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Research paper

Approach for Machine Health Monitoring System of a Machine

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Abstract

Vibration monitoring system has become a recognized technique to supervise the maintenance of machine. Machine health monitoring is the process of monitoring the condition of a machine to predict mechanical wear and tear and to predict failure of the machine. Vibration, noise, and temperature parameters are frequently used as key indicators to check the condition of the machines. This piece of study describes here is the development of a Machine Health Monitoring System using the vibration and the temperature of the tool of the machine as machining monitoring parameters. The selection of these parameters are based on the fact that this parameter is mainly responsible for the failure of a machine and also these parameters affect the quality of the part. The restrictions associated in this paper for Condition Based Monitoring are the installation of device on the machine and the cost of the Condition Based Monitoring Device increases with increase in number of measurement parameters, Condition based monitoring system helps in making the strategies to avoid unwanted tragic failure. This paper discusses the machine health monitoring using the vibration and tool temperature as an input parameter for health monitoring.

***Keywords**: Condition Monitoring, Machine health Monitoring, temperature Fault Diagnostics, Maintenance, Vibration.*

1. Introduction

Condition based monitoring and health diagnosis machine can be defined as the process of monitoring the condition of a machine to predict mechanical maintenance activity or it can also be defined as the process of monitoring the critical parameters like Vibration and Temperature of a machine and based on the readings of those parameters maintenance activity is optimally scheduled. The main reason for increasing demand of condition monitoring in industry is to avoid the vibrations and the part quality due to the increasing tool temperature. [1], [2], [3], [4], [5], [6]. Machine monitoring systems are widely adopted to monitor the behavior of machine structure during forced vibrations. Now days industry almost, half of the operating cost are related to machine maintenance. Vibration sensor use for condition monitoring of a machine such as lathe must be able to measure vibrations within a wide vibration range [7], [8]. Monitoring and fault diagnosis may also be used to improving end product quality of machining which can also be considered as a process monitoring tool. If the machine is not balanced or uneven, this will result a high energy vibration signal at the frequency near rotational speed, usually kind of 50 Hz [11], [12], [13]. If machine having bearing problems, signal with high frequencies will found, normally kind of 1–5 kHz [11], [12], [13]. From survey of literature available damage affinity and health checking of mechanical and structural systems from their vibration properties [14]. For better understanding of Condition Based monitoring one should understand that it is a kind of Maintenance activity. In early decades, a complete survey of a broad range of topics concerned with the fault diagnosis of dynamic systems is elaborated with different techniques, which stayed as a vital role in fault dynamics of a mechanical system [15]. Basically, there are three types of Maintenance activity which are Run-to-failure maintenance, Scheduled Maintenance and third one is Condition-Based Maintenance. Run-to-failure Maintenance is the kind of Maintenance in which the maintenance activity is performed when there is a breakdown or the failure in in a machine. This is generally followed where the replacement of part is cheaper or the part is easily available. The plants which work on run-to-failure maintenance has least availability of machines or the plant availability is minimum.

2. Maintenance

If a machine is maintained with a proper maintenance policy, this can lead to the increase in life of a machine. Scheduled Maintenance is the kind of Maintenance in which the maintenance activity is scheduled after a fix interval of time. The plants which work on scheduled maintenance has high availability of machines or the plant in comparison to run-to-failure maintenance. Waeyenbergh and Pintelon [16] have documented the evolution in maintenance strategies with time. The concept of evolution of maintenance strategies began after examining the pre-existing concepts of Total Productive Maintenance (TPM) [17], Reliability-Centered Maintenance (RCM) [18], Logistic Support Analysis [19] and Business Centered Maintenance (BCM) [20]. A recent approach in the maintenance strategies is coming up that is concept of e-maintenance [21], [22], [23], The concept of e-maintenance is dynamic in nature [24], [25].
Condition Based Maintenance as stated above is the type of maintenance in which the maintenance activity is scheduled according to the condition of the machine. The plants running on the Condition Based Maintenance has highest availability of machines. For the better understanding of Condition Based Monitoring of a Machine a graph between the Estimated Capacity/Load and Time in Service is plotted as shown in Fig-1

