Vibration Measurement System for the Low Power Induction Motor

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Abstract: The vibration as the first indicator of fault is widely accepted and used for condition monitoring of the motors and other machines. The vibration signature allows detecting many faults at their inception and allows avoiding damages which may occur due to faults like long running of the motor. Tri-axial MEMs accelerometers are widely used for the vibration measurement because of its low cost and ease of use. The low power induction is found in household and small industry applications. With the passage of time, these induction motors get faulty in terms of functionality and may lead to severe damage. Hence, low power induction motor monitoring is very important in order to avoid major damage. In this paper, vibration measurement system for the household and small industry induction motor is presented. The reported measurement system is an inexpensive and easy to implement. The vibration measurement system is developed using a small scale induction motor, Raspberry Pi 3B, and ADXL345 accelerometer.

Keywords: *Vibration, Condition Monitoring, Induction motor, MEMs accelerometer*

1. Introduction

The single-phase induction motor is widely used in household and small industry applications. Most common applications are the washing machine, water pump, blower, compressor, fans, elevator, conveyor belts, and machine tools like drills, lathes, and mills. The induction motors in these applications lose efficiency and generate vibrations due to aging, continuous running, friction, wear-tear and design-manufacturing flaws. With the time, induction motors starts producing vibration, temperature, sparks and also causes an increase in power consumption. Sometimes, induction motors generate serious damage like short circuit which can affect surrounding objects. Hence, it is essential to monitor induction motor vibration in the household and industrial settings [1].

The Vibration based condition monitoring includes signal acquisition, signal transduction followed by diagnosis and prognosis which is done through computational analysis [2]. In order to measure the vibrations of different systems, different sensors have been used in terms of cost, efficiency, power, size, and reliability. In recent times developments, MEMs (Micro-Electromechanical Systems) have got popularity and are widely used because of its advantages low cost, lightweight, small volume, low power consumption, shock tolerance, and high reliability. MEMs allow an easy interface between software and hardware that’s why it is a favorable method for many practical applications [3].

A vibration measurement system has been developed by Viral K. Patel and et al. [4] using Arduino microcontroller and a tri-axial digital vibration sensor. The developed system could acquire and store data locally. In [5] Chinedum Anthony Onuorah and et al. have presented an economic and portable vibration monitoring system using an accelerometer and a microcontroller board. The system performance was validated through assessment of vibration data. In [6] authors have studied and developed a Raspberry Pi and ADXL345 based vibration acceleration monitoring system. The authors have provided a general purpose and low-cost vibration measurement system.

This paper presents a vibration measurement system for the low power induction motor using Raspberry Pi and ADXL345 vibration sensor. The paper also includes characterization of the tri-axial vibration sensor which makes it more reliable and efficient in terms of the performance.

2. Material and Method

The components and methodology of the developed system are discussed as under:

2.1. Material

The vibration measurement system comprises of a small scale induction motor, Raspberry Pi, ADXL345 accelerometer, monitor, keyboard, mouse and some connecting wires. The details of each component are given as under:

2.1.1. Induction motor

A low power induction motor is used for the vibration measurement system. The specification of the motor are provided in the below given table:

Table. 1. Induction motor specifications

S. No.	Metrics	Value
1	Horse Power	0.5
2	Input voltage	220~230 V
3	RPM	1450

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4	Phase	1
5	Input current	3 A

2.1.2. Vibration sensor

The vibration sensor used for the system is ADXL345, a tri-axial digital vibration sensor. The sensor provides three axis vibration in the x, y, and z respectively. The ADXL345 is a low power, low weight, small size, and low cost vibration sensor. It has a high resolution of 13-bit and can measure up to ±16 g. It supports both the SPI and I2C digital interfaces. It can measure both the static and dynamic acceleration of gravity depending upon the application. The specification [7] of ADXL345 are given in the following table.

