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ORIGINAL ARTICLE

CONDITION MONITORING OF DIFFERENTIAL USING POWER SPECTRAL DENSITY

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ABSTRACT: This paper concentrates on a procedure which experimentally recognizes crown wheel and pinion faults of a typical differential system using power spectral density. The differential conditions were considered to be normal differential, broken teeth of crown wheel and broken teeth of pinion. In this study we were calculated RMS and power spectral density of Roa differential in different situation. The largest acceleration value was occurred in the condition of broken teeth of crown wheel and its value was about 0. 13g. The results showed that the area under power spectral density curves indicated a problem. More area below power spectral density curve showed that the faults were deeper. The results showed that with calculating PSD we could find some fault and diagnosis of electromotor as soon as possible.
KEYWORDS: Condition Monitoring, Roa Differential, Power Spectral Density.

INTRODUCTION

Condition monitoring of machines is gaining importance in industry because of the need to increase reliability and to decrease possible loss of production due to machine breakdown (Moosavian *et al.*, 2012). Reliability has always been an important aspect in the assessment of industrial products (Niu *et al.*, 2008). With the increase in production capabilities of modern manufacturing systems, plants are expected to run continuously for extended hours. Therefore, the condition monitoring of machines, especially early fault diagnosis, is proved to be necessary and has been received wide attentions in this decade (Bagheri *et al.*, 2011). Most of machinery used in the modern world operates by means of rotary parts which can develop faults. The monitoring of the operative conditions of a rotary machine provides a great economic improvement by reducing maintenance costs, as well as improving the safety level (Castro *et al.*, 2006; Ahmadi and Moosavian, 2011; Khazaee *et al.*, 2012). In this paper, investigate the correlation between power spectral density (PSD) and differential fault diagnosis. This was achieved by vibration analysis of differential. Numerical data produced by power spectral density were compared with power spectral density in healthy differential, in order to quantify the effectiveness of the PSD technique (Wowk, 1991). The results from this paper have given more understanding on the dependent roles of vibration condition monitoring and PSD curve in predicting and diagnosing of differential faults (Peng and Kessissoglou, 2003). Heidarbeigi *et al.*, (2009) illustrated that vibration condition monitoring and power spectral density technique could detect fault diagnosis of gearbox. Vibration analysis and power spectral density could provide quick and reliable information on the condition of the gears. Integration of vibration condition monitoring technique with power spectral density analyze could indicate more understanding about diagnosis of gearbox. Mollazade *et al.*, (2009) calculated power spectral density of vibration spectra for fault diagnosing of hydraulic pump of tractor steering system. Their results showed that peak value of PSD was occurred in the frequency range between 70-120 Hz for all conditions. At first glance it can be observed that the area under PSD-Frequency curves is different for different condition of pump. This characteristic can be used in the fault classification of pump.
In this research differential of Peugeot-Roa, that is one of high production automobile in Iran, was used as case study for condition monitoring of differential

EXPERIMENTATION AND TESTING

The test rig used for the experimentation was a differential. The experimental setup to collect dataset consists of Roa differential, an electrical motor and two shock absorbers under the base of test-bed. Test-bed was designed to install differential, electric motor and two shock absorbers under bases to cancel out vibrations. Figure 1 illustrates the experimental setup that was used in this study. The differential coupled

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to the electromotor that was initially run under normal operating conditions and its speed at 800 RPM was controlled by an inverter. The faulty crown wheel and pinion was provided from the car repair. All vibration signals were collected from the experimental testing of differential using the accelerometer which was mounted on the top of differential housing. For each configuration different fault conditions were tested that were faulty crown wheel and pinion. The signals from the accelerometer were recorded in a portable condition monitoring signal analyzer. The Easy-Viber used as data acquisition that was an interface between PC and sensor. All specification of Easy-Viber is presented by Vehmas, (2002). Figure 2 shows the kind of classes that were classified in this study.

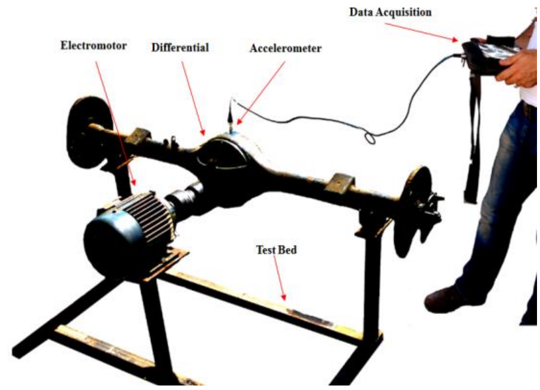

Figure 1: Experimental setup included Differential, test bed and etc.

Figure 2: Different conditions of crown wheel and pinion.

2.1. Power Spectral Density

Power spectral density (PSD) function indicates the vigor of the variations (energy) as a function of frequency. In other words, it shows at which frequencies variations are powerful and at which frequencies variations are weak. The PSD curve is the normal method used to describe random vibration specifications. Since the PSD curve is a plot of acceleration density, the overall rms acceleration can be found by summation of the density over frequency.