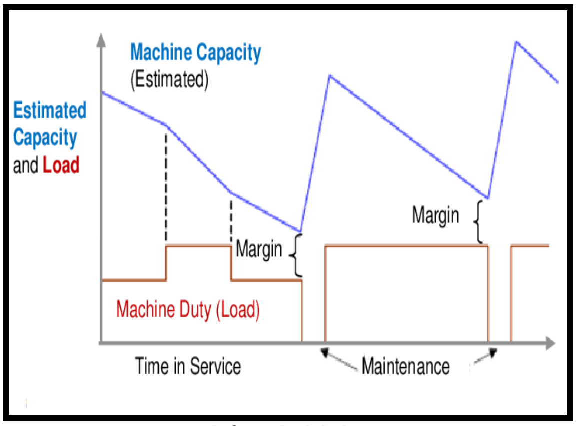

Fig.1: Graph for Scheduled Maintenance

Fig-1 shows the graph between the Estimated Capacity/ Load and Time in Service. This graph is basically showing two lines, one is estimated capacity line and other one is Machine Duty or Load line. Now, Machine duty or load line simply showing the variation of load on the machine with respect to the time. While Estimated Capacity line shows that with the passage of time the performance of the machine degrades or simply we can say that machine capacity decreases with time till the machine reaches a point when the maintenance is performed. After maintenance activity is performed its performance is improved again and as shown in graph the estimated capacity of the machine again increased.
The machine capacity and the machine load line never intersect each other but this margin is very small in comparison to the scheduled maintenance. This basically results in a longer time between maintenance activities than for scheduled maintenance. Another advantage of Condition Based Monitoring is that it can help in avoiding the unplanned downtime.

3. Objective of Machine Health Monitoring System:

Machine fault is normally defined by any change or unsatisfactory function of a machine spare parts which builds it not capable to perform its purpose acceptably or it can also be defined to discontinue the availability of a part or item to perform its intended purpose. Any fault in a machine are not abrupt, the machine follows certain stages in which the machine passed on before last failure. These are early failure, deterioration, distress and damage, all of these are sooner or later make the machine component unpredictable or unsafe for further use in the machines [14]. Machine failures are not only effects in loss of availability of the machine but also enlarged the operating cost of operation for a particular machine. In some of the cases, there are hidden and non-repairable failure can prime to tragic failures. Early detection of the fault is crucial for the prevention of damage to other machine parts. [26]
Here following certain objectives for fault diagnosis systems: -

1. To assure safety of the machine.
2. To schedule the maintenance.
3. To monitor the condition of a machine.
4. To reduce the down time of a machine.
5. To identify faults in a machine.
6. To ensure reliability of the process.

Correct and complete awareness of reasons which are responsible for discontinue the work of a machine is necessary information for an engineer. The doctor cannot guarantee a permanent cure of a patient unless he distinguishes what is at the root of the problem, in the same manner the future effectiveness of a machine generally depends on precise acquiescent of the causes due to machine failure. The correct maintenance can only be done for a machine when the proper information of origin source of failure is known of the machine

4. Description of the machine health monitoring device

The basic purpose for which this device will be used is to do the condition based monitoring of the machine. For that purpose, vibration sensor and temperature sensor is used which collects the data and send it to the micro-processor based unit. Then, the collected data is send to the Arduino micro-controller unit and micro-controller sent these data is via serial communication protocol to the LCD display attached to Arduino device.

4.1 Vibration Sensor

Cantilever-type low cost Mini sense-100 sensor used vibration measurements shown in Fig-2 weighed down by a small mass to offering more sensitivity at low value frequencies. The pins attached to it are designed in such a way that they offer easy installation and can be solder to board. Vertical and horizontal installation options are available as well as a compact height form is also available. The active sensor area is isolated for improved RFI/EMI rejection signals. Rough and flexible PVDF sensing element which endures high shock overload. Mini sense-100 Sensor has excellent linearity and vibrant range, and used for detecting moreover continuous impacts or vibration coming on machine components.