Table. 2. ADXL345 specifications

S. No.	**Metric**	**Value and unit**
1	Operating voltage range	2.0 to 3.6 V
2	Weight	20 m grams
3	Dimensions	3*5*1 mm
4	Operating temperature range	-40 to 85 ℃
5	Sensor input (selectable)	±2 to 16
6	Output Resolution (selectable)	10 to 13 bits
7	Output data rate	0.1 to 3200 Hz

2.1.3. Raspberry Pi

The Raspberry Pi is a Linux based microcomputer. It is low cost but still powerful computer for hobbyists and students. The Raspberry Pi Model 3 B is used for the developed system. This model comes with the 1 GB RAM, 1200 MHz quad-core ARM Cortex-A53 processor, and other functionalities. It has got built-in Wi-Fi and Bluetooth capabilities. It also allows SPI and I2C serial communication.

2.1.4. Software

The data acquisition is done using python programming on the Raspbian operating system. The syntax of python is very easy than other languages like C/C++. The developed system is programmed using some libraries like 'SMBUS' that is used to acquire serial data.

2.2. Method

The vibration measurement system is developed through two parts. Initially vibration sensor is characterized using a characterization system specifically developed for the sensor characterization. Then it was connected with Raspberry Pi and programmed using python. ADXL345 connections with Raspberry Pi board are shown in Figure 1.

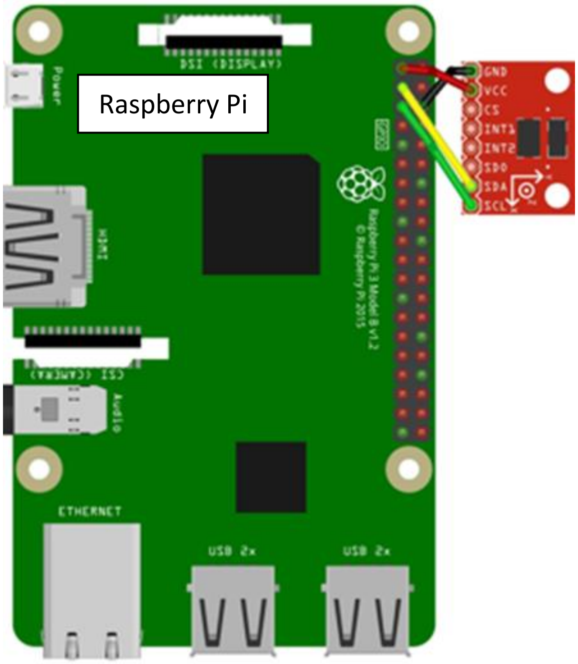

Figure 1. ADXL345 connection with Raspberry Pi board

Both characterization of sensor and data acquisition stages are detailed as under:

2.2.1. Characterization of accelerometer

In order to get accurate vibration data ADXL345 is characterized. The characterization setup shown in figure 2 was developed consisting of protractor block, sensor block and a pointer attached to the sensor block for angle selection.

