CONDITION BASED MONITORING OF ROTATING MACHINES USING PIEZOELECTRIC MATERIAL

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Abstract

Now days, vibration is drawing much more concern in almost all industry. Vibration possesses existence in every machine. Due to this vibration the efficiency of operation decreases further it creates very much noisy environment. It causes wearing and tearing of material in components, so it is necessary to prevent vibration in the system. The use of piezoelectric materials to capitalize on the ambient vibrations surrounding a system is one method that has seen a dramatic rise in use for condition monitoring. Piezoelectric materials have a crystalline structure that provides them with the ability to transform mechanical strain energy into voltage charge. Our efforts are for utilizing this effect in Lathe machine for monitoring condition of machine. And also monitor the condition of the machine to increase the quality of the product hence we can compete in the today's competitive market.

Keywords: *Condition monitoring, CBM, Piezo based monitoring, CBM of lathe machine.*

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1. INTRODUCTION

Condition monitoring of machinery is the measurement of various parameters related to the mechanical condition of the machinery (such as vibration, bearing temperature, oil pressure, oil debris, and performance), which makes it possible to determine whether the machinery is in good or bad mechanical condition.

If the mechanical condition is bad, then condition monitoring makes it possible to determine the cause of the problem. Once the integrity of a machine has been estimated, this information can be used for many different purposes. Different types of data that can be useful for assessing machine condition and these should not be ignored.

1.1 Condition Monitoring-Concept

CBM is determining the condition of equipment, machines and systems etc. by observing, checking, measuring, and monitoring signals which was obtained.

Using piezoelectric materials connected with transducer can measure voltage and by help of harmonic oscillator measure frequency of vibration. Also we can find linearity and measuring precision and Accuracy. In condition monitoring we take a different parameter reading like frequency, voltage, force and compare that parameter in different condition, forces of machines and analyze.

Condition monitoring (or, colloquially, CM) is the process of monitoring a parameter of condition in machinery (vibration, temperature etc.), in order to identify a significant change which is indicative of a developing fault.

1.2 Predictive Maintenance

The use of conditional monitoring allows maintenance to be scheduled, or other actions to be taken to prevent failure and avoid its consequences. Condition monitoring has a unique benefit in that conditions that would shorten normal lifespan can be addressed before they develop into a major failure. Condition monitoring techniques are normally used on rotating equipment and other machinery (pumps, electric motors, internal combustion engines, presses), while periodic inspection using non-destructive testing techniques and fit for service (FFS).

2. AREA OF WORK

We are attempting to (1) Measure the vibrations on one of the lathe by providing a cheap and alternative method to conventional vibrometers. (2) Attempt to establish a condition based monitoring for any typical rotating machine using Piezo-electric crystals.

Vibrations produced by the machine do not transmit into floor properly, but they reflect high forces back onto machine & this reflected forces has been converted into heat.

2.1 Need of Vibration Analysis

Vibration Analysis is necessary for providing information as below:

1. Evaluation of machine condition
2. Recognition of on-going machine damage symptoms.
3. Identification of the cause and the damaged components
4. Prognosis of remaining service life.

3. PROPOSED METHOD OF WORK

As described above many methods can be used for vibration analysis. From that we select using piezoelectric materials to absorb the vibration and from that signal produce in the form of voltage.

Fig-1: Vibration measuring and analysis system

3.1 Why we use this method?

The direct measurement is required without any great deal of post processing (analysis or calculation.)

1. Equipment is cheaper (approx... 100 times) than any professional vibrometer. Hence permanent installation to monitor is possible.
2. Variation in accuracy and precision by choosing different type of software.
3. Data can be directly logged into computer and plotted if necessary.