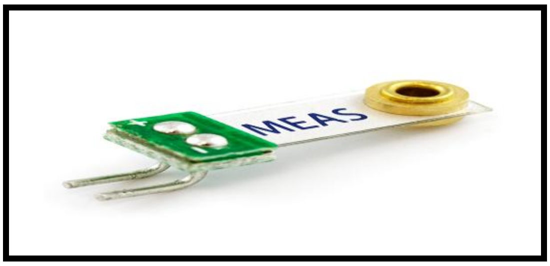

Fig.2: Vibration Sensor

4.2 Temperature Sensor

Figure 3 shows DHT11 digital humidity and temperature sensor. This is a composite Sensor that comprises of a calibrated digital signal output of the temperature and humidity data. The application of a steadfast digital components collection technology and the humidity and temperature identifying technology is used word wide to ensure the product reliability and excellent long-term steadiness. The DHT11sensor consist of a resistivity based sense of drizzling components and an NTC temperature measurement devices that are connected with a high performance 8-bit microcontroller.

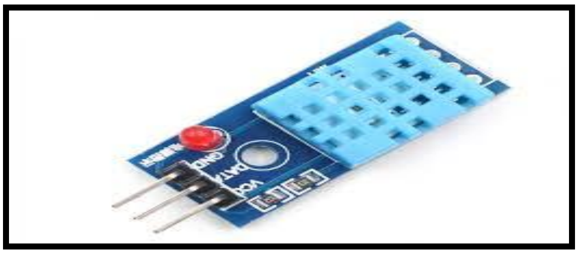

Fig.3: Temperature Sensor

4.3 LCD Display

LCD (Liquid Crystal Display) screen as shown in Fig-4. This is an electronic display unit which has a wide variety of applications. It is a 16x2 LCD which is a very basic module for digital display and is very commonly used in many component and electronic circuits. These unit are preferred over seven segments display unit and other multi segment LED. The reasons being, LCD are economical, easily programmable, and have no limitation of displaying special & even custom characters (unlike in seven segments display unit). A 16x2 LCD means that this can display 16 characters per line and there are 2 such lines. In this LCD each character is display in 5x7 pixel matrix. This LCD has two registers, one is command register and data register.

Fig.4: LCD Display

4.4 Signal Acquisition Using Arduino

The Arduino Uno "Uno" means 1 in Italian language A a microcontroller board based a Tmega-328 as shown in Fig-5. It contains which is needed to support a microcontroller. This unit simply attach to a laptop with the help USB cable, DC adapter or battery used to power this device. One biggest benefit of using the Uno is that the chip used in it can be swapped for comparatively very low cost. For this model, the UNO board will be sufficient. The Interfacing of SEN-09199 and DHT-11 with Arduino is straight forward and the parts required for this process are SEN-09199, DHT-11, LCD 16x2, connecting wires.

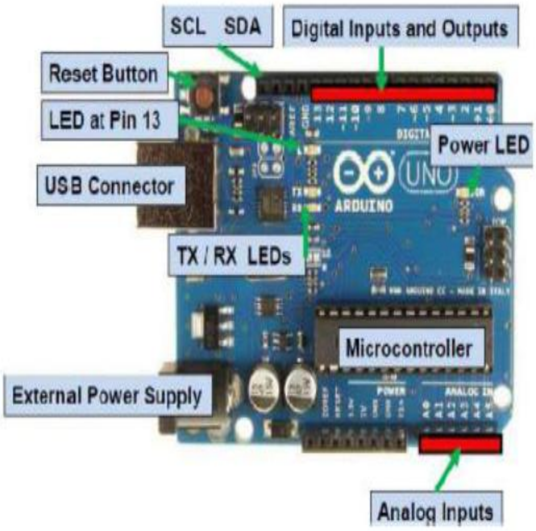

Fig.5: Ardunio UNO

4.5 Circuit of the Machine Health Monitoring System

Piezo electric sensors are exclusive in nature because they produce an alternating current (AC) voltage when stressed and then it convert mechanical energy to electrical energy. The voltage spears from it are reaching almost +20V and -12V. Electrical signals at that high level may permanently damage a microcontroller's analog-to-digital converter (ADC) pins. To reduce those voltage peaks, the easiest way is to load the piezo with a large electrical resistor. By placing a 1MΩ resistor in parallel with the piezo sensor one can drop down voltage peaks to safer levels.

