Internet of Things (IoT) Enabled Vibration Monitoring

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Abstract

Nearly 70 % of machines are driven by induction motors. Their failure incidence is 40% which is mainly due to mechanical faults connected with bearing and rotor. These failures increase vibration levels beyond safety limits. Several research works have focused on vibration monitoring of induction motors. But, a few have worked on remote monitoring of induction motors. The objective of the paper was to develop Internet of Things enabled vibration monitoring system for induction motors. The monitoring system was developed using Arduino microcontroller and ADXL 335 accelerometer sensor. ESP 8266 Wi-Fi module was used to communicate the sensor readings to Blynk IoT platform. The obtained readings were plotted for peak acceleration and the same was compared with the standard vibration severity chart. The experiments were carried out on three different induction motors and in each case real time acceleration data was recorded on the IoT platform.

Keywords: *ADXL 335 accelerometer, IRD Mechanalysis, Blynk, Internet of things (IoT)*

1.0 Introduction

About 70% of industries utilize Induction motors as major tools to drive machines [1]. Faults in induction motors have led to increased downtime affecting productivity of machines [2]. Bonaldi et al. [3] suggested preventive maintenance techniques as simpler and economical means of preventing catastrophic breakdown of induction motors in industrial machines. Nandi et al. [4] have performed condition monitoring of induction motors in real time to detect occurrence of faults. Types of faults in induction motors commonly identified were mechanical faults such as air gap, eccentricity, stator faults and bearing faults. Kande et al. [5] suggested and compared different condition monitoring techniques such as vibration monitoring, acoustic emission monitoring, Multiple Signature Current Analysis (MSCA), and thermal monitoring. Vibration monitoring as a preventive maintenance technique offers advantages of easier mechanical fault detection and economical measuring instruments [6].

Internet of Things (IoT) was used as a tool for remote sensing and monitoring in real time on industrial machines. Sensor data was acquired in real time and pushed to cloud in order to access the data through a smartphone application

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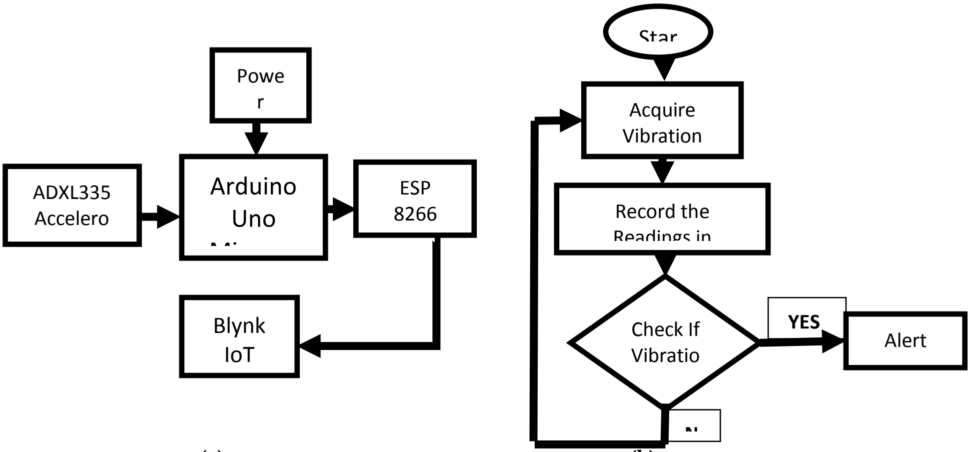
[7-9]. Internet of Things (IoT) based vibration monitoring system was developed to obtain vibration readings in real time to perform fault diagnostics [10]. However, the literature does not mention development of an IoT based system which sends an alert when the vibration levels are exceed a certain limit. Only a platform for monitoring real time data without a control alert has been created. The present work focused on development of an IoT based vibration monitoring system for acquiring vibration data in real time and checking it against vibration severity chart by IRD Mechanalysis Ltd. [11] to detect whether the vibration levels are in safe limits. The system sends an alert notification in the form of an email and short text message to the user if the vibration levels exceed safe limits.

2.0 Experimental Details

The block diagram (Fig.1(a)) shows the major components and sequence of signal flow in the IoT enabled vibration monitoring system. Power supply of 5V is provided to the Arduino microcontroller, which in turn supplies power to the accelerometer and Wi-Fi module. The accelerometer acquires vibration data in the form of acceleration and sends it to Arduino microcontroller. Arduino microcontroller is responsible for calculating absolute acceleration from the three axis acceleration readings and pushing the values in real time to the Blynk IoT platform via ESP 8266 Wi-Fi module.