The complex spectrum of a vibration x(t) in the time range (t_1, t_2) for any frequency f in the two-sided frequency domain (-F, +F) can be expressed as:

$$X(f) = \int_{f_1}^{f_2} x(t)\, e^{-2\pi i f t}\, dt \qquad (1)$$

Generally, if FFT of vibration signal be applied, PSD can be computed directly in the frequency domain by following formula:

$$PSD = \frac{g^2_{rms}}{f} \qquad (2)$$

Where, Grms is the Root Mean Square of acceleration in a certain frequency f (Moosavian *et al.*, 2012; Samanta *et al.*, 2003).

RESULT AND DISCUSSION

Figures 3-5 showed frequency spectrum result of differential. Figures 3 showed frequency spectrum result of healthy gearbox. The largest acceleration value of healthy condition was occurred at 14 Hz and its value was about 0.025 g. The largest acceleration value of broken teeth of crown wheel was occurred at differential speed and its value was about 0. 13 g and for broken teeth of pinion was occurred at the same frequency and its value was 0.07g. The results showed that with calculating power spectral density, we could diagnose differential faults very fast. It was shown that power spectral density provides a good and rapid method to show faults of differential. The results of this paper have given more understanding on the dependent roles of vibration analysis and power spectral density curves in predicting and diagnosing of an differential faults. The frequency spectrum of each fault was different and overall vibration values also were different at the same frequency. The results showed that the area under power spectral density curves indicated a problem. More area below power spectral density curve showed that the faults were deeper. Figure 6 showed the power spectral density of differential in different situations. The results showed that with calculating PSD we could find some fault and the differential diagnosis as soon as possible.

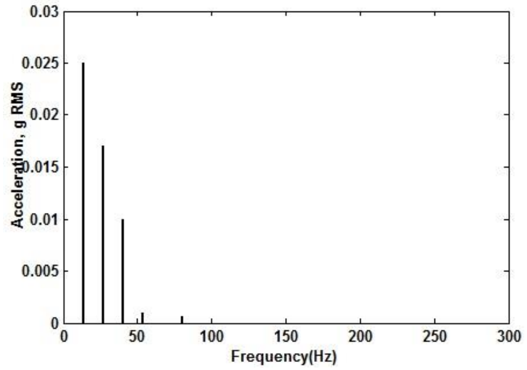

Figure 3: Frequency spectrum result of healthy differential.

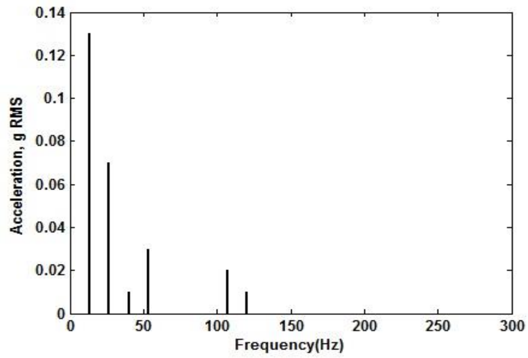

Figure 4: Frequency spectrum result of broken teeth of crown wheel.

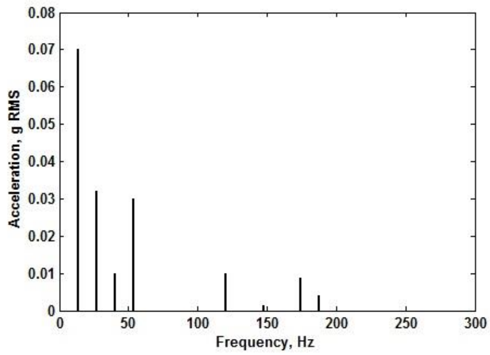

Figure 5: Frequency spectrum result of broken teeth of pinion.

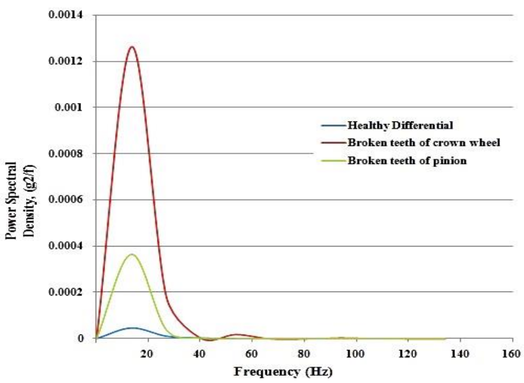

Figure 6: Power Spectral Density results of differential.

CONCLUSION

In this research we have calculated RMS and PSD of differential in different faults situations. We have calculated Grms and PSD for different faults. The results showed that different faults were showed different PSD vs. frequency. Results showed that vibration condition monitoring and power spectral density technique could detect fault diagnosis of differential. Three states of differential was detected, namely, normal, broken teeth of crown wheel and broken teeth of pinion conditions. Integration of vibration condition monitoring technique with power spectral density analyze could indicate more understanding about diagnosis of differential.

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