REVIEW ON VIBRATION SENSOR BASED MONITORING SYSTEM FOR FAULT DETECTION IN MECHANICAL INSTRUMENTS USING LABVIEW

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Abstract—This system is a portable multi-function monitoring system that bridges the gap between the overall level vibration meter. Vibration meter is converted into LabVIEW based system. This system can do FFT data analysis and collection. It is a complete machine condition diagnostic tool that produces results on computer. It is designed for the technician, engineer and consultant who require portability; they can use and speed to identify prime machinery faults without taking expensive delicate instruments to plant sites. This is an industrial product that is used for system monitoring. In this we can find the mechanical instrument working properly or not based on the FFT of sensor output. By using some standard values we can find the fault in the mechanical instrument.

This monitoring system identifies machine faults like Unbalance, Looseness and Alignment. An anti-friction bearing health level indication is also incorporated. This single system undertakes overall Vibration Measurement means acceleration, velocity, displacement, FFT Spectrum, Time Wave Form, Diagnostics and Temperature.

Keywords—Vibration Measurement, Accelerometer, LabVIEW Software, spectrum analysis, Arduion board, NI-VISA DRIVER

I. INTRODUCTION

In the field of machine monitoring, the analysis of the vibration is very effective. In fact, each machine defect produces vibrations with distinctive characteristics that can be measured and compared with reference for fault detection and diagnosis. Both time domain and frequency domain methods can be used to analyses vibration signals. The time domain approaches provide the physical nature of the vibrations, become practically impossible to analysis in presence of multi-tone vibration signals. Vice versa frequency domain approaches provide the amplitude and phase spectrum to identified the fault and more useful for the vibration analysis [1-3].

Vibration analysis is widely used by industries and researchers to predict the health condition of the rotating machines. The vibrations are usually caused by failures or defective conditions in the electrical or mechanical parts of the machines. In this approach the data recorded by the accelerometer sensors are analyzed to extract out information about the source of vibration. In [6], authors utilized the accelerometer signals to detect the defective bearing and unbalanced load condition on the induction machine. This approach demonstrated an acceptable accuracy in condition monitoring of defective mechanical parts, which can be easily used to develop handheld diagnostic tools for the technicians [6].

This monitoring system is depends upon vibration signal so this system is also called as vibration monitoring system .In Present days, Vibration monitoring and vibration diagnosis of machines are done by Vibration analyzer .This vibration analyzer is portable instrument so we have to take that to near the machine for diagnostic [1].This vibration analyzer is converted into software using LABVIEW so we can do diagnosis without going to near the machine. This monitoring system is based on vibration sensor or acceleration senor.
Vibration sensor gives the output in the form of acceleration. When we take the integration of acceleration we get the velocity and double integration gives the displacement. In vibration analysis, system stability is expressed in the form Fast Fourier Transform (FFT). In this system accelerometer is interfaced with Arduino board. Arduino board is connected with pc using USB. LABVIEW is used for signal analysis and calculate FFT of incoming signal from sensor.NI-VISA driver is used for interfaced Arduino with LabVIEW.This system also measures the Temperature. This monitoring system identifies prime machine faults: Unbalance, Looseness and Alignment.

II. RELATED WORK

A. SENSORS

After reviewing many articles in this area, few papers show that 3 axial Accelerometer as a reliable vibration sensor.ADXL 355 is one of the 3 axial Accelerometer sensors. Other sensors like MMA7455L 3-Axis digital Output Accelerometer sensor, capacitive type MEMS Accelerometer has been used as vibration sensor [8].

MMA7455L 3-Axis digital Output Accelerometer sensor can sense acceleration in between ±0.0156g and ±8g (where 1g = 9.81 m/s²).

B. METHODS OF DATA ACQUISITION IN LABVIEW

The data acquisition is used to measures different types of electrical and physical values like Voltage, Current, pressure and Temperature.PC-based data acquisition uses a combination of hardware and software. While each data acquisition system is defined by its application requirements, every system shares a common goal of acquiring, analysing, and presenting information. Data acquisition systems contain signals, sensors, actuators, signal conditioning, data acquisition devices, and application software.

There are different types of data acquisition systems like NI-DAQMX, NI-ELVIS and NI-VISA. All these system gives input/output in the form of analog and digital. Difference between these systems is only cost. Cost of NI-DAQMX, NI-ELVIS are very high as compare to NI-VISA because it’s required only Arduion board for interfacing. So cost of Arduion board is very less as compared to other data acquisition system. NI-VISA use to communicate with most instrumentation buses including GPIB, USB, Serial, and Ethernet.JKI Software’s VI Package Manager (VIPM) makes using and distributing an NI LABVIEW add-on simple. With VIPM, it is easy to manage and share reusable VIs across multiple projects.

C. METHODS OF FEATURE EXTRACTION

Different methods for analysis of vibration signal for fault detection.

Methods -
I. FAST FOURIER TRANSFORM [FFT]

FFT is gives the frequency domain representation of time domain signal. The time domain signal is nothing but vibration signal which is taken from accelerometer. The FFT is faster version of discrete Fourier Transform [DFT].

The N point DFT of a signal

$$X[k] = \sum_{n=0}^{N-1} x[n]e^{-i(2\pi/N)kn}$$

(1)

IDFT,

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] e^{i(2\pi/N)kn}$$

(2)

Where N is number of point for calculation of DFT.$X[k]$ is frequency domain signal and $x[n]$ is discrete time domain signal. For direct calculation of N point, DFT required $N^2$ complex
multification and \( N(N-1) \) additions. For this calculation required more time. Due to this we use FFT. For calculation of \( N \) point, FFT required \( \frac{N}{2} \log_2 N \) complex multification and \( N \log_2 N \) additions.