(a) **(b)**

Fig. 1. (a) Block Diagram of system and **(b)** Process flow chart

Fig. 1(b) depicts the functioning of the IoT enabled vibration monitoring system. The vibration data acquired is compared against threshold values. If the acquired value exceeds the threshold, an alert notification is sent to the receiver, else the system keeps on continuously acquiring and storing data.

The absolute acceleration is determined from the triaxial accelerometer readings using equation (1).

$$A = \sqrt{X^2 + Y^2 + Z^2} \quad (1)$$

where,

X = Acceleration along X-axis in g

Y = Acceleration along Y-axis in g

Z = Acceleration along Z-axis in g

A= Absolute acceleration in g

g = Acceleration due to gravity =9.81 ms^{-2}

In order to determine if the absolute vibration (in g) is safe or not, vibration severity charts are used. IRD vibration severity chart developed by IRD Mechanalysis Limited (Fig. 2) was used.

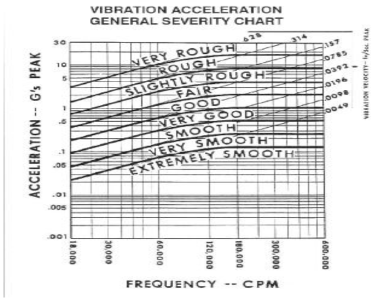


Fig. 2. IRD Vibration severity chart

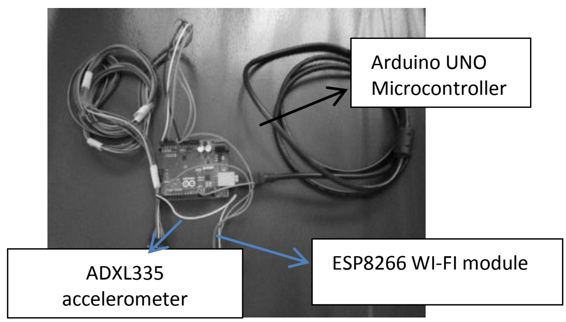


Fig. 3. Circuit setup

IRD vibration severity chart characterizes vibrations based on acceleration in g peak. In general, vibration levels around 1 g is taken to be safe limit. For induction motors, the angular speed in rotations per minute (rpm) is equal to frequency in cycles per minute (cpm).

The developed setup is as shown in Figure 3.The system was tested on three different Induction motors of different machines as follows:

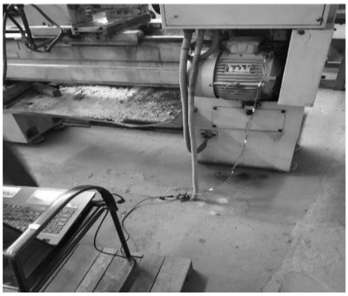
Case 1: Vibration monitoring on Induction motor of a centre lathe machine. The specification of the induction motor of a Centre lathe machine is as shown in Table 1.

Table 1. Specifications of induction motor of a center lathe

Power Supply :	415 V, 11 A
H.P	7.5
kW	5.5
RPM	1450

An accelerometer was mounted at the shaft end (Fig. 4a and 4b). As the mounting should have less damping effect and firm grip, masking tapes were used to mount the accelerometer, which was placed such that the accelerometer's Z direction is collinear with gravitational force. The machine was operated under no load condition at a particular speed.

The vibration data obtained from the machine was captured using accelerometer and pushed to the Blynk platform where the data was presented pictorially.



(a) **(b)**

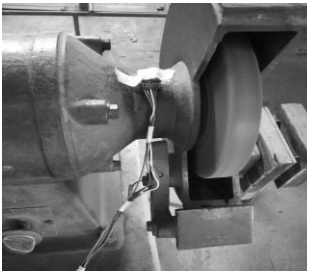
Fig. 4. (a) Experimental setup of Centre lathe and (b) Mounting of the accelerometer

Case 2 Vibration monitoring on Induction motor of a Bench Grinding machine. The specification of the induction motor of the Bench Grinding machine is shown in Table 2.

Table 2. Specifications of induction motor of bench grinding machine

Power Supply :	415 V, 0.9 A
H.P	1
kW	0.75
RPM	2800
SIZE	250 mm

The accelerometer was mounted on the casing of the grinding wheel as shown in Fig. 5a and 5b.



(a) **(b)**

Fig. 5. (a) Experimental setup - grinding wheel and **(b)** mounting of the accelerometer

Case 3 Vibration monitoring on a stand-alone induction motor**.** The specification of the stand-alone induction motor is shown in Table 3.

Table 3. Specifications of stand - alone induction motor

Power Supply :	220 V, 1A
H.P	1
kW	0.75
RPM	4800

The accelerometer was mounted at the shaft end of the induction motor as shown in Fig. 6.