4. IMPLEMENTATION

4.1 Piezoelectric Material

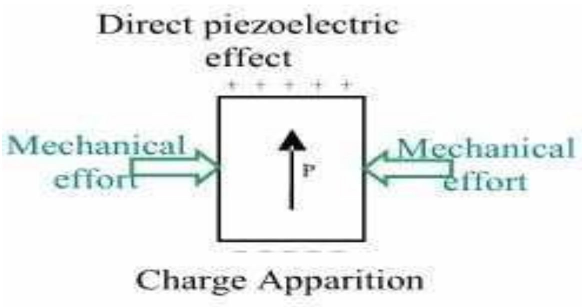

Fig-2: Electromechanical conversion via piezoelectricity

These devices contain one or more piezoelectric crystal elements (natural quartz or man-made ceramics), which produce voltage when stressed in tension, compression or shear. This is the piezoelectric effect. The voltage generated across the crystal pole faces is proportional to the applied force.

(Physical Quantity) ⟹ (Electrical Quantity)

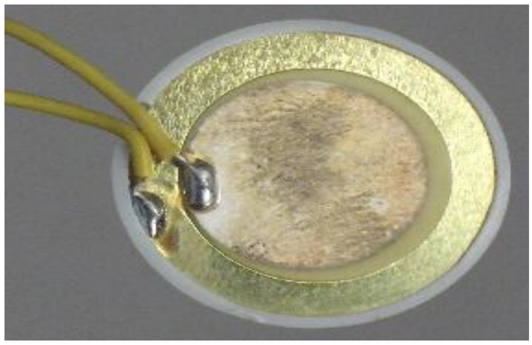

Fig-3: Piezoelectric material

4.2 Electronic Circuit

This sketch reads a piezo element to detect a vibration. This circuit is receiving all Analog signals from the piezo-electric transducer and transfer to the computer through cable in digital form. In simple it converts Analog quantity into digital quantity.

Analog input ⟹ Digital output

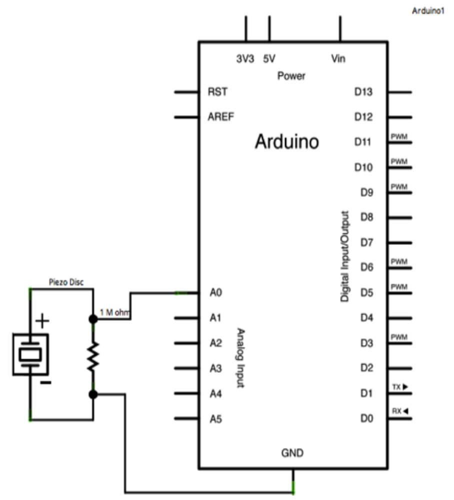

Fig-4: Electronic circuit

4.3 Use of Tuning Fork in Project

Tuning fork is used only for testing purpose in the condition monitoring i.e. we can measure frequency of machine which is to be monitored. By measuring the frequency we can plot various linearity and precision graph accuracy graph for various conditions.

4.4 Electrical Resistor

Resistor is a devise to control voltage of the system. Its protect the system for heavy current. In this systemwe used 1 ohm capacity of resistor.

5. WORKING

The whole system is divided into a several sub-system which is not only convert, measure or transfer the different quantity of the system to the other.

Fig-5: Working module

This system attaching piezo-electric material is placed between the lathe machine based and the foundation based to absorb the vibration of the machine which produces during the working condition. And this Piezo-electric material is solder at two points in centre of the material which work as a positive and the outer face of the material work as a negative.

The piezo materials positive wire is connected to the analog pin 0 and negative wire is connected to the ground. With this resister of 1 ohm one end is connected in analog pin 0 and the other end is connected to the other ground of the circuit. Same as end of the circuit the cable is connected to the computer for signal transfer. This signal is in the form of digital quantity. Now the whole system is assembled. Second step is to check that the system is working or not for this knock operation is used. We used the software to note a digital signal in the form of reading.

5.1 Knock

This sketch reads a piezo element to detect a knocking sound. A knock on a door, table, or other solid surface is the example of knocking.

A piezo is an electronic device that generates a voltage when it's physically deformed by a vibration, sound wave, or mechanical strain. Similarly, when you put a voltage across a piezo, it vibrates and creates a tone. Piezo can be used both to play tones and to detect tones.