DHT 11 module has three output terminals viz Signal, VCC (+), Ground (-). First connect the GND (ground) pin of DHT 11 to the GND (ground) pin of Arduino Uno. Then, connect the VCC to Arduino's 5V, then the signal pin is connected to digital pin 7. The Circuit diagram of the Machine Health Monitoring System is as shown in Fig-6.

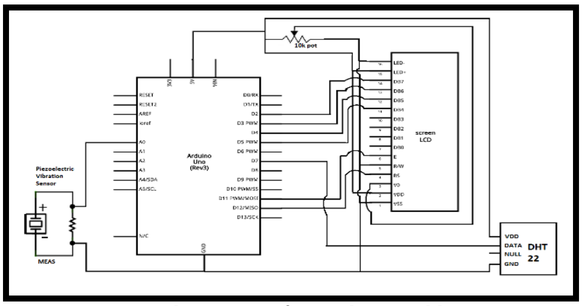

Fig. 6: Ckt. Diagram for Machine Health Monitoring

5. Machine for Testing as Setup

In this research experiment a Lathe Machine is choosing for the installation and of our device. The main reason for choosing the lathe machine is that we can perform variety of operation on the lathe machine. After successful installation of device on the machine. The readings of Vibrations and Temperatures in different conditions are chosen and on the basis of those readings we have made the following conclusions.

6. Result and Discussion

After successful installation of device on the machine the following graphs are plotted and based on this data we have made several conclusions. The graph which have been plotted are as follows:

(i) Load Vs Vibration at constant Speed.

(ii) Load Vs Temperature at constant speed.

For taking the readings and for plotting this graph one has to identify certain places like tool, belt-pulley bearing casing and motor. After that placed three vibration sensors on the above identified three places and one temperature sensor at tool.

6.1 Load Vs Vibration Graph for Motor

The Fig-7, (a), (b), (c) below shows the variation of vibration with Load at constant rpm on motor. At a particular load taken here are the five readings. After taking this reading, graph between the average value of vibration and load is plotted.

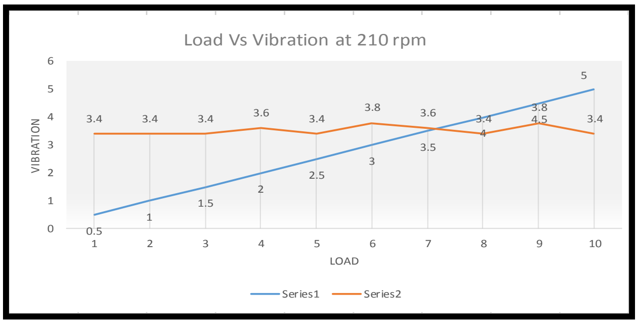

Fig-7, (a)

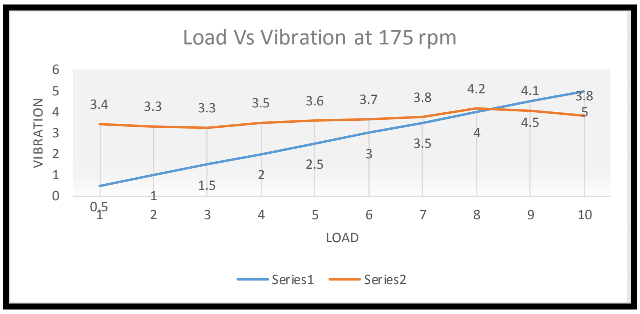

Fig-7, (b)

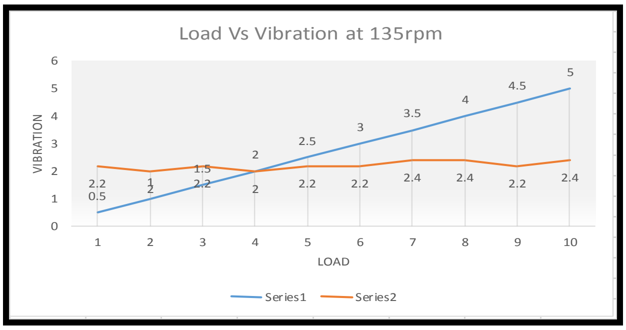

Fig-7, (c)

6.2 Load Vs Vibration Graph for Belt-Pulley

The Fig-8, (a), (b), (c) below shows the variation of vibration with Load at constant rpm on belt pulley. At a particular load taken here are the five readings. After taking this reading, graph between the average value of vibration and load is plotted.

