Research on Gasoline Engines Health Monitoring and Fault Diagnosis based on Vibration Signal Analysis

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Abstract: Aiming at research on engine health monitoring and fault diagnosis based on the characteristics of the surface vibration signals measured from the engine, a measured method by using wireless acceleration sensor is proposed in this paper. The basic characteristics of engine vibration signal taking the Chevrolet Epica 2HO automotive engine as an example was measured in this paper. The original measured data was pre-processed using the Fast Fourier Transform (FFT) to suppress abnormal interference of noise, and avoid the pseudo mode functions. Finally, the vibration signals of automotive engine are analyzed and the results show that the method is feasible and effective in feature extraction and condition evaluation of engine health monitoring and fault diagnosis.

1 INTRODUCTION

More and more importance of health monitoring and fault diagnosis has been realized, which is no longer a supplementary accessory to the system, but a necessary and essential element to ensure reliability and productivity in an effective and cost-efficient way (Jin, 2014). Gasoline engines, as one of the key equipment in a variety of applications, have always been popular as the subject of condition health monitoring. Engine contains abundant fault messages. Thus the gasoline engine health monitoring and fault diagnosis technique based on the characters of engine vibration signal is adopted to enhance the operation reliability and reduce the blindness of the maintenance work. Actually, engine is a complicated mechanical system with various vibration excitations and different corresponding excitation mechanisms. For instance, automotive engine is chosen as an illustrative case study. In normal condition, the gas pressure and inertia force are the most common and immediate excitation sources of the automotive engine. They act on the automotive engine with their own effect rule and frequency and cause a wide variety range of vibration signal. Specifically, the gas pressure acts mainly on the cylinder head and the frequency band covers from tens to thousands Hz; but the inertia force acts on the cylinder block and manifest a slow frequency harmonic oscillations. So the accurate extraction of vibration signals is very important to the engine health monitoring and fault diagnosis (Chandroth, 1999; Taglialatela,2013; Gravalos, 2013; Geng, 2003).

Recently, In order to monitor engine health and further diagnose faults in gasoline engines, various successful methodologies have been developed. S. P. Mitchell Lebold et al intensively investigated several different methods to analyse faults based on injector signal, vibration signal, and speed encoder signal. Misfire faults have been successfully identified using time domain, frequency domain and order domain analysis tools. Signals of each category of every method were presented to show the difference between normal and faulty condition, and the quantization of the difference is later formulated. All the approaches had the ability to identify the faulty cylinder location (Jin, 2014). Mollazade et al. presented a fault diagnosis method for external gear hydraulic pumps based on a fuzzy inference system (FIS) (2009). Sakthivel et al. used decision tree and other machine learning algorithms for fault detection of mono-block centrifugal pump. Ahmadi and Mollazade investigated fault diagnosis of an electro-pump in a marine ship using vibration analysis (2010). Muralidharan and Sugumaran presented a

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procedure for mono-block centrifugal pump fault diagnosis based on vibration signals (2013).

However, few of research works are designed and researched based on the actual vibration circumstance in practical applications. In order to research on engine health monitoring and fault diagnosis based on the characteristics of the surface vibration signals measured from the engine, a measured method by using wireless acceleration sensor is proposed in this paper. Firstly, for convenience, the paper measures and analyzes the basic characteristics of engine vibration signal taking the Chevrolet Epica 2HO automotive engine as an example. Secondly, the original data is pre-processed using the Fourier transform to suppress abnormal interference of noise, and avoid the pseudo mode functions. Finally, the vibration signals of automotive engine are analyzed and the results show that the method is feasible and effective in feature extraction and condition evaluation of engine health monitoring and fault diagnosis.

2 MEASUREMENT OF ENGINE VIBRATION SIGNAL

To elaborate on basic characteristics of engine vibration signal and emphasis on the need to incorporate real vibration environment, the paper take the Chevrolet Epica 2HO automotive engine as the monitoring content and records the vibration signals on the cylinder head in both time and frequency domains. The engine vibration collection system is provided by YMC PIEZOELECTRIC INC and the schematic is shown in Figure 1.

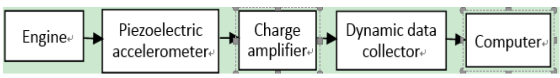


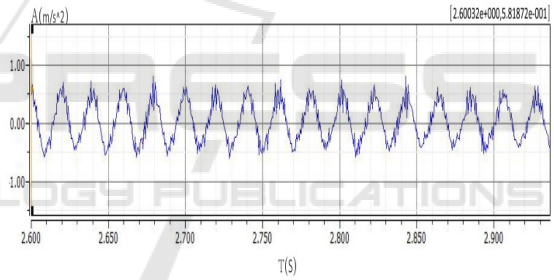
Figure 1: The schematic of the engine vibration test system

Vibration signals are collected in normal and no-load running conditions and vary from seven different speeds, as summarized in Table 1. All the data are taken from the z-axis, which is normal to the deck (C. Polonowski, 2007).

