Ms.Shubhangi R.Saraf., Rajesh M. Holmukhe. / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue4, July-August 2012, pp.1316-1321

Cost Effective System For Real Time Monitoring Of Vibrations & Analysis Of A D.C. Motor Vibrations Using It.

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Abstract

In many industrial processes the vibrations play a vital role regarding the safety, machine life, economy of supply, load & hence overall power system. Hence a real time monitoring of machine vibrations is an important constraint. There are many options for real time vibration monitoring and FFT is most advanced option. But for a cost effective & portable monitoring of different types of machines a microcontroller based system is a good option. In this paper a microcontroller based system is designed & used for the different machines under various conditions & analysis is carried out for the same.

Keywords: ***piezoelectric Sensor ,Data Acquisition System, Microcontroller 8051, D.C. Motor Analysis, VB Software***

I. INTRODUCTION:

The electrical machine parameters under various operating conditions play a essential role in the considerations for the performance, efficiency, reliability and life of machine The vibrations along both axes viz vertical and horizontal axis give important knowledge about internal conditions & processes. They can be measured by respective position of sensor . If the vibrations are found within the limits or out of limits then maintenance schedule can be planned accordingly. Hence it is considered as a very important parameter to monitor machine condition. Hence such parameters should be constantly measured & monitored & its data acquisition should be scheduled for the database to be available for the control of these parameters and also in the automation of different machine dependent processes.

Conditional monitoring results can be stored & analysis can be carried out. So that nature of fault can be determined & hence corrective action, & maintenance schedule can be planned.

II . MOTOR VIBRATIONS

2.1 Significance of Measurement of Vibrations*:*

In an industrial atmosphere where overall equipment efficiency (OEE) is becoming increasingly important, preventing unexpected failures of equipment is vital.

Electric motors as the prime movers in all industry sectors are a major example. Generally regarded as highly reliable, due to tried and tested construction techniques, they are, nonetheless, subject to number of harmful conditions that can affect their performance and reduce operational life.

One of the most common of these conditions is vibration, resulting from either electrical or mechanical imbalance in the motor.

Reliability of different types of motors in any type of industry reduces to a great extent due to the problem of vibrations. Vibration problem is a cumulative & uncontrolled process if not controlled in limits within time .Vibration can cause damage to electric motors in numerous ways.

1] It can speed up bearing failure by causing indentations on the bearing raceways at the ball or roller spacing.

2] it can loosen windings and cause mechanical damage to insulation by fracturing, flaking or eroding of the material.

3] The excessive movement it causes can result in lead wires becoming brittle. Fourth and final, it can cause brush sparking at commutators or current collector rings. As a result of these problems, whenever vibration is located in an electric motor, its source should be located quickly and corrected. However, this is not always the case.

Hence sophisticated monitoring and detection tools that would enable engineers to isolate such problems is essential.

2.2 Causes of Vibration*:*

There are many electrical and mechanical forces present in induction motors that can cause vibrations.

Additionally, interaction of these various forces makes identification of the root cause indefinable.

i]. Broken Rotor Bar

If a broken rotor bar or open braze joint exists, current will not flow in the rotor bar .Hence this the field in the rotor around that exacting bar will not exist. Therefore the force applied to that side of the rotor would be different from that on the other side of the rotor again creating an unbalanced magnetic force that rotates at one times rotational speed and modulates at a frequency equal to slip frequency times the number of poles.