The sketch reads the piezo output using the analog Read command, encoding the voltage range from 0 to 5 volts to in a process referred to as analog-to-digital conversion. If the sensors output is stronger than a certain threshold, your Arduino will send the string "Knock!" to the computer over the serial port. To get higher threshold we hit the material by means of finger. If we hit the material in low intensity knock is not noted in the screen.

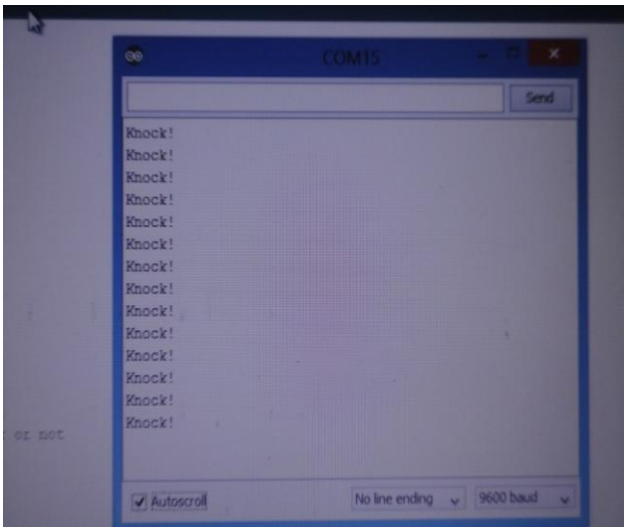

Fig-6: Knock Analysis

By knocking we get that voltages is generated from the vibration but it is not given the value of it , some change is require to get the value of voltage in frequent manner so we can generate value of voltage and thus from that value we get the frequency of vibration. So we change the programme on Arduino circuit which shows Analog voltage reading in serial monitor.

5.2 Read Analog Voltage

Read analog voltage is a process of convert the digital form of energy into a voltage form. As we tested that circuit is working then moving further circuit connection is same as the knock process only the difference is to change program of read analog voltage.

Then after put the piezo-electric material under the lathe machine which is going to conduct before machine has been started. Check the whole system is working or not by means of see that the reading has come zero continuously or not. If there reading are not come then check that all connection is ok then check further.

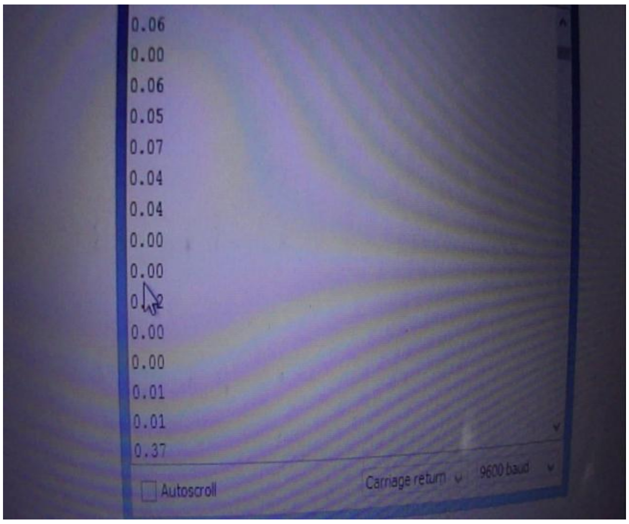

Fig-7: Read analog Analysis

When machine has been started the serial monitor show reading in positive value that value is in voltage form we take this reading value for plotting graph.

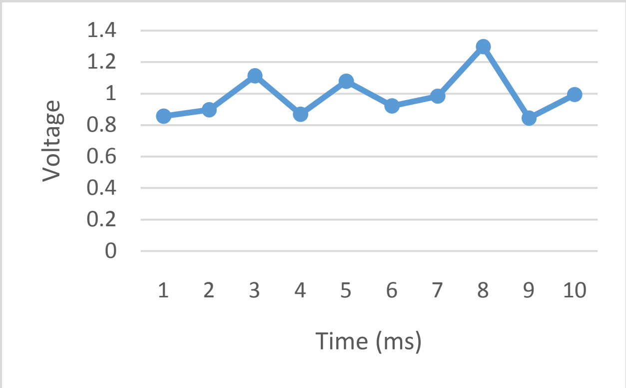

Fig-8: Piezo structure Frequency variation

Fig shows various frequencies in different layer of piezoelectric material, if some range of frequency is obtained in piezo structure but it is not uniform at all time. But when the structure of the material changes it goes up to the upper layer of frequency. So we take the maximum of the voltages obtained by the piezoelectric material.

