signal in Frequency Domain of Faulty Gear

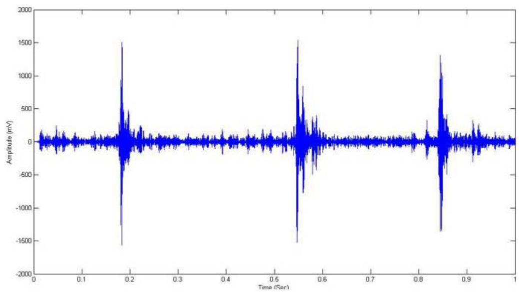

Figure 8: Filtered Signal in Time Domain of Faulty Gear

After filtering the signal, the frequency component is converted into time component through Inverse Fast Fourier Transform (IFFT). This is shown in Figure 8. Now the envelope of this filtered time signal is created. The envelope of filtered signal as shown in figure 9

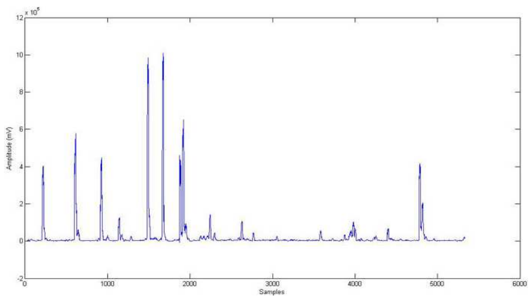

Figure 9: Enveloping of the Filtered Signal

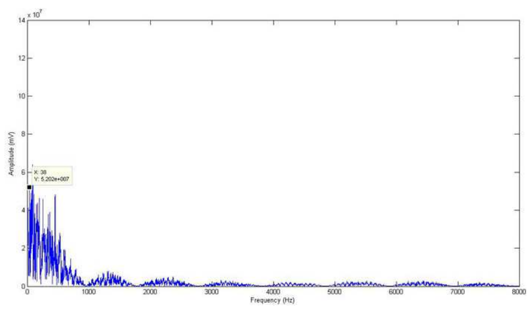

Figure 10: Spectrum of Defect

After enveloping, Fast Fourier Transform of signal has been done i.e. the time domain signal is converted into frequency domain. It is clear from figure 10, that the second harmonic of the defective fault occurs at 38 Hz frequency, therefore the frequency of the defect is 19 Hz.

CONCLUSIONS

The frequency of the Spalling defect was found to be 19 Hz. Experimental work was carried out with the intention to use demodulation technique to show how the different faults manifest themselves in frequency domain but due to severe non-stationarity, we can detect the fault but cannot predict the fault on the basis of signature.

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