International Journal of Engineering & Technology, 7 (3.27) (2018) 170-173

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Virtual Instrumentation Programming and Psoc Embedded Design for Bearing Fault Detection: Uses Impulse Excitation Technique

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Abstract

This paper describes, a novel innovative design for generating vibration signals in a bearing, which is in static mode not in dynamic mode like other usual measurements reported in literatures, for various types of bearing faults analysis supports users with a technique based on monitoring vibration signals. This paper reports the computed power spectrum from vibration signal clearly identifies the fault signature with its raise in amplitude. Hence, in an impulse excitation technique vibration analysis with computed power spectrum provides an efficient monitoring of fault in axle bearings in a short timing. Programmable System on Chip (PSoC) creator design and Virtual Instrument program written in LabVIEW, a graphical language, provides efficient implementation of impulse excitation technique possible in static test method in a minimal time.

Keywords: *Programmable System on Chip (PSoC), Virtual Instrument programming (VI), Impulse Excitation Technique (IET), Bearing Fault detection.*

1. Introduction

Bearing faults causes mechanical imbalances in a system, calls for maintenance in industries, R&D labs and house hold operated electric machines, challenges for cost and maintenance savings. Motors are still the heart of any rotating electric machines in industry, due to their cost effective, ruggedness, and reliability in nature. Mostly main cause faults in rotating machinery are fault in rotating bearing. Hence maintenance is required in regular intervals. Mechanical systems vibration monitoring, analysis and technique to predict and detect the faults in the systems is an essential requirements. So the main purpose of this work is to find out the fault in the system by monitoring vibration signal and rectify it with proper action. This requires vibration signal of the system to be processed acquired with suitable sensor like piezoelectric, accelerometer etc and analyzing it by compute the spectrum analysis. It has complexity in finding the exact fault from vibration signal alone. An efficient method to be carried out for vibration signal monitoring. Most of the works are done in MATLAB programming language in complex code writing. Even though many bearing fault diagnosis techniques are available but still there is a need of a comprehensive method to be developed for accurate detection of the fault. Several methods have been proposed in the literature for bearing fault detection [1,2]. However, an effective bearing fault diagnostic technique is critically needed to support industries for the detection of faulty bearing so as to prevent system performance degradation and malfunction. In this paper MEMS accelerometer interfaced with PSoC microcontroller with its creator tool, the vibration signal obtained by impulse excitation (*Impulse Excitation Technique, IET, is based on the analysis of the vibration signal from a test sample by 'impulse excited' i.e. gently tapped. The resonance frequencies are the main characteristics for the test element, as they are related to its stiffness, mass and geometry.[3]*) of bearing inner race by a tiny hammer automated with LabVIEW program, which plays a vital role in identifying the bearing faults by computing the averaged auto power spectrum of time signal obtained from MEMS accelerometer.

2. Indigenous Test Bench Design

This design carries out its measurements on the short transient vibration resulting from the mechanical disturbance in the test object caused by striking the test object with a small hammer. In operation, an accelerometer, a MEMS sensor, is mounted on outer surface of the test material, viz., ball bearing, to pick up and to measure vibration signals as a function of time, which can provide information on health condition of bearing under test. Fig.1. shows he block diagram and principle of Impulse excitation technique used for bearing fault detection.

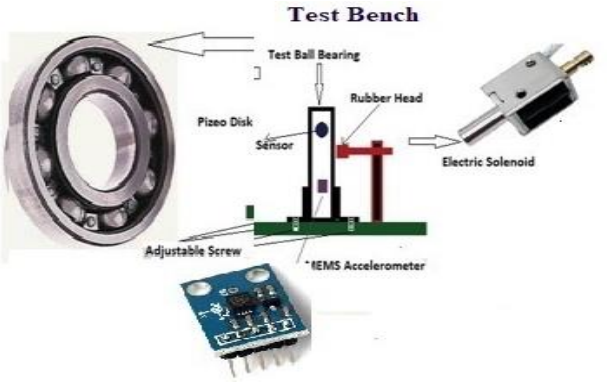

Fig. 1: Block diagram of impulse excitation technique used in bearing fault detection system

