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Predictive Maintenance of Rotating Machines using Arduino Platform

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Abstract: Predictive maintenance plays an important role in modern industry. This type of maintenance depends on analyzing the results of vibrations caused by the machines. The present work aims to implement this type of maintenance with the help of Arduino platform and its sensors. This allows reading and analyzing vibrations with a low cost and easy to use. Also the results of analysis can be easily done on computer or modern smartphones and tablets. In addition, the results of the vibration analyzes are compared to ISO 10816-1 to see how the machine is performing and is it satisfied or not. This method has been applied to number of case studies of different machines. The results has showed that the root mean square value of cases studies are varying from 0.4597 to 0.74355. These results located in good and satisfactory region for class 1 in ISO 10816-1.
Keywords: Predictive maintenance – Vibration analysis - Rotating machine – Arduino platform

NOMENCLATURE

Symbol	Definition	Dimension
D	The displacement	mm
V	The velocity	mm/s
A	The maximum amplitude	mm/s^2
ω_n	The angular velocity-natural frequency	rad/min
a_{max}	The maximum acceleration	mm/s^2
N	Number of rotation	rpm
t	Time	s
H	The measurement data read out from the Arduino	mm/s^2
H_{adj}	The adjusted measurement data	mm/s^2
ASA	The sensitivity adjustment value	-
$v_{r.m.s}$	Root mean square value for velocity	mm/s

I. INTRODUCTION

Predictive maintenance plays an important role in detecting the problem in different types of machines. Early prediction of these problem in machines is very important to avoid more complicated problems. This kind of maintenance depends on vibration monitoring. Vibration monitoring reveals machine knowledge and verifiable rate of change. All workshops and production lines in modern industry techniques needs to apply this method of maintenance to ensure stability in there production. The data obtained can then be analyzed to give a warning about failure. Most of the defects encountered in rotating machines lead to a distinct vibration pattern. Vibration monitoring has the ability to record and identify "signatures" for vibration, making this technology extremely powerful for rotating machine monitoring. Vibration analysis is usually applied using an expensive transducers to measure acceleration, speed, or displacement.

The choice depends to a large extent on the frequencies analyzed. Vibration analysis consists of vibration monitoring and analysis. Vibration monitoring: Vibration monitoring usually consists of transducers connected to a specific location and in a specific direction [1].

To avoid the experimental complexity analysis and high cost to participate in this work we propose using the Arduino platform and sensor. This technique provides satisfactory accuracy, simple data analysis and low initial cost. [2-3]. Arduino plays the role of data collecting from the sensors. In addition Arduino is very popular with the increase of use of smartphones and tablets [4]. In the

present work an Arduino Uno board with the motion processing units MPU-9250 was used to predict the performance of different machines with use of ISO 10816-1 standards chart.

II. ISO 10816-1 STANDARDS CHART

International Standard ISO 10816-1 was prepared by technical committee ISO / TC 108, mechanical vibration and shock, subcommittee SC 2, measurement and mechanic vibration testing and shocks as applied to machinery, vehicles, and components. This part of ISO 10816 is a basic document that sets out standard guidelines for measuring and testing mechanic vibration equipment, as measured in horizontal parts. The machine partitioning is as follows:

1) *Class I:* Individual parts of engines and machinery, firmly connected to a complete machine in its normal working condition. (Generating up to 15 kW electric motors are typical examples of machines in this category.)
2) *Class II:* Standard equipment (typically 15 kW to 75 kW) with no special supports, tightly installed engines or machines (up to 300 kW) on special foundations.
3) *Class Ill:* Prime-movers and other large rotating machines are mounted on sturdy and heavy-duty foundations directly at the Vibration scale.
4) *Class IV:* Prime-movers and other large-scale rotary equipment mounted on soft foundations in the direction of vibration measurements (for example, turbo generator sets and electric turbines running above 10 MW) table (1) shows -ISO 10816- 1 chart of rates and acceptance criteria for vibration [5].