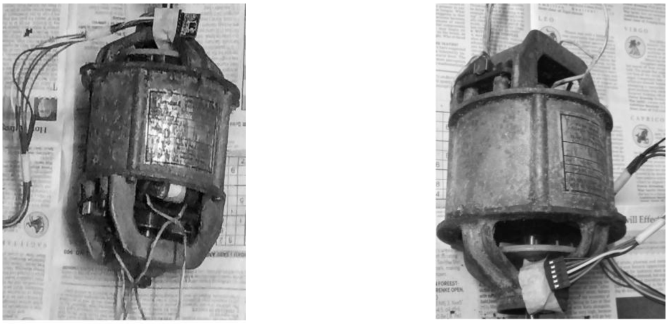


Fig. 6. Experimental setup of a stand-alone motor

3.0 Results and Discussion

The accelerometer readings obtained on performing different experiments (cases 1 to 3) were plotted on the Blynk app platform as shown in Figure 7 to 12. The Blynk platform also allows the accelerometer readings to be exported as a Comma-Separated Values (CSV) document that can be viewed by a spreadsheet reading platform. However, it becomes difficult to convert the data to real time units, as the time is a cumulative value in seconds. Hence, the readings were displayed on the home screen of the Blynk app itself along with the plots. The plots obtained for the experimental cases are follows:

Case 1 Vibration monitoring on induction motor attached to a center lathe

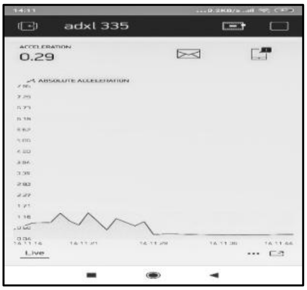


Fig. 7. Absolute acceleration value with graph (case 1)

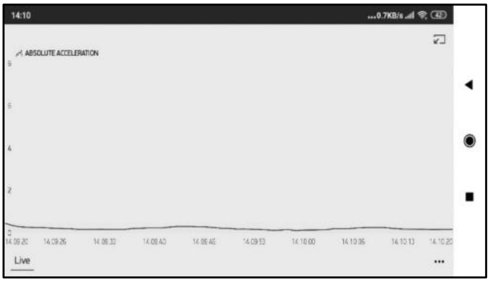


Fig. 8. Landscape view of real time Absolute acceleration plot (case 1)

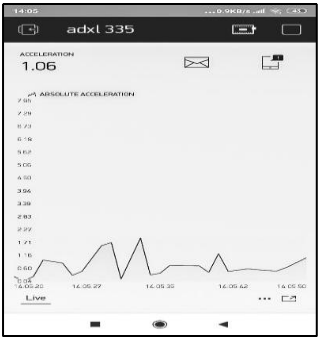
Fig. 7 shows accelerometer readings as absolute acceleration, in units of ‘g’, obtained on performing vibration monitoring on the induction motor of a center lathe machine rotating at an angular speed of 1450 rpm. Landscape view of the plot is shown in Fig. 8.

As observed from the values, the peak value was below 1g. On comparing with the IRD vibration severity chart, it was inferred that the vibration levels were under permissible limit for a frequency of 1450 cpm. As a result, no alert notification was displayed on the screen. Hence, the monitoring goes on continuously.

Case 2 Vibration monitoring of induction motor of a bench grinder

Fig. 9 shows accelerometer readings as absolute acceleration in units of ‘g’, obtained on performing vibration monitoring on the induction motor of a bench grinder machine rotating at an angular speed of 2800 rpm. Landscape view of the plot is shown in Fig. 10.

As observed from the values, the peak value is just about 1g. On comparing with the IRD vibration severity chart, it was noticed that the vibration levels were under permissible limit for a frequency of 2800 cpm. As a result, no alert notification was displayed on the screen. On comparing case 2 with case 1, it was observed that the vibration levels were slightly greater on the induction motor of bench grinder machine (case 2) as against that of the center lathe machine (case 1). This was to be expected as the angular speed of operation in case 2 was roughly twice that of case 1.



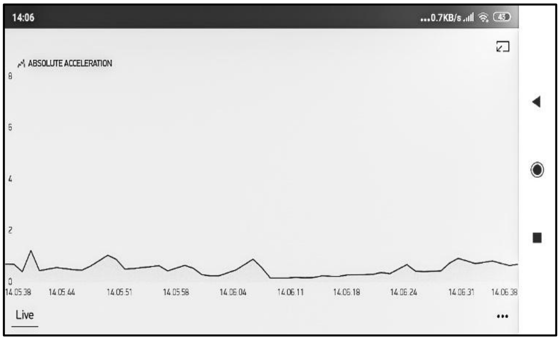


Fig. 9. Real time Absolute acceleration value with graph (case 2)

Fig. 10. Real time Absolute acceleration graph (case 2)

Case 3 Vibration monitoring of a stand-alone induction motor

Fig. 11 shows accelerometer readings as absolute acceleration in units of ‘g’, obtained on performing vibration monitoring on the stand-alone induction motor rotating at an angular speed of 4800 rpm.