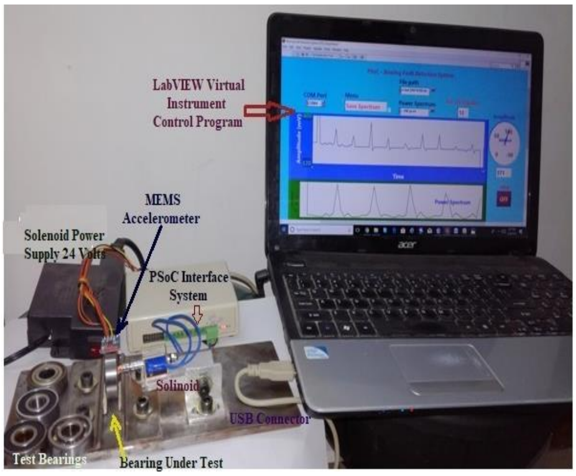

Fig. 2: PSoC based embedded automated test bench supported with LabVIEW virtual instrument program for bearing fault detection system

Fig.2 shows the design automation of an indigenously fabricated test bench, has mounting clamp to mount the bearing under test. An electrically operated solenoid mounted in a test bench, act as a hammer, such a way, to adjust its rubber mounted tip to strike the inner race of test bearing gently. In this setup ADXL 335, tri axial accelerometer [4] is used to acquire the vibration signal from bearing housing, the bearing under test are mounted on the test bench and the accelerometer is mounted on the top of the bearing outer race as shown in fig.2.

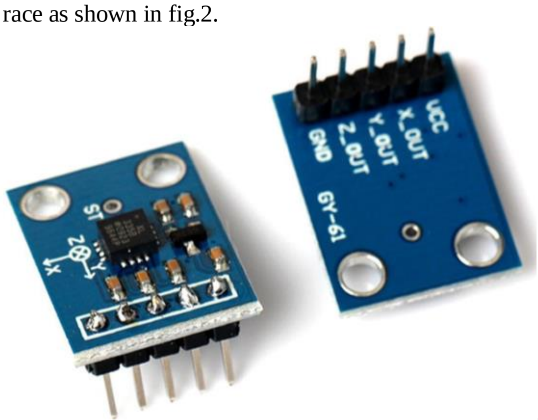

Fig. 3: Photograph of analog device make ADXL335, tri axial accelerometer top and bottom view [4]

3. Programmable System on Chip (Psoc) Creator Design

In order to acquire data from the accelerometer interfaced with Programmable System on Chip (PSoC) microcontroller based embedded interface design, interface to personal computer (PC) through its USB_UART port for collecting vibration signal from MEMS accelerometer and activating the solenoid for providing striking impulse to the test bearing. Fig.3 shows the accelerometer used for acquiring vibration signal from test bearing. Embedded design automation, which enables this innovative approach possible, using PSoC Creator 3.0 is shown in fig.4.

In a PSoC creator design, a Delta sigma ADC of 12 bit resolution is used with built-in buffer of gain 2, for digitizing the vibration signal obtained from MEMS accelerometer, a PWM, (pulse width modulator) is used to simultaneously activate the electrical solenoid (striking hammer) while ADC acquires signal, a USB_UART module for communication to PC and LabVIEW program to handle the acquired vibration data and LCD module for on-line displaying the vibration data. Annexure –A shows the C-coding list of PSoC Creator program.

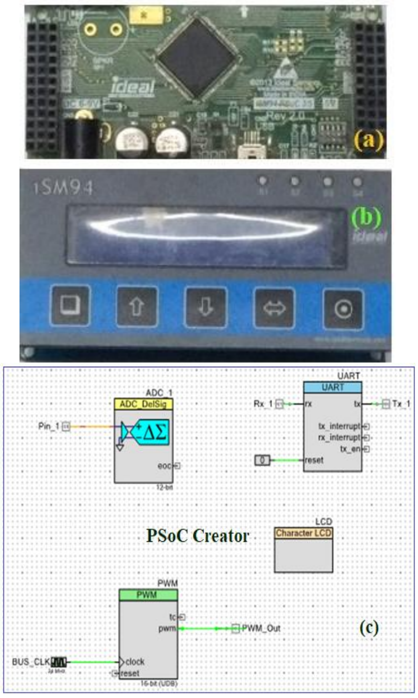

Fig. 4: (a) and (b) PSoC 3 Board and LCD Display, (c) PSoC Creator program for this design automation