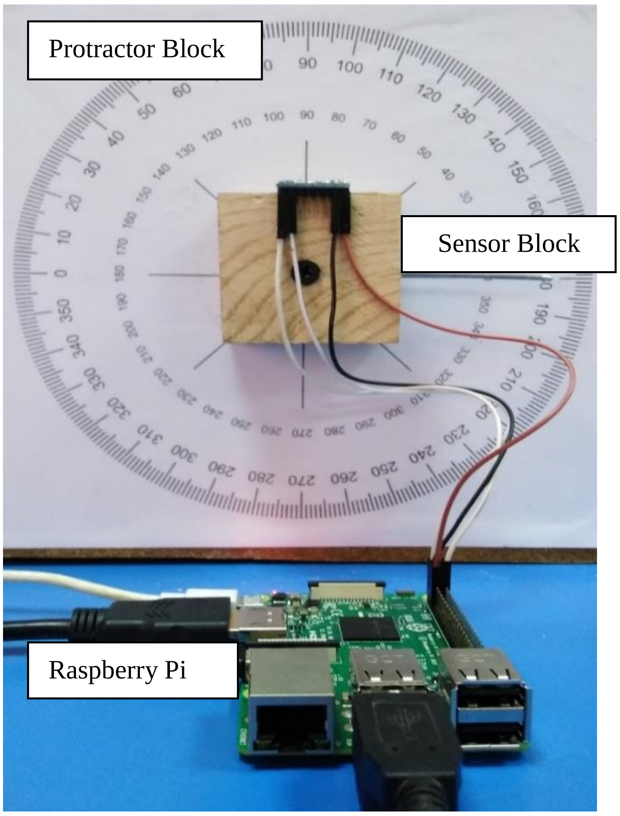

Figure 2. Developed characterization System of accelerometer

The ADXL345 was characterized in two axes x and y receptively. Initially, ADXL345 was attached on sensor block in direction of the x-axis to get the value of the g in the x-direction at which g value in the y-direction was observed constant. Then ADXL345 was attached on sensor block in y-axis to get value of the g in y-direction at which g value in x-direction was observed constant. The readings of the sensor were taken at the variation of 5 degrees in protractor block. The sensor shows the saturation after 75 degrees hence the readings are taken up to the 75 degrees.

The below given graph shows the sensor results along the x-axis. Initially, data do not follow the trend line until 10 degrees after that it follows the linearity. After 60 degrees data again falls below the trend line. The graph includes the R2 (R-squared) value which is quite satisfactory. The R2 is a statistical value which determines the relation of the dependent and independent variables using a regression line. It determines the goodness of the fit statistics by calculating the equation that decreases the distance between the linear line and total data points. The relation would be better the fit; if the R2 value is closer to 1. It visually depicts the reliability of the data by drawing a regression line. It also allows to find the equation of the relation. The R2 value is for the x-axis data is near to 1 which depicts a better fit in terms of the linearity.

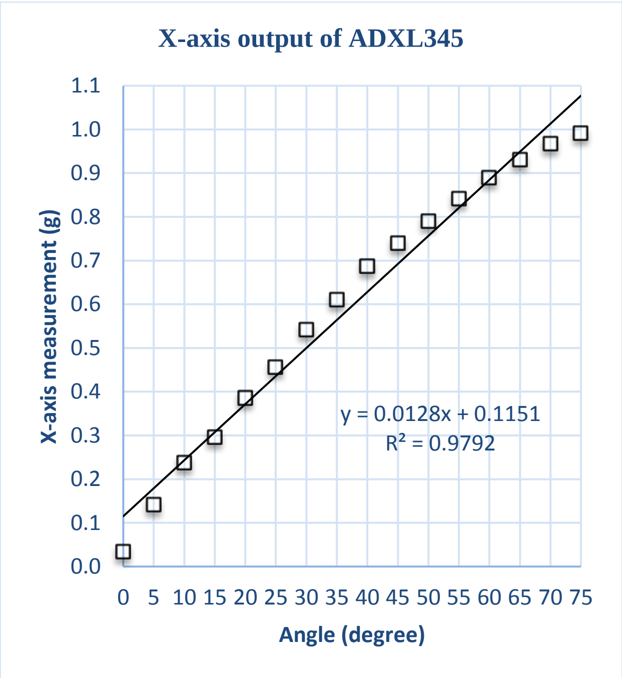

Figure 3. ADXL345 data for the x-axis

The second graph shows the sensor readings for the y-axis. From beginning, data do not follow the linearity but from 10 degrees it starts following the linear regression line till 65 degrees after that it deviates from the linear line. The R2 value for Y-axis data of the ADXL345 is also close to l which means it can also be considered as a reliable data in terms of the linearity.