As observed from the values, the peak value exceeds 2 g. On comparing with the IRD vibration severity chart, it was noticed that the vibration levels were beyond permissible limit of 1.5 g for a frequency of 4800 cpm. As a result, alert notification was displayed on the screen as shown in Fig. 11 and an email was sent to the receiver as shown in Fig.12.

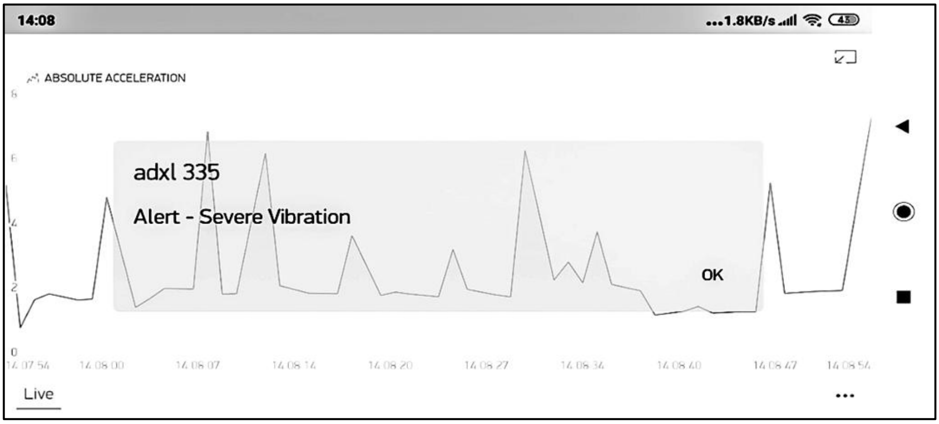


Fig. 11. Real time Absolute acceleration graph with alert notification (case 3)

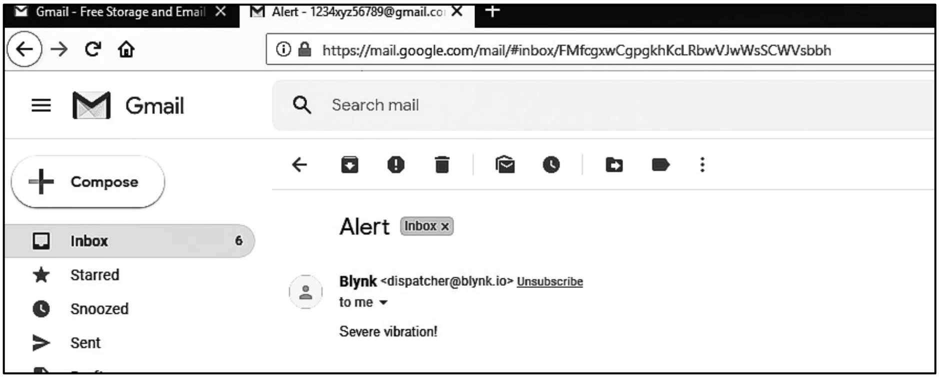


Fig. 12. Email alert notification (case 3)

The acceleration readings in case 3 were greater than that of cases 1 and 2 because the stand-alone motor had degraded owing to aging and wear. Therefore, clearances and eccentricities had developed which gives rise to severe vibration.

The conducted experiments bring out the application of a vibration monitoring system in industries for several machines running continuously and connected to internet. Whenever a fault occurs, the receiver receives a notification. The receiver on receiving the alert notification is supposed to take necessary steps in controlling vibration levels. The monitoring will still happen continuously and alert notifications are repeatedly displayed and sent to the receiver until the receiver himself resets the monitoring system and takes necessary steps towards fault diagnosis and vibration control.

4.0 Conclusions

The IoT enabled vibration monitoring system was found effective for preventive maintenance of machines. The system sends alert notification whenever the vibration exceeds the permissible value for the operating speed of induction motor.

In case of induction motor of centre lathe and bench grinder, the peak acceleration levels were below ‘1.5 g’ which is in the permissible limit of vibration severity corresponding to rotational frequency below 18000 cpm. Hence, no alert notification is sent in these cases.

In case of stand-alone induction motor, the peak acceleration level exceeded ‘1.5 g’ permissible limit corresponding to rotational frequency below 18000 cpm. The system successfully sent an alert notification by means of text message and email indicating vibration severity.

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