6. RESULT ANALYSIS

6.1 Step - 1

From the tuning fork we get the voltages related to the standard frequency, from this reading various graphs are plotted between frequency vs voltages which is obtained from the standard tuning fork, various readings are

Table 1: Voltages related to the standard frequency

	5hz	10hz	15hz	20hz	25hz	30hz	35hz	40hz	50hz
1	0	0	0	0	0	0	0	0	0
2	1.7	2.65	2.03	0.38	3.31	3.31	1.09	1.18	2.56
3	0.1	0	0	1.02	0	0	2.49	3.27	1.5
4	0	0.91	2.04	3.3	0	0	3	1.48	0
5	2.42	0.06	0	0	2.15	2.15	1.63	0.9	0
6	0	0	2.05	1.65	0	0	0.18	0	0.02
7	0.11	1.8	0	0	1.2	1.2	0	0	2.81
8	1.68	0	2.05	0	0.71	0.71	0	0	1.25
9	0	2.7	0	1.01	0	0	1.33	2.03	0
10	1.91	0	2.06	0	2.62	2.62	2.23	0	4.8
11	0	1.67	0	2.69	0	0	0	0	0
12	0	0	2.07	0	0	0	0	0.3	1.42
13	2.23	0	0	2.55	2.86	2.86	1.25	2.11	0
14	0	1.06	2.07	0	0	0	2.28	3.02	1.19
15	0.31	0	0	0.86	0.47	0.47	0	1.22	0
16	1.48	2.77	2.08	0.09	1.44	1.44	0	0	1.01
17	0	0	0	0	0	0	1.17	0	0
18	2.11	2.41	2.08	1.79	1.91	1.91	2.38	0	0.73
19	0	0	0	0	0	0	0	2.9	0
20	0	0.68	2.09	3.27	0	0	0	1.13	0.49
21	2.68	0.3	0	0	3.31	3.67	1.09	2.93	0
22	0	0	2.09	1.77	0	0	2.44	2.2	0.26
23	0.52	2.04	0	0	0	0	0	0.38	0
24	1.27	0	2.1	0.07	2.17	2.17	0	0	0.02
25	0	2.14	0	0.88	0	0	1.03	4.26	0.2
26	2.32	0	2.1	0	1.19	1.19	2.53	0	0
27	0	1.43	0	2.57	0.72	0.72	0	0.15	0.43
28	0	0	2.11	0	0	0	0	1.96	0
29	2.83	0	0	2.65	2.61	2.61	0.95	3.15	0.66
30	0	1.3	2.12	0	0	0	2.6	1.37	0
31	0.73	0	0	0.98	0	0	0	0	0.89
32	1.07	2.8	2.12	0	2.87	2.87	0	3.7	0
33	0	0	0	0	0	0	0.86	0	1.13
34	2.52	2.17	2.13	1.67	0.45	0.45	2.67	0	0
35	0	0	0	0	1.46	1.46	3.89	0.98	1.36

From all this reading we plot the calibration curve from the vibration analysis which is shown below.