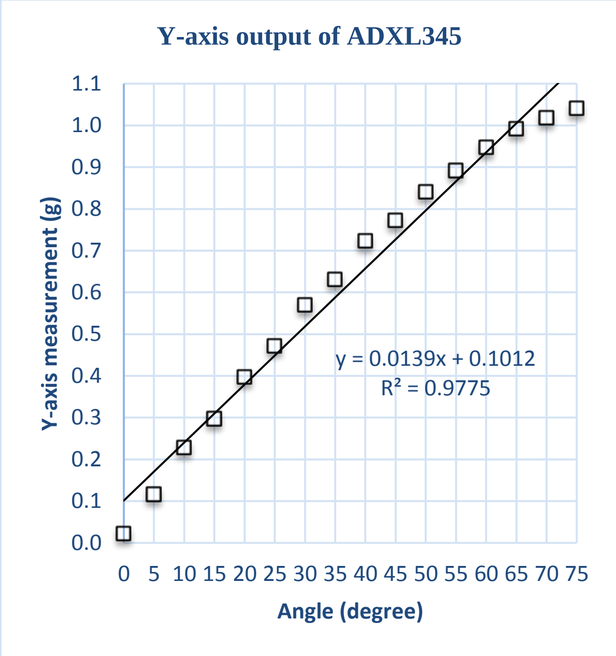

Figure 4. ADXL345 data for the y-axis

The hysteresis for the data of ADXL345 along the x-axis is shown below.in figure 5. The squares show the increasing order data and crosses shows the decreasing order data. The graph shows the negligible hysteresis at the data points. The maximum hysteresis can be obtained at point (10, 0.208) which are 0.01.

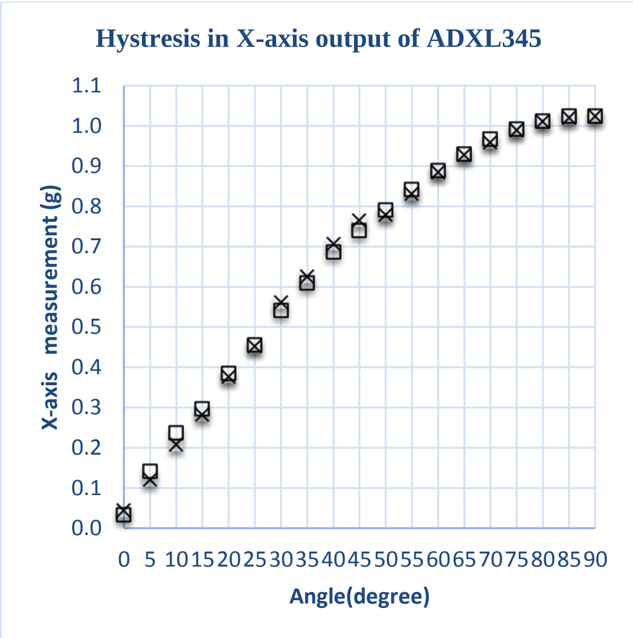

Figure 5. X-axis hysteresis of the ADXL345 data

Figure.6 shows the hysteresis in Y-axis data of ADXL345 data. The maximum hysteresis can be observed at a data point (30, 0.553) are 0.001 which are negligible.

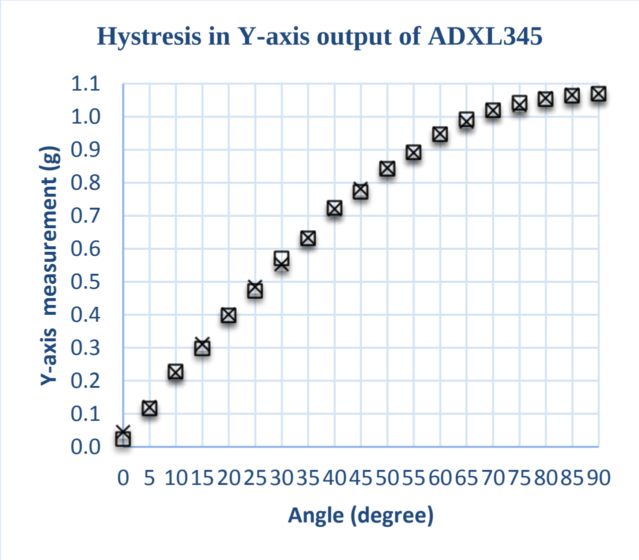

Figure 6. Y-axis hysteresis of the ADXL345 data

2.2.2. Data Acquisition

The vibration data is acquired using Raspberry Pi and ADXL345 with some connecting wires. The system is programmed using python for acquiring serial data from the sensor. The serial data is acquired using I2C serial protocol. The below given figure depicts the complete developed system for vibration data acquisition. The developed system is shown in figure 7.