Table I
ISO 10816- 1 standards chart

Velocity Severity		Velocity Range limits and Machine Classes ISO standard 10816-1			
RMS (mm/s)	Peak (in/s)	Small Machines Class 1	Medium Machines Class 2	Large Machines	
				Rigid supports Class 3	Less Rigid Supports Class 4
0.28	0.02	Good	Good	Good	Good
0.45	0.03				
0.71	0.04				
1.12	0.06	Satisfactory			
1.8	0.1		Satisfactory		
2.8	0.16	Unsatisfactory (Alert)		Satisfactory	
4.5	0.25		Unsatisfactory (Alert)		Satisfactory
7.1	0.4	Unacceptable (Danger)		Unsatisfactory (Alert)	
11.2	0.62				Unsatisfactory (Alert)
18	1		Unacceptable (Danger)	Unacceptable (Danger)	
28	1.56				Unacceptable (Danger)
45	2.51				

III. ARDUINO SETUP

Arduino is an open source microcontroller platform. What has become popular among the general public for its ease of use, easy installation and low cost, makes it an ideal tool for rapid assembly and evaluation of electronic forms [6]. In the present work the Arduino Uno board was used. The unit processing unit MPU-9250 was also used.

A. Arduino Uno Board

Arduino Uno is a microcontroller board based on ATmega328P (database). It has 14 digital input / input pins (6 of which can be used as PWM output), 6 analog input, 16 MHz quartz crystal, USB connection, power jack, ICSP and button reset Contains

everything needed to support the microcontroller; simply plug it into a computer with a USB cable or power it with an external AC-to-DC adapter or battery to get started [7].

Fig. 1. Arduino UNO board

B. Motion Processing Unit MPU-9250

The MPU-9250 is the second-generation 9-axis Motion Processing Unit ™ for smartphones, tablets, wearable sensors, and other consumer markets. The MPU-9250, is the smallest 9-axis motion tracking device in the world [8].

Fig. 2. MPU-9250

The MPU-9250 has two devices, a magnetometer and an accelerometer-gyroscope, on the same board. The axes of the devices are different from each other. The magnetometer axis is aligned with the NED coordinates. The axis of the accelerometer-gyroscope is different than the magnetometer on the MPU-9250. The accelerometer and gyroscope axis need to be adjusted and / or inverted to fit the magnetometer axis [9].
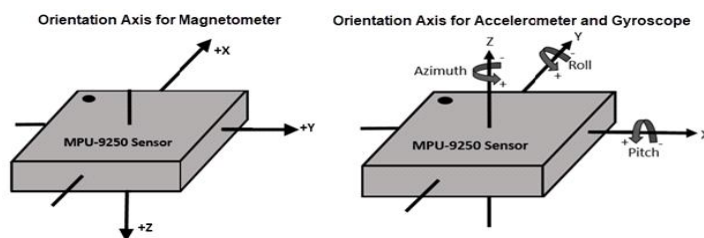

Fig. 3. MPU-9250 Orientation

C. Sensitivity Adjustment

The sensitivity adjustment is done by the equation below;

$$H_{adj} = H.\left(\frac{(ASA-128).0.5}{128} + 1\right) \tag{1}$$

Where H is the measurement data read out from the measurement data register, ASA is the sensitivity adjustment value, and H_{adj} is the adjusted measurement data [10].

D. Arduino Package

The test equipment (the Arduino package after implementation) used to Measurement vibrations is shown in Figure 4.
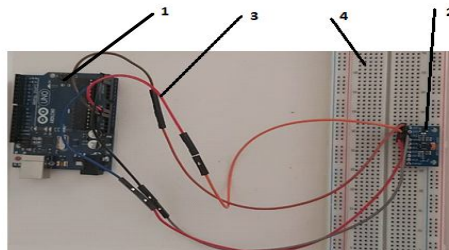
1. Arduino UNO board, 2. MPU-9250, 3. Connection wires and 4.Arduino bread board.

Fig. 4. Components of present work Arduino package

IV. VIBERATION ANALYSIS

The main vibration equations used in the present work are:
For finding displacement:

$$D = A \sin(\omega_n t) \tag{2}$$

For finding velocity:

$$V = A\omega_n \cos(\omega_n t) \tag{3}$$

For finding acceleration:

$$a = A\omega_n^2 \sin(\omega_n t) \tag{4}$$

For finding maximum amplitude:

$$A = \frac{a_{max}}{\omega_n^2} \tag{5}$$

For finding angular velocity-natural frequency:

$$\omega_n = \frac{2\pi N}{60} \tag{6}$$

V. CASE STUDIES

Four case studies are used in the present work to check the mechanism and compare it with the ISO 10816- 1. This section will illustrate each machine used in the present work and its main properties.