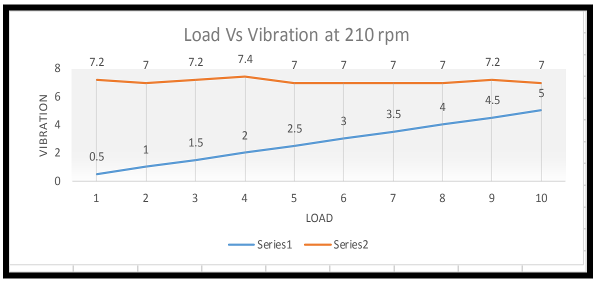

Fig-

Fig 8, (a)

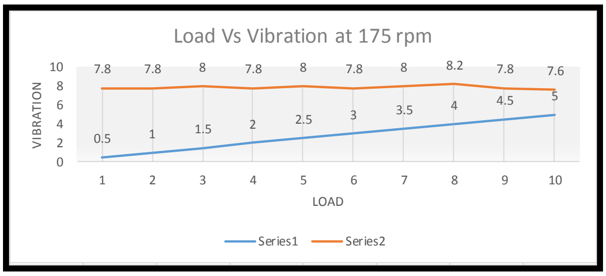

Fig-

Fig 8, (b)

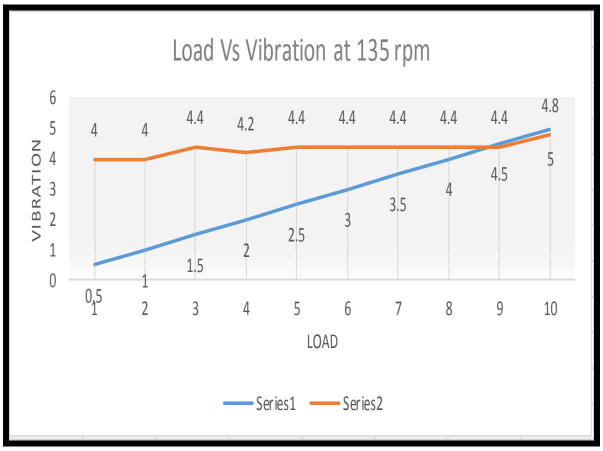

Fig-

Fig 8, (c)

6.3 Load vs Vibration Graph for Tool

The Fig-9, (a), (b), (c) below shows the variation of vibration with Load at constant rpm on lathe tool. At a particular load taken here are the five readings. After taking this reading, graph between the average value of vibration and load is plotted.

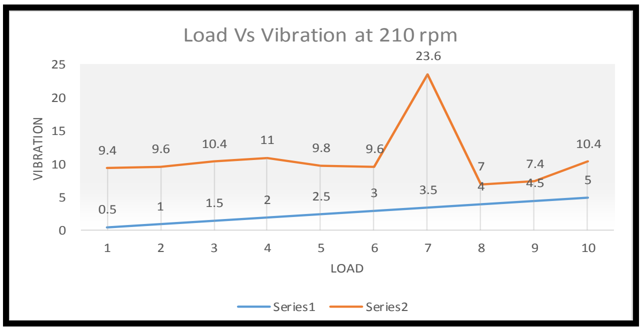

Fig-9, (a)

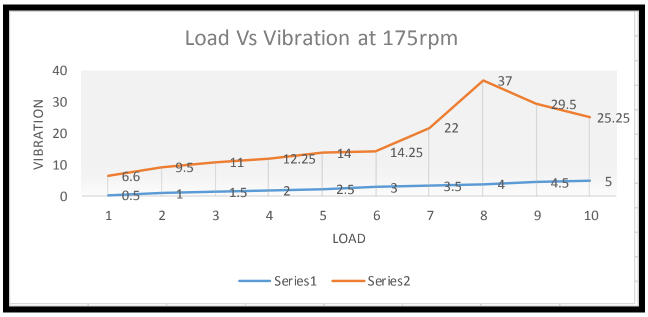

Fig-9, (b)