II. WAVELET TRANSFORM

A wavelet is a mathematical function used divide a given function or continuous time signal into different scale component. A wavelet transform is representation of function by wavelets. In wavelet transform signal is converted into scale and translated version of mother wavelets. Wavelet transform gives 3 dimensional information of any given signal. This 3 dimensional information is nothing but time, amplitude and frequency. Wavelet transform has very high time resolution and very high frequency resolution [11].

Mathematical expression for wavelet transforms,

\[
X_{WT}(\tau, s) = \frac{1}{\sqrt{|s|}} \int_{-\infty}^{+\infty} x(t) \psi^* \left( \frac{t-\tau}{s} \right) dt
\]  

(3)

Wavelet transform is very suitable for study the local behaviour of the signal for example discontinuity or spikes. Some mother wavelets are Haar, Shannon or Sinc, Mexican Hat, Gaussian. Figure 1, 2, 3 shows some mother wavelet.

Figure 1 Haar wavelet

Figure 2 Shannon or sinc wavelet

Figure 3 Mexican Hat

Figure 4 Gaussian

Fast Fourier Transform (FFT) is an important algorithm in the field of digital signal processing (DSP) to compute the discrete Fourier transform (DFT Fourier analysis) involves representing a signal as the summation of its constituent sine waves at various frequencies. If a signal contains a transient of a finite time interval, its Fourier transform includes the contribution from the transient pulse, but the information about the transient is lost on the time axis. However, only wavelet analysis can adequately handle signals with transients that have both high and low-frequency components [11]. Wavelet analysis accomplishes this by dividing a signal into shifted and scaled versions of a fixed function, the original (or mother) wavelet. Thus, wavelet analysis eliminates the restrictions of Fourier techniques by considering a signal locally i.e., in time and frequency by “windowing in” only on a small portion of the signal. So wavelet analysis better than FFT for vibration analysis. But present day’s vibration analyzer is based on the FFT. Wavelet transform is not used in any analyzer so we can add this feature extraction technique in this monitoring system.
III. MONITORING SYSTEM BLOCK DIAGRAM

![Block Diagram of Monitoring System](image)

Figure 5 block diagram of monitoring system

Monitoring system contains sensors, hardware and software part. Acceleration sensor or vibration sensor is used for analysis of fault. Vibration sensor gives the output in the form of acceleration. When we take the integration of acceleration we get the velocity and double integration gives the displacement. In vibration analysis, system stability is expressed in the form Fast Fourier Transform (FFT). In this system accelerometer is interfaced with Arduino board. Arduino board is connected with pc using USB. LABVIEW is used for signal analysis and calculate FFT of incoming signal from sensor. NI-VISA driver is used for interfacing Arduino with LABVIEW. LABVIEW GUI includes graph of time domain signal, graph of frequency domain signals, peak to peak value, RMS value of signal.

IV. SETUP PROCEDURE FOR LABVIEW AND ARDUINO INTERFACING

1. Install LABVIEW
2. Install the NI-VISA drivers.
4. Install the LABVIEW Interface for Arduino using VI package manager.
5. Connect your Arduino to your PC.
   (The firmware can be found in <LABVIEW>\vi.lib\LABVIEW Interface for Arduino\Firmware\LVIFA Base. Use the arduino IDE to deploy this firmware to your Arduino.)
7. Run the arduino file in LVIFA_Base.

V. FEATURE DETECTION AND ISO STANDARDS

In this system, output of sensor is in time domain. When we calculate the FFT of signal we get some amplitude at particular frequency. Amplitude is nothing but Acceleration. This acceleration is converted into velocity and displacement by taking integration of acceleration. These are the feature for analysis of fault in mechanical instruments. These features are compared with ISO 10816 standard data sheet [9]. This sheet provided standard values of acceleration, velocity and displacement. Using this sheet we decide the fault in system.
VI. EXPERIMENTAL RESULT

Neelam Mehala and Ratan Dahiya show a comparison between spectrum of healthy rotor bar and broken rotor bar in paper [10]. The spectral analysis clearly shows that some spectral component is present in broken bar spectrum. The power-spectrum magnitudes of left sidebands are shown that the healthy and broken rotor bar have −44 and −7.5 dB, respectively. In addition, the power spectrum magnitudes of the right sidebands are −26 and −6.5 dB, respectively [10]. So spectrum analysis is useful for fault in broken bar, bearing.

![Figure 6 ISO standard 10816 data sheet](image)

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<tr>
<th>Machine</th>
<th>Class I small machines</th>
<th>Class II medium machines</th>
<th>Class III large rigid foundation</th>
<th>Class IV large soft foundation</th>
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</table>

![Figure 7 spectrum of healthy rotor bar](image)
VII. CONCLUSION

In this paper, the authors have proposed a LABVIEW based vibration monitoring system. Interfacing of Accelerometer sensor with Arduino-derived microcontroller board has been explained. The setup procedure is explained for interfacing of Arduino and LABVIEW. Graphical user interface was developed using National Instruments’ LABVIEW software for vibration monitoring. In this paper explain the different types of feature extraction techniques like FFT and Wavelet transform.

REFERENCES