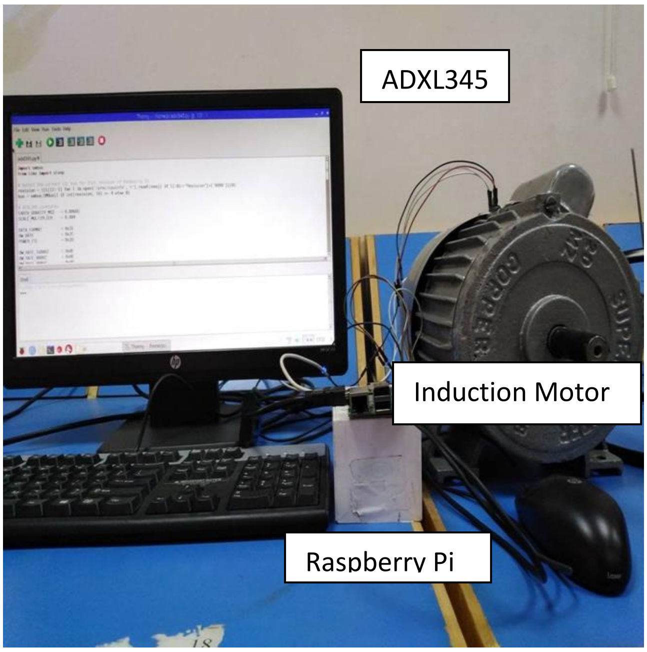

Figure 7. Developed prototype

3. Results

The developed system gives vibration data (g-values) along the three axes x, y, and z respectively. The below given figure shows the console results of the developed system and the data could be saved to the CSV file for further analysis. The vibration data obtained for corresponding three axes is can be seen in figure 8.

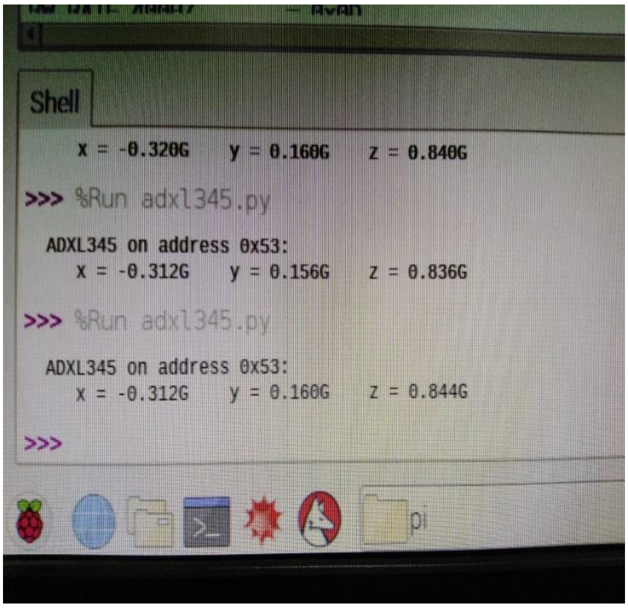

Figure 8. Results on Raspberry console

5. Conclusion

In this paper, a cost effective and reliable vibration measurement system was developed for the low power induction motors. It allows avoiding damages which could occur due to long-running, friction, and other faults. So, the developed system could be used for effective monitoring motors used in elevators, conveyor belts, compressors, and machine tools. Moreover, the developed system could help to avoid faults at their inception as vibration is the very first indicator of the faults. It was observed in this study through the characterization of the sensor that the system give quite satisfactory and reliable results for the vibration. The data analysis graphs show the quite low hysteresis which allows this system to be considered as a reliable vibration measurement system. The components used in the system like Raspberry Pi and ADXL345 accelerometer make it cost effective.

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