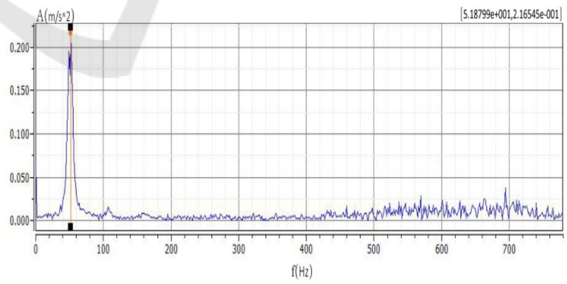
As shown in figure 1, the vibration signals on the cylinder head of engine are measured by the piezoelectric acceleration sensor (accelerometer). But this signals are too small to show in the measured instruments, so the measured signals are amplified by feeding into the charge amplifier, and the amplitude of signal are enhanced. Moreover, the noise signal is suppressed by using dynamic data collector. Finally, the vibration data are transmitted to the computer by wireless communication method. The vibration signals are measured at the condition of the lowest 800 rpm and highest 4000 rpm for engine speed.

3 ANALYSIS OF THE MEASURED DATA

Vibration analysis is the most successful and cost efficient group of condition monitoring methods. Vibration analysis is a promising technique which is particularly used for some time as a predictive maintenance method and as a support for machinery maintenance decisions (Ahmadi H, 2009). In the proposed health monitoring system, the vibration signals in Z direction on the cylinder head of the engine are analysed by using the Fast Fourier transform (FFT) in detail as follows. The plots of vibration signal at the lowest 800 and highest 4000 speed are given in Figure 2 and 3, respectively.

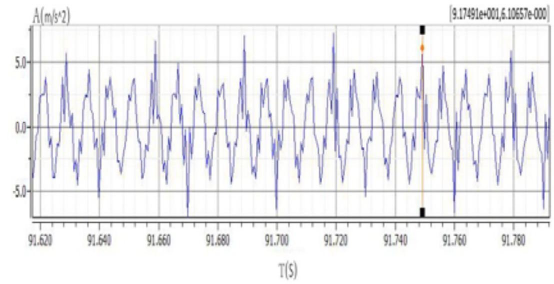


(a) Time domain

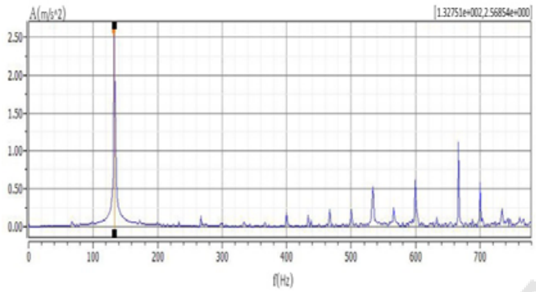


(b) Frequency domain

Figure 2: The acceleration amplitude of vibration signal in Z direction on the cylinder head of the engine at the lowest 800 rpm of speed



(a) Time domain



(b) Frequency domain

Figure 3: The acceleration amplitude of vibration signal in Z direction on the cylinder head of the engine at the highest 4000 rpm of speed.

Although the time domain wave forms of vibration signals in Figure 2 and 3 are bewildering, periodic gas force excitation can be observed obviously, which is consistent with theoretical analysis in previous. In addition, the FFT results demonstrate the gas force's prompted vibration is laid on low frequency band and the value of the frequency is apparently positively related to engine speed, which is also confirmed in Table 1.

Table 1: The values of vibration signal in Z direction on the cylinder head of the engine

Speed (r/min)	Acceleration amplitude (m/s^2)	Acceleration frequency (Hz)
800	-0.49 ~ 0.58	51.88
1500	-0.76 ~ 0.98	53.41
2000	-1.63 ~ 1.76	74.77
2500	-2.30 ~ 2.32	94.60
3000	-3.45 ~ 4.60	111.39
3500	-5.97 ~ 5.95	129.70
4000	-6.67 ~ 6.10	132.75

Such these characterizations provide practical performance requirements for the design of the engine health monitoring and fault diagnosis used in the particular application (B. Badawi, 2006). Adapted for engine vibration conditions under different speeds, the designed vibration structure should work in withstand accelerations of $7m/s^2$ and extract the electrical response in around 50 to 130Hz frequency range.

4 CONCLUSION

In order to research on engine health monitoring and fault diagnosis based on the characteristics of the s from the engine, this paper proposed one method of measuring vibration signals of engine by using wireless acceleration sensor. The original measured data was pre-processed using the Fast Fourier transform (FFT) to suppress abnormal interference of noise. The vibration signals of automotive engine are analyzed and the results show that the method is feasible and effective in feature extraction and condition evaluation of engine health monitoring and fault diagnosis.

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