If one of the rotor bars has a different resistivity a similar observable fact (as in the case of a broken rotor bar) can exist.

ii. Coupling Unbalance

The coupling unbalance limit given in API 671 of 40W/N, when applied to a classic 1000 HP 3600 rpm 2 pole
motor for example, results in a value equal to about one-third of the motor unbalance limit for one end.

iii .Eccentric Rotor

An eccentric rotor, This means the rotor core OD (outer diameter) is not concentric with the bearing journals, creates a point of minimum air gap which rotates with the rotor at one times rotational frequency. There will be a net balanced magnetic force acting at the point of minimum air gap associated with this, since the force acting
at the minimum gap is greater than the force at the maximum gap. This net unbalance force will rotate at rotational frequency, with the minimum air gap, causing vibration at one time rotational frequency.

iv. Thermal Unbalance

Thermal unbalance is a special form of unbalance. It is caused by uneven rotor heating, or uneven bending due to rotor heating. The proper solution is to find out the reason for uneven heating affecting shaft straightness, and fix the rotor.

v. **Weak Motor Base**

If the motor is installed on a fabricated steel base, such as weak base, then the possibility exists that the vibration which is measured at the motor is greatly influenced by a base which itself is vibrating. Ideally the base should be stiff enough to meet the 'Massive Foundation' criteria defined by API 541 . It is essential that, this requires that support vibration near the motor feet to be less than 30% of the vibration measured at the motor bearing. To test for a weak base, measure and plot horizontal vibration at ground level, at bottom, middle, and top of the
base, and at the motor bearing.

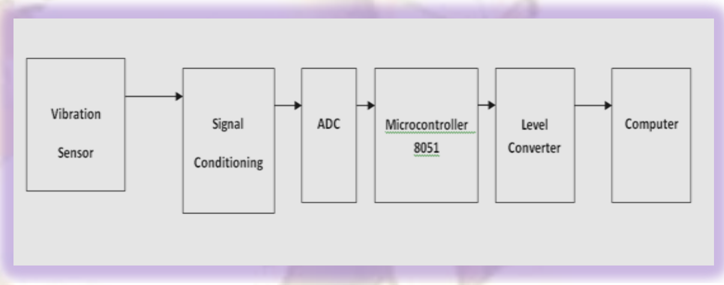
2.**3 Vibration Limits**

There are various publications available which specify vibration limits. The IEE std 541 is taken as reference for considering the vibrations and their effects, and also for deciding schedule for repair & maintenance in the different cases like degradation of the bearings (sleeve bearings), loosening of rotor bars , accumulation of debris in the oil guards, between rotor and stator, etc.,• changes in mounting conditions: deterioration of grouted base, changes in alignment/soft foot, etc, Loosening of things mounted to the motor.

The following table gives the vibration limits given by different standard publications.

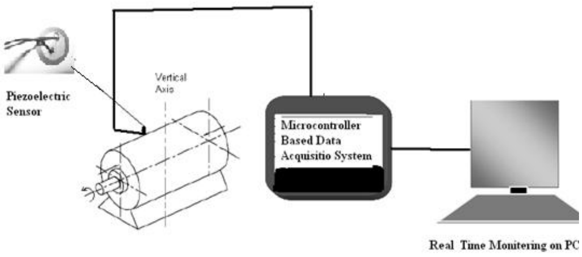
Motor Speed (RPM)	NEMA MG1-7.08.1 Unfiltered Vibration (in/sec peak velocity)	NEMA Max. Amplitude (P-P Mils)	IEEE-841 1994 Unfiltered Vibration (in/sec peak velocity)	Typical Vibration EQP III, XS & 841 (in/sec peak velocity)
3600	0.15	1	0.08	≤0.08
1800	0.15	1.5	0.08	≤0.08
1200	0.15	2	0.08	≤0.08
900	0.12		0.06	≤0.06
720	0.09		Not spec'd	
600	0.08		Not spec'd	

III. DATA ACQUISITION SYSTEM DESIGNED FOR ELECTRICAL MOTOR VIBRATION MEASUREMENT:



1] Vibration Sensor: The piezoelectric sensor is used to sense vibrations. It produces electrical output which is proportional to the applied vibrations.
2] Signal Conditioning Circuit: For manipulating an analog signal in such a way that it meets the requirements of the next stage for further processing i.e here it is converted to volts and is further given to analog-to-digital converters.
3] Analog to digital converter: ADC 808 is used. It is a monolithic CMOS device. This is used to convert analog voltage to digital which is hexadecimal form.
4] Level Converter: The MAX232 is an integrated circuit that converts signals from an RS-232 serial port to signals suitable for use in TTL compatible digital logic circuits. The MAX232 is a dual driver/receiver and typically converts the RX, TX, CTS and RTS signals.
5] Microcontroller: The hexadecimal output of analog to digital converter is converted to decimal & then in ASCII form as the display or personal computer requires the input in this form.
6] Personal Computers: It is used to display and store the result of this data acquisition system