4. LabVIEW Programming

Virtual instrumentation (VI), a graphical language, mimics a process control automation which are in remote area, has encompassed the area of computer based automation, with minimal hardware and maximum support of software. This enhances VI as the dominant instrumentation applications and sensor interface systems[5]. LabVIEW, Laboratory Virtual Instrumentation Engineering Workbench, can be interfaced with many intelligent hardware such as Programmable system on chip (PSoC), Microcontrollers, FPGA, VLSI design based embedded system etc. LabVIEW is a development environment based system design platform working on the concept of data flow technique and allows he designer to create programs with graphical icons instead of text based programs. Data acquisition systems, monitoring and controlling the system parameters, data analysis are easily possible with LabVIEW. Hence, LabVIEW is used to simulate the vibration signal for testing and also processing the vibration signal. A Virtual instrument menu driven graphical program written in LabVIEW resides in PC memory, acquire the vibration signal, and does online plotting of vibration signal as a function of time and auto computed Power Spectrum from the acquired vibration signal. An indigenously developed mechanical platform interfaced with PSoC embedded design and LabVIEW virtual instrument program (VI), for testing bearing healthy condition by exploiting Impulse excitation technique (IET)], in a static condition of motor of any rotating element. The Impulse Excitation Technique constitutes a fast and easy to implement technique to determine elastic properties of materials. Also composite materials can be measured easily with this technique.

Fig.5. shows the front panel diagram and fig.6a shows function pallet diagram of virtual instrument user-friendly menu driven program written in LabVIEW, a graphical language. Menu driven program includes, (1) VISA configuration of USB port for enabling communication between PSoC design and LabVIEW menu driven program residing in PC, (2) User required menu selection button to select Measurement mode, Save data mode, Load data from saved file location and Clear Graph etc, (3) File path selection for data storage and (4) Number of Impulse required for the measurement, i.e., striking inner race of bearing with solenoid mounted hammer and acquiring vibration data from MEMS accelerometer, ADXL335 as a function of time.

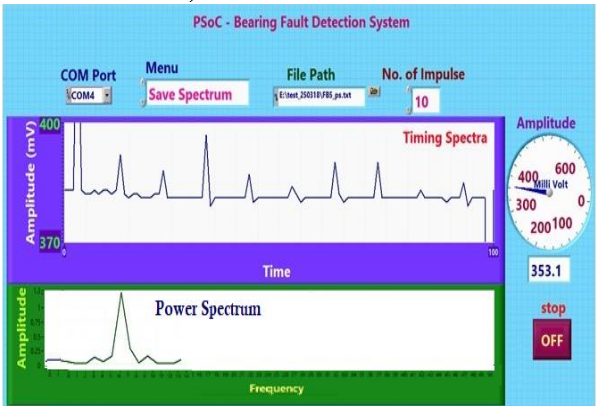

Fig. 5: Front panel diagram of LabVIEW, graphical language, menu driven program for automated bearing fault detection system

In fig.5, top graph shows the online acquisition of vibration data as a function of time, acquired from MEMS accelerometer and the bottom graph shows the online Power Spectrum computed with acquired vibration data online from first graph (passing through Power Spectrum pallet, fig.6b, in LabVIEW program). With this icon, the averaged auto power spectrum of time signal can be computed the from the vibration data acquired from MEMS accelerometer.

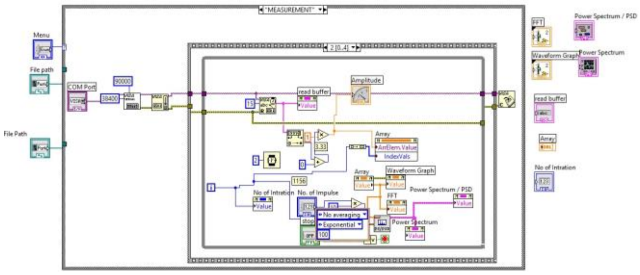

Fig. 6a: LabVIEW program function pallet diagram

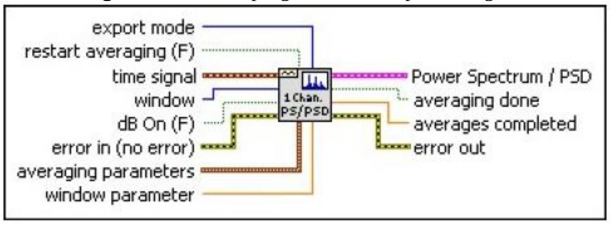

Fig. 6b: LabVIEW power spectrum pallet plays a major role in this IFD for identifying fault signature

5. Results and Discussion

Fig.7(a) is the vibration signal acquired from MEMS accelerometer as a function of time, fig.7(b) is auto computed online Power Spectrum (PS) obtained through LabVIEW Palette (i.e., Power Spectrum.vi), for 10 excitation (i.e, for 10 impulses to the bearing under test), computes the averaged auto power spectrum of time signal obtained from MEMS accelerometer. The power spectrum (fig.7b) provides clear signature of faulty and good bearing in all cases tested. Since it reflects the energy spent by fault bearing is larger compared to the smooth and lesser energy consumed good bearing for the given excitation, i.e, for an impulse. A number of test were carried out, with HCF make model number 6201-2RS (brand new as well as faulty bearing of same make and size. A good bearing from working system also tested), to establish a simple and effective approach in detecting faulty bearings using a indigenously designed customized bench top monitoring system. Defective bearings increase the amplitude of the peaks in the power spectrum after FFT is carried out which indicates the presence of the defect (as shown in fig.7b).

