Feature extraction of rotating apparatus using acoustic sensing technology

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***Abstract*—This article presents a feature extraction of rotating apparatus using acoustic sensing technology (AST). The kernel algorithm is based on an acoustic signal enhancement filter (ASEF). The acoustic feature extraction algorithm is implemented by using Mel-scale frequency cepstral coefficient (MFCC) theory. The system utilizes an National Instruments (NI) cRIO-9067 embedded controller and a real-time signal sensing module to analyze rotation performance and predict malfunctions in rotating apparatus. AST can adopt low noise array microphone which the effective bandwidth is 20 to 10000 Hz. Experimental results showed that the acoustic signal method could effectively perform real-time early fault detection and prediction in proposed system. Smart AST was proposed that can distinguish the acoustic feature differences of normal and abnormal ones.**

***Keywords*—acoustic sensing technology (AST); MFCC; embedded controller; array microphone**

I. Introduction

Mainly produced source from rotating apparatus in industrial facilities, e.g., fan and motor. They are used to remove exhaust emissions, ventilate, compress air, and driving line conditioning systems. Such rotating apparatus typically operate continuously for long durations and improper maintenance can result in malfunctions, including vibrations, temperature, and acoustic noise. General mechanical faults are mostly caused by bearing failures, looseness, shaft cracks, poor balance, and misalignment [6]. Figure 1 indicates the general maintenance procedures for rotating apparatus. Rotating machinery are typically indicated by the presence of abnormal vibration, noise or temperature issues. Portable measurement and online real-time monitoring methods based on the ISO 13373 standards [1].

General digital signal processing involves transforming the measured the vibration signal by fast Fourier transform (FFT) into frequency spectrum feature values. In addition, the shaft rotational speed of rotating apparatus changes with factory production conditions, and many environmental variables. Therefore, the measured analog vibration signals of plant mounts produce a non-linear, non-stationary time domain signal, while the traditional Fourier transform is only appropriate for linear and stationary time domain signals and cannot accurately reflect time-variant factors to respond to the non-stationary behavior. Spectrum analyses may not indicate the vibration energy distributions of the harmonics feature when other harmonics change with the rotating conditions.

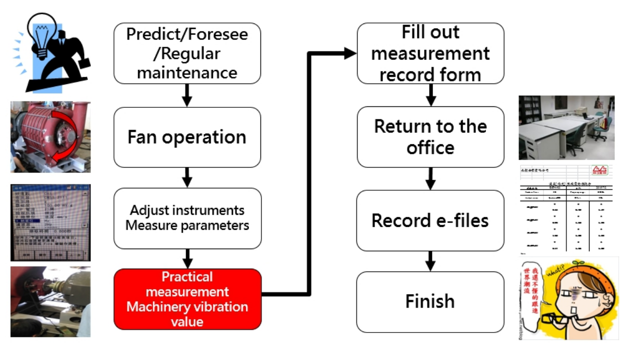

Fig. 1. The maintenance procedures of rotating apparatus.

Order analysis is a very effective method for the rotational analysis of non-stationary in rotating apparatus. However, the use of order tracking methods alone with performing dynamic signal analysis results in inadequate signal resolution following Fourier transform spectrum analysis. Thus, the traditional FFT order tracking algorithm can easily cause undesirable smearing while order analysis cannot improve the resolution of each harmonic order. Hence, an advance order tracking integrates the Recursive Least-Squares Method and the Recursive Kalman Filter [2,3]. Spectrum analysis of Acoustic signals, and to identify signal signatures as a means of diagnosing faults [4]. However, vibration sensors typically are more sensitive to low frequencies [5], limiting their utility in early fault detection for rotating apparatus. Furthermore, Acoustic signals have better frequency resolution at medium and high frequencies bandwidth. Two algorithms that acoustic enhancement filter and adaptive order analysis was implemented early fault prediction [6].

General digital communication processing method was focused on feature extraction and low frequency of acoustic signals. In addition, the cepstrum coefficient representation can be widely used and known as an MFCC) [7]. It can be used to separate the components of acoustic signal convolution for the rotating apparatus. This technique utilizes an MFCC algorithm, the information of rotating apparatus measured by an array microphone. It is implemented on an NI compact RIO 9067 embedded platform for evaluating the performance. Acoustic signals provide the wide bandwidth information for feature extraction and the fault to be find out early.

For the nonperiodic dynamic signal, it relies mainly on the MFCC algorithm along with the acoustic signal to perform abnormal feature analysis for early diagnosis of the failure. It is an innovative method for predictive maintenance in rotating apparatus. The proposed is carried out real-time analysis and prediction of rotating apparatus conditions before failure occurs. Unexpected failure of crucial rotating apparatus can be prevented through the development of a fault prediction system better able to identify preliminary damage. Experiments are implemented to estimate the proposed system with practically running tests. Regulating or modifying the parameters during driving processes avoids can prevent accidents efficiently.

II. Signal Feature Extraction Theory

The acoustic signals of rotating apparatus must be calculated, and then one transfers the discrete time signals to spectrum domain. The cepstrum of a signal is defined as

, (1)

where the is the spectrum.