A. Case #1: Drilling and Milling Machine

The first machine we use is a drilling and milling machine. As shown in figure (5-a) the drill is generally designed to cut along the z-axis along the drill bit, to make the z-axis hole only. The milling machine moves the tool up and down to cut it so that it can drill, but the work table is specially designed to move a piece of work while it is cut. While figure (5-b) shows the present work Arduino package fixation.
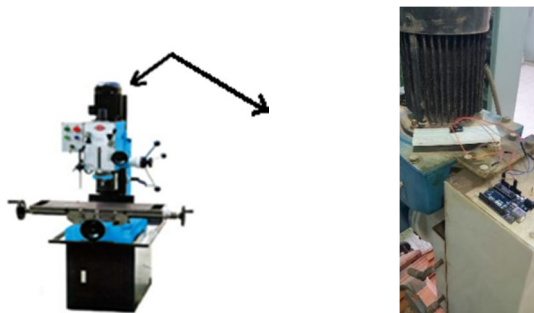
(a) General view   (b) Measuring position
Fig. 5. Case #1 Drilling and milling machine

B. Case #2: Grinding Machine

The second machine used in the present work is the grinding machine. Figure (6) shows a grinding machine, usually shortened for grinding, is one of the power tools or machine tools used for grinding, it is a form of machine using a rough wheel as a cutting tool.

Fig. 6. Grinding machine

C. Case #3: lathe Machine with Outside Measurements

The third case study is lathe machine with measurements fixed on the outer surface of machine as shown in Figure (7).

1. Fixation of present work Arduino package
Fig.7. Lathe machine with outside measurements

D. Case #4: Lathe Machine with Inside Measurements

The last case study is lathe machine with measurements fixed inside the machine as shown in figure (8).

(a): Side view for lathe machine   (b): fixation of present work Arduino package.
Fig. 8. Inside view of lathe machine

VI. RESULTS AND DISCUSSION

In this section results of the present work is discussed in details. The data was obtained via the Arduino software, it was collected using Excel and graphed using Grapher software. From measured Vibration acceleration and transform it to velocity and distance with time change. The r.m.s. (root mean square) value of the velocity may be may be determined approximately from the relationship [5]:

$$v_{r.m.s} = \sqrt{\frac{1}{2}\left(v_{max}^2 + v_{min}^2\right)} \qquad (7)$$

All case studies located in class 1 for small machines in ISO standard 10816-1. In case 1, it has been found that the root mean square value of the vibration velocity is 0.74355 mm/s which lies in satisfactory region. While, for case 2, case3 and case4 this value is 0.4597, 0.4968 and 0.5123 mm/s respectively. These three case lies in good region. So, if these readings are take periodically the predictive maintenance of each machine can be determined and give early alarm for the machine case. Figure (9) shows different output for the present work Arduino package. These output can used in different studies for vibration, predictive maintenance and comparison between machine performances in different fields.

(a): Acceleration for case #1   (b): Velocity for case #1   (c): Displacement for case #1

(d): Acceleration for case #2   (f): Velocity for case #2   (g): Displacement for case #2

(h): Acceleration for case #3   (i): Velocity for case #3   (j): Displacement for case #3