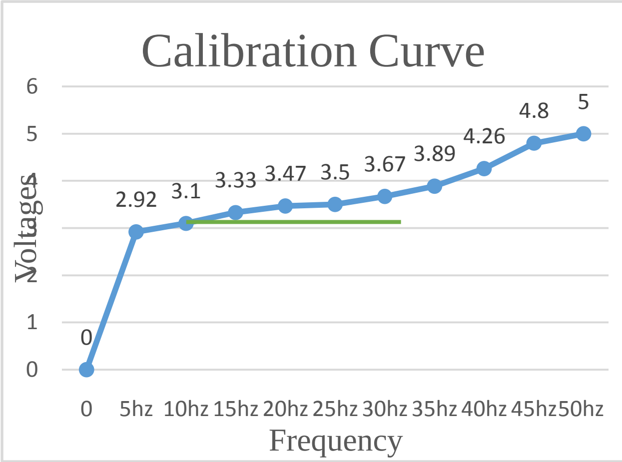

Fig-9: Calibration Curve

Slope of this calibration curve gives the multiplication factor which gives the relation between the two axes, so we can get the frequencies from the different obtained voltages

6.2 Step - 2

We performed the experiment with this system on the lathe machine because there are most of the operations are performed on the lathe in the company. Lathe machine include many operations but we focus on maximum performed operations (turning, grooving, knurling etc.).

Reading of voltages obtained during these operations is.

Table 2: Voltages obtained during these operations

Time	Grooving	Turning	Knurling
1	0	0	0
2	0.15	0.01	0.01
3	0.13	0	0
4	0.19	0.6	0
5	0	0.03	0.13
6	0.07	0.13	0
7	0.21	0.07	0.25
8	0.09	0	0.01
9	0.12	0.26	0.08
10	0.22	0.1	0
11	0	0.19	0
12	0.06	0	0
13	0.09	0.15	0.1
14	0	0	0
15	0.2	0.07	0.03
16	0.11	0.12	0
17	0.12	0.17	0.06
18	0	0	0
19	0.07	0.13	0.08
20	0.24	0	0.02
21	0	0.25	0.01
22	0.19	0	0.07
23	0.06	0.05	0
24	0	0	0
25	0.21	0.1	0
26	0.12	0	0
27	0	0.22	0
28	0.11	0	0
29	0.02	0.45	0.12
30	0	0	0
31	0.1	0.12	0
32	0	0	0.11
33	0	0.13	0
34	0	0	0.17