3.1 Practical Implementation of system

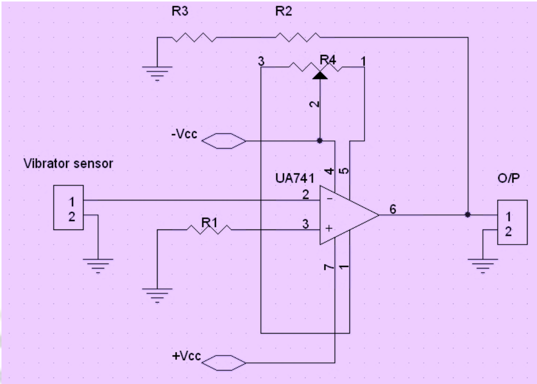


In this project , for design and development of the system, the methodology used involves the software and hardware implementation. The actual implementation of the system involves the following steps

1] System characterization: Defining the system broadly for monitoring vibration of machine composing the block diagram for the system.
2] Circuit Design: Selecting all the devices viz sensors, signal conditioner, analog to digital converter, microcontroller, level converter and PC considering different factors, requirements, advantages and disadvantages according to system definition. Design of hardware circuit and its testing on laboratory kits with some simple microcontroller software routines.
3] PCB Design and Fabrication: Generation of schematic diagrams and the production of circuit board outline layout data for the procurement of circuit board.
4] Hardware Modifications: Making any hardware alterations found necessary after the initial hardware tests, to produce a revised circuit board schematic diagram and layout.
5] Software Design: Developing algorithm for the system, allocating memory blocks as per functionality, coding and testing.
6] Integration and Final Testing: Integrating the entire hardware and software modules and its final testing for data acquisition functioning.

Thus the complete design is divided into two parts:
1) Hardware Implementation.
2) Software Implementation.

3.2 **Signal Conditioning for Vibration Sensor:**



The output of the sensor is given to non-inverting pin no 12 and circuit is formed as a voltage follower circuit for buffering the signal. The voltage follower is also called as a non inverting buffer. When placed between two networks it removes loading on the first network. Transistor is used so that the signal can interface with most of the logics ; ADC in this case.

3.3 AT89C51 Microcontroller

The 8051 family of microcontrollers is based on an architecture which is highly optimized for embedded control systems. It is used in a wide variety of applications from military equipment to automobiles to the keyboard. Second only to the Motorola 68HC11 in eight bit processors sales, the 8051 family of microcontrollers is available in a wide array of variations from manufacturers such as Intel, Philips, and Siemens. These manufacturers have added numerous features and peripherals to the 8051 such as I2C interfaces, analog to digital converters, watchdog timers, and pulse width modulated outputs. Variations of the 8051 with clock speeds up to 40MHz and voltage requirements down to 1.5 volts are available. This wide range of parts based on one core makes the 8051 family an excellent choice as the base architecture for a company's entire line of products since it can perform many functions and developers will only have to learn this one platform.

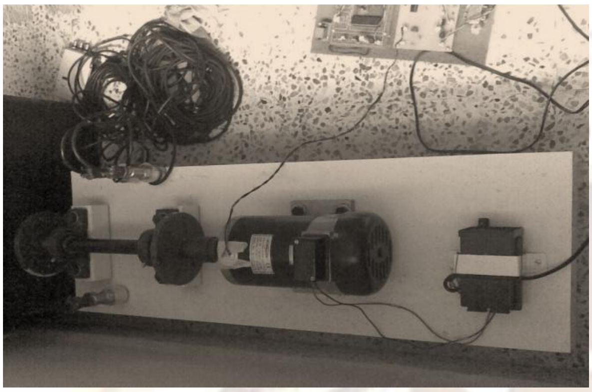
*3.***4 The ADC 808**

The ADC0808, ADC0809 data acquisition component is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8-channel multiplexer can directly access any of 8-single-ended analog signals.