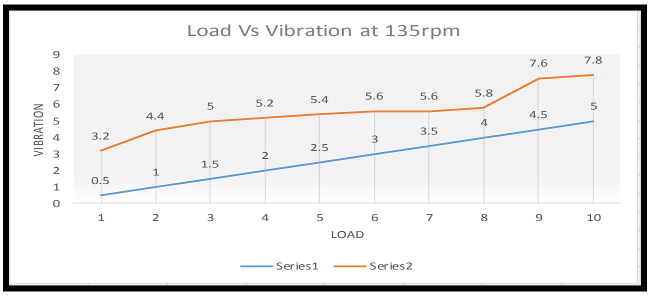

Fig-9, (c)

6.4 Load Vs Temperature at Constant Speed

We also plotted a graph as shown in Fig-10 (a), (b), (c) between Load and Temperature on the basis of the reading shown by the device. In this we show the variation of temperature with load at constant speed. There are three speed ratios in the lathe machine and the graph is plotted on all the three speed ratios

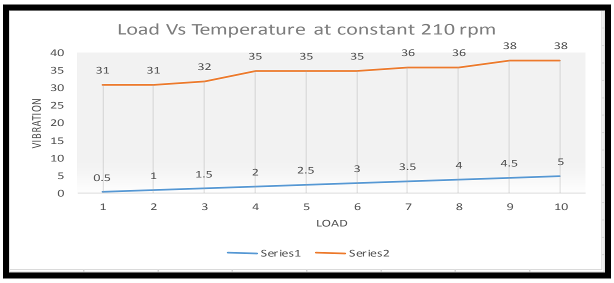

Fig-10, (a)

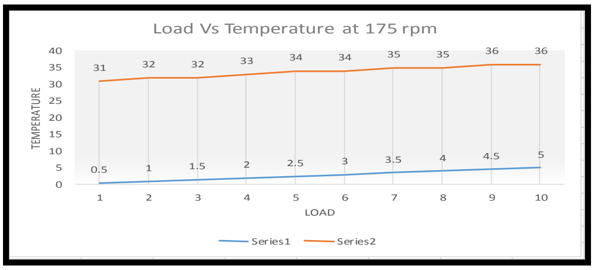

Fig-

Fig 10, (b)

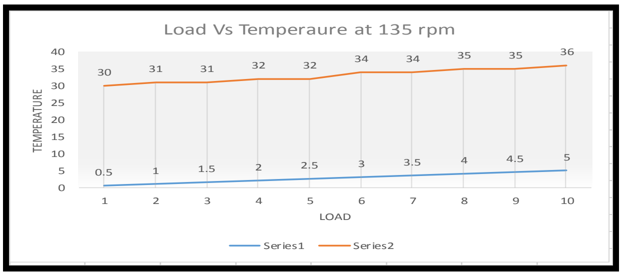

Fig-10, (c)

In this way the graphs are plotted between various parameters. Based on the trends of the graph and on the basis of other observations, we made the below mentioned conclusions

7. Conclusion

This paper listed the complete methodology for the development of Machine Health Monitoring System. This system can be used for the Condition Based Monitoring of any Machine and also it can be installed on any stationary part or the part having linear motion. Other than the failure of a machine components the vibration can also be created due to other reasons like chatter, Tool dislocation or the defect in the material itself.

This observation is, the maximum permissible value of vibrations is in the range of 0-20Hz @ 210 rpm. The maximum permissible value of vibrations is in the range of 0-15Hz @ 175 rpm. The maximum permissible value of vibrations is in the range of 0-10Hz @ 135rpm. If an appropriate machine health monitoring is used then we can reduce the failures of machines and increase the reliability and availability of machine. The above given method are fast growing method for appropriate maintenance technique.

8. Future Scope

There always a scope of improvement in each and every thing. The same thing is also applicable to this device. There are some changes that could be made to increase its functionality and performance: -

- The device is impossible to install on the rotating parts of the machine, so we can work upon making the device wireless.
- We can also work upon improving the device for some other parameters like Condition- Based Monitoring of some other parameters like Condition- Based Monitoring of Oils in a machine and for Noise Analysis etc.