We extracted the sensed signals and proceeded to signal preprocessing. A discrete cosine transform (DCT) of the mel-filter outputs is shown as

, (2)

the mfcc[n] is evaluated for a number of coefficients N_{mfcc}. All of these are crucial algorithms to the proposed prediction system which requires immediate response and can effectively and accurately detect abnormalities.

III. Result and Verification

This study is mainly based on applying a digital MFCC algorithm and uses the acoustic sensors. To sense signals to extract and analyze then determine, figure 2 shows the rotating apparatus experimental structure. Acoustic signals are measured by using an array microphone located close to the rotating apparatus. The system module is an embedded 667MHz CPU with four 24-bit analog I/O channels by using an MFCC filtering algorithm. The specification of the microphone sensor used is shown in Table. The experimental structure in figure 2 can be operated in the central control room or on smart networked devices for remote monitoring.

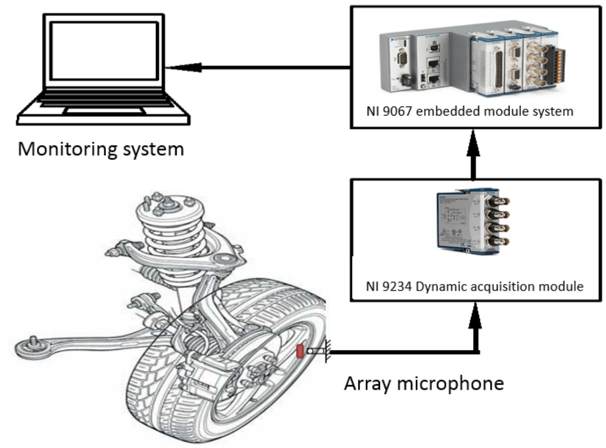

Fig. 2. Rotating apparatus experimental structure.

TABLE I. The specification of array microphone

Type	Frequency response	Sensitivity
PCB 130E20	20 to 10k Hz	45 mV/Pa

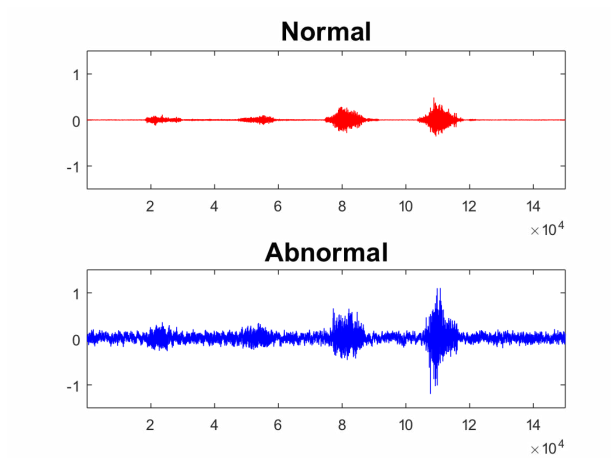

Fig. 3. Raw data information of normal and abnormal conditions.

The acoustic signals are simultaneously sampling to be acquired with shown as figure 3. The signal preprocessing procedures and their individual signal waveform variations are described as follows. We applied the Hanning window with a certain bandwidth. AST to perform real-time computing was early find out the abnormal features, figure 4 shows the experimental results; the dash line shows the power energy spectrum of abnormal condition even more than normal. This study applied an MFCC algorithm with the array microphone sensor, then to predict the rotating apparatus all conditions.

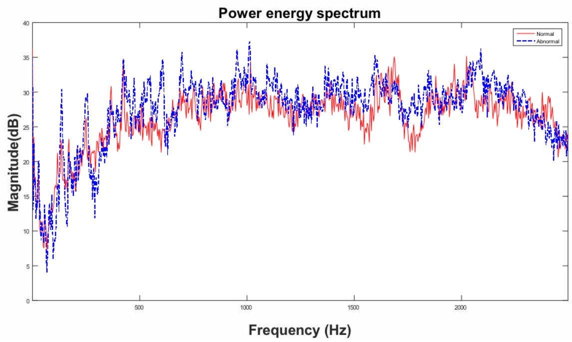

Fig. 4. Comparison of normal and abnormal condition of rotating apparatus.

CONCLUSION

Online rotating apparatus fault feature extraction based on acoustic signals. The proposed method was successfully applied to perform early fault detection on rotating apparatus, using acoustic sensor with better sensing resolution frequency bandwidth features. Popular modern embedded system provides real-time collection and computation of wide bandwidth acoustic raw data from rotating apparatus. The system makes good use of acoustic sensor with a digital communication processing technology to detect abnormal features. It is effective for predicting early stage abnormalities in rotating apparatus. Experimental results show that the acoustic signal and MFCC filtering analysis method could effectively perform real-time early fault detection and prediction on rotating apparatus. In addition, this embedded system can also allow for the use of smart controls and remote monitoring via networked devices. It can be instantly adjusted in response to fault signs to prevent production downtime and to reduce maintenance costs.

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