(k): Acceleration for case #4   (l): Velocity for case #4   (m) : Displacement for case #4
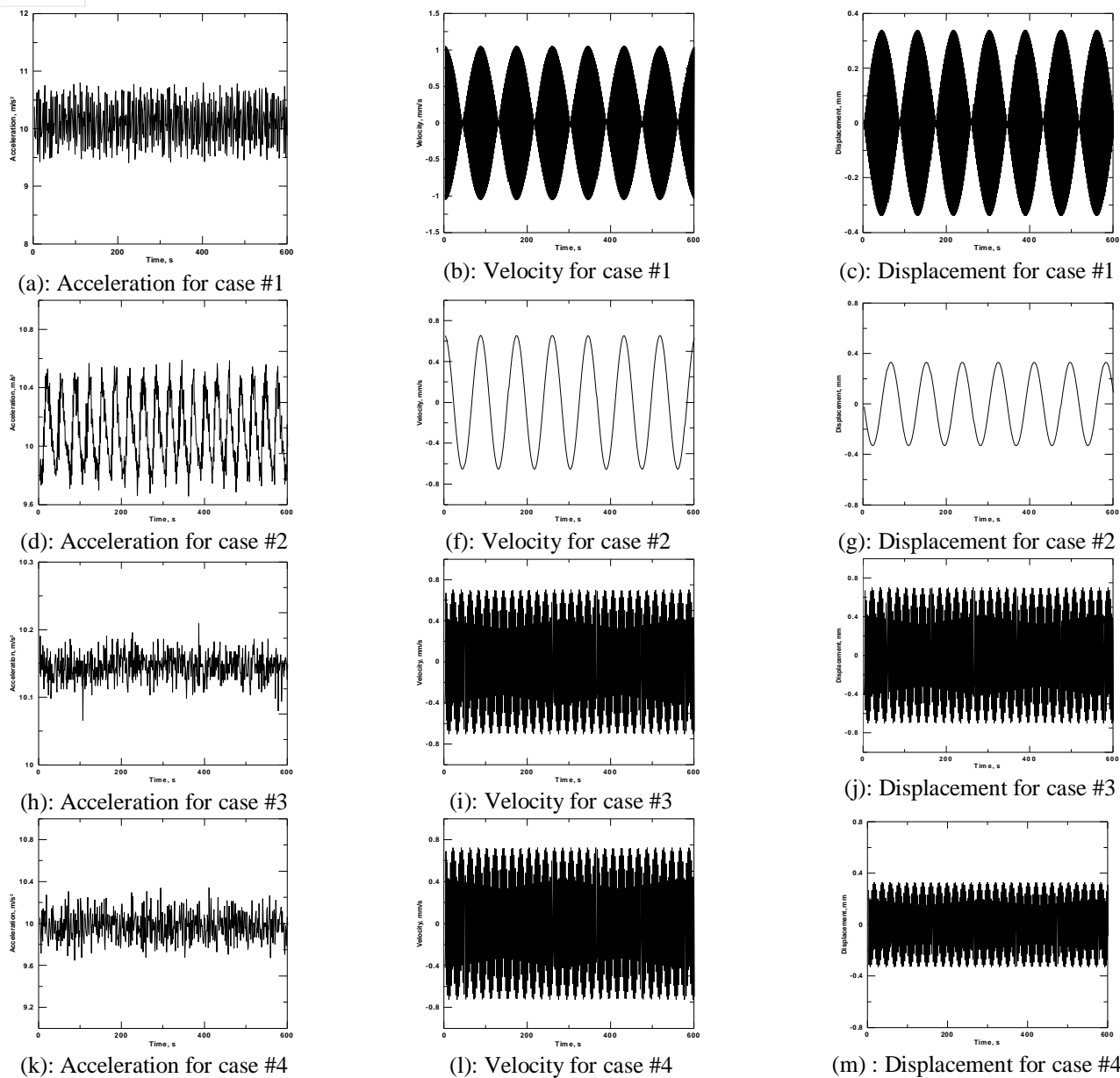
Fig. 9. Output of the present work Arduino package

VII. CONCLUSIONS

This paper has discussed different case studies for predictive maintenance and how each can generate characteristic vibration. This present work presents a new method for predictive maintenance of rotating machines using Arduino platform for vibration measurement. Methodology applied to a different types of machining machines. The results obtained in this work suggest that this method may be also useful for any other machines. Also the features of the present work can be summarized as:

1) Low cost price.
2) Easy to install and use.
3) The results are 100% achieved.
4) It can be used to measure the vibrations of different types of machines such as punching, milling, turning and grinding.
5) The results are used to find out the Predictive maintenance of rotating machines by comparing it with ISO 10816-1 standards chart.

Generally this technique will give an early warning of incipient damage or deterioration for different types of machines. In addition this technique can used in general vibration analysis for any rotating machine.

REFRENCES

[1] Sagar Sutar, Vilas Warudkar and Rajendra Sukathankar,"Vibration Analysis Of Rotating Machines With Case Studies", International Journal of Scientific & Technology Research , volume 7, Issue 7, July 2018.

[2] J. Sarik and I. Kymissis, in: Frontiers in EducationConference, edited by Y. Wang (IEEE, New York,), p. T3C-1, 2010.

[3] R. Balogh, in Proceedings of the 1st International Conference on Robotics in Education, edited by R. Stelzer (Slovak University of Technology, Bratislava), p. 119, 2010.

[4] M. Monteiro, C. Cabeza e A.C. Marti, Revista Brasileira de Ensino de F´ısica 37, 1303, 2015.

[5] International standard manual of Iso 10816-1, 1995.

[6] M. Bhmer, Beginning Android ADK with Arduino, Apress, New York, 2012.

[7] https://www.arduino.cc/.

[8] https://www.invensense.com/products/motion-tracking/9-axis/mpu-9250/.

[9] https://www.mathworks.com/help///supportpkg/arduinoio/ug/estimating-orientation-using-inertial-sensor-fusion-and-mpu9250.html.

[10] InvenSense Inc., Document Number: RM-MPU-9250A-00, MPU-9250, Register Map and Descriptions, Revision 1.4, 2013.

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