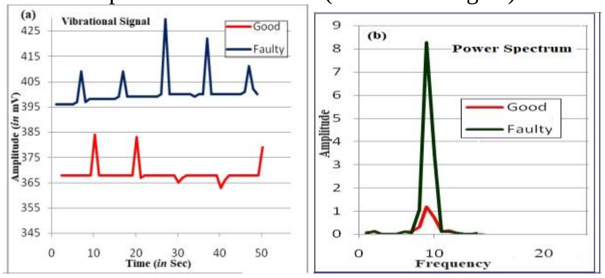

Fig. 7: (a) Vibration Signal acquired from MEMS Accelerometer for excited impulses, (b) Auto computed FFT Power Spectrum in LabVIEW of Vibration Signals acquired for two bearings (good - red trace and faulty - blue trace), of same size and make (HCH 6201-2RS).

Fig.8. shows the auto computed power spectrum of vibration signal acquired through MEMS accelerometer as a function of time for two good bearings, in which one is old and in usage (shown in Blue trace) and other one newly purchased bearing of same model, make and size. The old functional bearing (Blue trace) shows fluctuations in base line indicates its depreciation due to ageing factor, even though it is functional. Both the bearing peaks are same, hence confirms no faulty signature.[6]

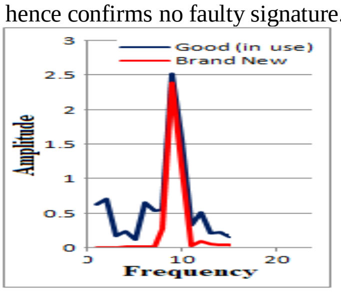

Fig. 8: Auto computed FFT Power Spectrum in LabVIEW of Vibration Signals acquired for two Good bearings (Good in use - Blue trace and Brand New - red trace), of same size and make (HCH 6201-2RS)

6. Conclusion

Major advantage with this novel test bench is: it identifies good and faulty bearing within a short while, less than a minute. The test bench has the facility to adjust the mechanical mounting clamp for various bearing size also for easy mounting and demounting from test bench. The electrically operated solenoid mounted with flexible adjustment in such a way to strike gently with the rubber head on the inner race of any dimension of bearing, to enable the triggering impulse to the bearing for its measurement of vibration, the vibration signal amplitude varies for good and faulty bearing, which is the main idea of this design.

Also with this setup, original make bearing can be identified with its resonance frequency in power spectrum, which can support to get quality bearing from market while purchase. The main advantage in this non-destructive testing is a fast diagnostics and testing of any size of bearing, also without disturbing the existing machine, the measurement can be carried out by properly mounting the accelerometer and the electrical hammer supported by solenoid.

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Annexure-A

PSoC Creator Programming Code for Bearing Fault Detection System

```
/*
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 *
 *Design Engineer: J.J.Jaykanth. Dept. of Mechanical Engineering,
 *Vels Institute of Science, Technology & Advanced Studies (VISTAS).
 *Chennai. Tamil Nadu. India.
 *Project Title: Embedded PSoC Bearing Fault Detection System.
 *
=====================================================
==============
*/
#include <project.h>
#include<stdio.h>
#include <device.h>
void main()
{
   int16 output;
   char8 res[10];
   CyGlobalIntEnable;  /*necessary to use this for usb_uart*/
   LCD_Start();
   PWM_Start();     /* PWM is Used to Activate Relay Operation for
                   Solenoid ON/OFF,Its an arrangement for Hammer,
                        which will strike inner race of Ball Bearing Under
                   Test. PWM ON time and OFF time configured in the
                   Creator design */
   ADC_1_Start();
         UART_Start(); /* USB_UART is used for Communication
between Bearing
                  Test PSoC platform and PC */
   LCD_Position(0u,3u);
   LCD_PrintString ("JKs_Bearing Test");
   ADC_1_StartConvert();
  for(;;)
   {
     ADC_1_IsEndConversion(ADC_1_RETURN_STATUS);
     output=ADC_1_GetResult16();
     sprintf(res,"%d", output);
     LCD_Position(1u,3u);
     LCD_PrintString(res);
          UART_PutString(res);
          UART_PutCRLF(0x20);
          CyDelay(5);
   }
}
/* [] END OF FILE */
```