Acknowledgement:

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References

[1] S. W. Doebling, C. R. Farrar, M. B. Prime, and D. W. Shevitz, “Damage Identi-fication and Health Monitoring of Structural and Mechanical Systems from Changes in their Vibration Characteristics: A Literature Review,” Report No. LA-13070-MS, Los Alamos National Laboratory, Los Alamos, NM, 1996.

[2] L. BalisCrema and F. Mastroddi, “Frequency-Domain Based Approaches for Damage Detection and Localization in Aeronautical Structures,” Proceedings of the 73th International Modal Analysis Confer-ence, pp. 1322-1330, 1995.

[3] Budipriyanto and A.S.J. Swamidas, “Experimental and Analytical Verification of Modal Behavior of Uncracked/Cracked Plates in Air and Water,” Proceedings of the 72th International Modal Analysis Conference, pp. 745-752, 1994.

[4] H.M. Kim and T.J. Bartkowicz, “Damage Detection and Health Moni-toring of Large Space Structures,” Sound and Vibration, vol. 27, no. 6, pp. 12-17, 1993.

[5] J.M. Ricles, “Nondestructive Structural Damage Detection in Flexible Space Structures Using Vibration Characterization,” NASA report CR-185670, 1991.

[6] C. J. Kaufman, Rocky Mountain Research Laboratories, Boulder, Colo., personal communication, 1992. (Personal communication)

[7] C. Chien, I. Elgorriaga, and C. Mc Conaghy, “Low-power directsequence spread-spectrum modem architecture for distributed wireless sensor net-works,” ISLPED’01, Huntington Beach, California, pp: 251-254, Aug. 2001.

[8] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, “Wireless sensor networks: a survey,” Computer Networks, vol. 38, pp. 393–422, 2002.

[9] G. S. Maruthi and K. P. Vittal, “Electrical Fault Detection in three phase squirrel cage induction motor by vibration analysis using MEMS accel-erometer,” Proc. IEEE Power Electronics and Drive System (PEDS), pp. 838-843, 2005.

[10] L. Hou and N.W. Bergmann, “Novel Industrial Wireless Sensor Networks for Machine Condition Monitoring and Fault Diagnosis,” IEEE transactions on instrumentation and measurement, vol. 61, no. 10, pp. 2787-2798, 2012, doi: 10.1109/TIM.2012.2200817.

[11] S. Nandi, H.A. Toliyat, and X. Li, “Condition Monitoring and Fault Diagno-sis of Electrical Motors—A Review,” IEEE transactions on energy conversion, vol. 20, no. 4, pp. 719-729, 2005, doi: 10.1109/TEC.2005.847955.

[12] B. Li, M. Y. Chow, Y. Tipsuwan, and J. C. Hung, “Neural-Network-Based Motor Rolling Bearing Fault Diagnosis,” IEEE transactions on industrial elec-tronics, vol. 47, no. 5, pp. 1060-1069, 2000.

[13] Vogl, D.T.Wang, P. Storas, T. Bakke, M.M.V. Taklo, A. Thomson, and L. Balgard, “Design, process and characterisation of a high-performance vi-bration sensor for wireless condition monitoring,” Sensors and Actuators A, vol. 153, pp. 155–161, 2009

[14] Doebling, S.W., Farrar, C.R., Prime, M.B., and Shevitz, D.W., Damage identification and health monitoring of structural and mechanical systems from changes in their vibration characteristics -A literature review," los alomos national laboratory report, no. La-13070-ms.1996.

[15] Patton, R.J., Frank, P.M., and Clark, R.N., "Fault diagnosis ,,in dynamic systems/theory and application," London, prentice hall international, 1989

[16] G. Waeyenbergh and L. Pintelon, “A frame for maintenance concept devel-opment,” International Journal of Production Economics, vol. 77, pp. 299– 313, 2002.

[17] S. Nakajima, TPM: Introduction to TPM: Total Productive Maintenance, Productivity Press Inc., Cambridge, MA, 1988.

[18] J. Moubray, Reliability Centered Maintenance, Butterworth-Heineman, Ox-ford, 1997.

[19] B.S. Blanchard, Logistics Engineering and Management, Prentice-Hall, Eng-lewood Cliffs, NJ, 1992.

[20] Kelly, Maintenance Organizations & Systems: Business-CentredMaintenance, Butterworth-Heinemann, Oxford, 1997.