Analyse the condition of various operations here

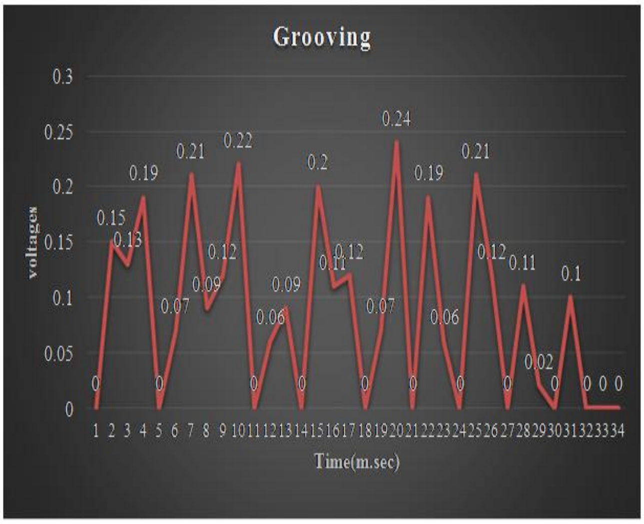

Fig-9: Grooving Analysis

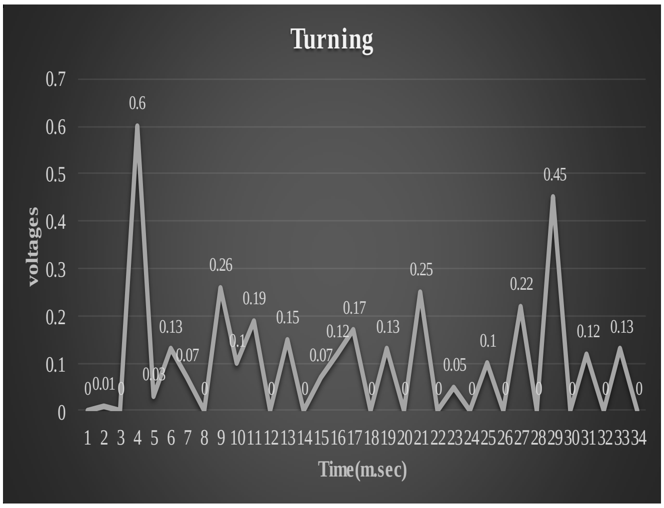

Fig-10: Turning Analysis

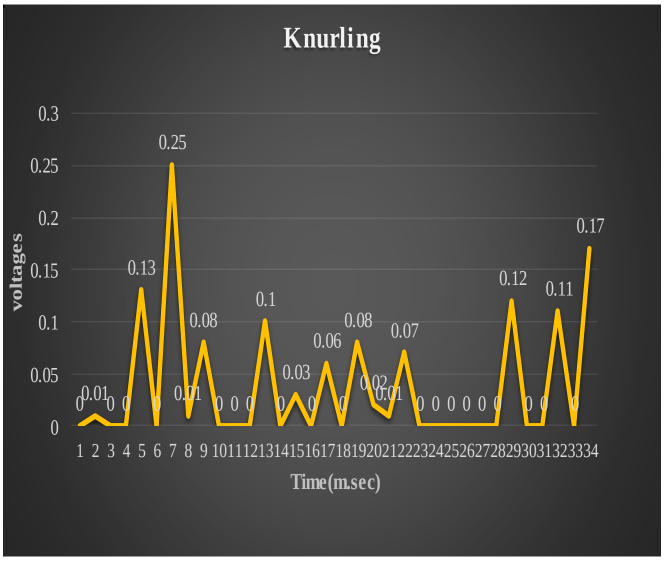

Fig-11: Knurling Analysis

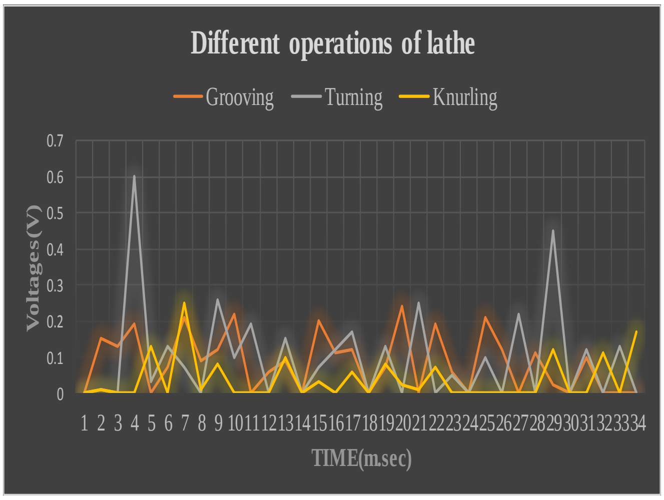

Fig-12: Analysis of Different operations of lathe

As we show that for different operation the voltage generated is different at any time interval. It is clear that for different operation some internal parameter of the operation is responsible for it.

For different operations, value of frequency also differs that's why we observed there are some parameter which affect during the operation so we short out the possible factor that affect the process is noted below.

Table 3: Lathe operation Analysis

OPERATIONS ⇨ **PARAMETER** ⇩	**Turning**	**Grooving**	**Knurling**
Depth of cut	Yes	No	Yes
High Cutting speed	Yes	Yes	No
Loose foundation	More	Less than turning	More than grooving
Misalignment	No	No	Yes
Human error	Yes	Yes	Yes

So, if we found the vibration frequency more which has been shown in the above graph than we decide the problem and check out them to reduce the vibration for increasing the quality of product. Above table describe the parameter which affects most for the particular operation.

7. CONCLUSIONS

We studied that for different operations, the frequency value is change due to the effect of particular parameter if we control those parameter in such a way that the operation performance is carried out smoothly than the vibration frequency is less affected and it will not harm to the machine as well as component or a product. Also this system gets the exact frequency at any time interval during the operation.

By this we can observed and get the exact parameter which is responsible for high vibration. Once we get the particular parameter by which vibration is developed then we can control those parameter and monitoring the machine by means of adjusting according condition based monitoring by using piezoelectric material. This can use in future for a maintenance purpose; also it can protect the machine from breakdown.

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