[21] J. Szymanski, T. Bangemann, J.P. Thomesse, C. Lang, M. Thron, X. Reboeuf, E. Garcia and Proteus, “A European initiative for e maintenance platform development,” Proceedings of the ETFA IEEE Conference, pp. 415–420, 2003.

[22] R. Yu, B. Iung and H. Panetto, “A mutli-agents based e-maintenance sys-tem with case-based reasoning decision support,” Engineering Applications of Artificial Intelligence, vol. 16, pp. 321–333, 2003.

[23] M. Koc and J. Lee, “A system framework for next-generation e-maintenance system,” Proceedings of Second International Symposium on Envi-ronmentally Conscious Design and Inverse Manufacturing, Tokyo, Japan, 2001.

[24] R.Yu, B. Iung and H. Panetto, “A multi-agents based E-maintenance system with case-based reasoning decision support,” Engineering Applications of Ar-tificial Intelligence, vol. 16, no. 4, pp. 321-333, 2003.

[25] Muller, A.C. Marqueez and B. Iung, “On the concept of e-maintenance: Review and current research”, Reliability Engineering and System Safety, vol. 93, pp. 1165–1187, 2008.

[26] Ilhan Asilturk, Halit Aslanci, Ugur Ozmen "Machinery monitoring Using Vibration Signal Analysis," submitted to Mechanical Engineering Department, Konya, Turkey, February, 2017

Appendix: Programming in Ardunio

After interfacing the sensors with the Arduino, next step is programming of ATmega328 controller via USB to serial programmer.

```
#include <LiquidCrystal.h>
#include <dht.h>
dht DHT;
#define DHT11_PIN 7

const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2; //vdd-5v,
vss=0, a=5v, k=0, rw=0

LiquidCrystal.h lcd (rs, en, d4, d5, d6, d7);
const int PIEZO_PIN1 = A0;
const int PIEZO_PIN2 = A1;
const int PIEZO_PIN3 = A2;

int count=0, data, data1, data2;
void setup () {
  Serial.begin(9600);
  lcd. Begin (16, 2);
  lcd. set Cursor (0, 0); //H, V
}

void loop () {
 //lcd. Clear ();
  int piezo DC=0, piezoADC1=0, piezoADC2=0, Hertz=0,
Hertz1=0, Hertz2=0;
  float piezo, piezoV1, piezoV2;
  while (1)
  {
  delay (50);
  count++;
  piezo ADC = analog Read(PIEZO_PIN1);
  piezoADC1 = analog Read(PIEZO_PIN2);
  piezoADC2 = analog Read(PIEZO_PIN3);

  data = constrain (piezoADC, 0.001, 1000000000);
  data1 = constrain (piezoADC1, 0.001, 1000000000);
  data2 = constrain (piezoADC2, 0.001, 1000000000);

  if(data>Hertz)
  {
    Hertz=data;
   piezoV = piezoADC / 1023.0 * 5.0;
  }
  if(data1>Hertz1)
  {
    Hertz1=data1;
   piezoV1 = piezoADC1 / 1023.0 * 5.0;
  }
  if(data2>Hertz2)
  {
    Hertz2=data2;
   piezoV2 = piezoADC2 / 1023.0 * 5.0;
  }
  if(count==100)
  {
  int chk = DHT.read11(DHT11_PIN);
  //Serial.print(piezoV,6);
  //Serial.print("\t");
  Serial.println(Hertz);
  //Serial.print("\t");
  //Serial.print(piezoV1,6);
  //Serial.print("\t");
  Serial.println(Hertz1);
  //Serial.print("\t");
 // Serial.print(piezoV2,6);
  //Serial.print("\t");
  Serial.println(Hertz2);

  lcd. clear ();
  lcd. set Cursor (0,0);
  lcd.print("Temp=");
  lcd.print (DHT. Temperature);
  lcd.print("C");
  lcd. set Cursor (0,1);
  lcd.print("P:");
  lcd.print(Hertz);
  lcd.print (",");
  lcd.print(Hertz1);
  lcd.print (",");
  lcd.print(Hertz2);
  lcd.print (",");
  lcd.print("Hz");
  count=0;
  break;
  }
```