The device eliminates the need for external zero and full-scale adjustments. Easy interfacing to microprocessors is provided by the latched and decoded multiplexer address inputs and latched TTL TRI-STATE outputs.

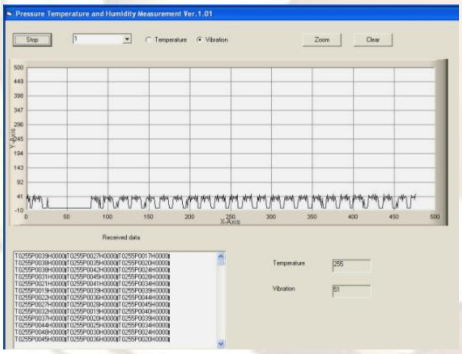
IV. PRACTICAL TESTING & XPERIMENTATION:

The Experiment is carried out on the test motor which is a D.C. motor where faults can be created for simulation.
It is a 0.25Hp, 180V ,1.8A, 3000 rpm CE make D.C. motor.



4.1 Motor in Healthy condition and running at speed of1500 rpm.

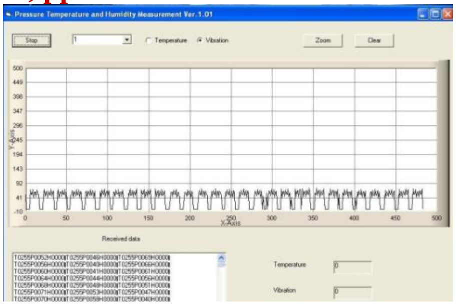
The most repeated pattern of vibrations was obtained as below:



For all the test the pattern in the time region where vibrations have settled is considered viz from 20 to 25 sec [200 to 250 on screen] is considered.
Here vibrations are occurring 3 times and of amplitude 41 micrometers during 5 sec. Hence per second vibrations can be calculated as
3 x 41/5 = 24.6 micrometers [µm] per second are the vibrations.

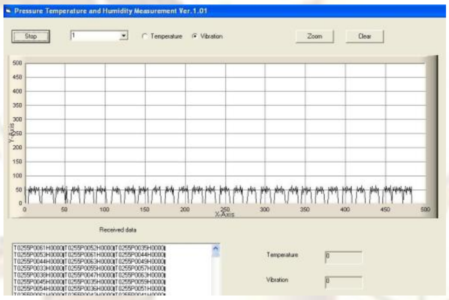
4.2 Motor under faulty condition-1 i.e. Soft Foot of 0.5 mm thickness:

This condition is created by previously arranged set –up of slightly unbalancing the installed motor by a minute iron chip. Under this condition depending upon this unbalance the vibrations will be observed. The iron chip is of very less thickness about 0.5 mm. The vibration pattern observed is as follows.



Here vibrations are occurring 3 times and of amplitude 50 micrometers during 5 sec. Hence per second vibrations can be calculated as
3 x 50/5 = 30 micrometers [µm] per second are the vibrations.

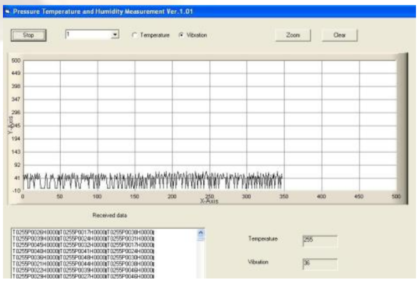
4.3 Motor under faulty condition-2 i.e. Soft Foot of 1mm thickness:



Here vibrations are occurring 3 times and of amplitude 67 micrometers during 5 sec. Hence per second vibrations can be calculated as
3 x 67/5 = 40.2 micrometers [µm] per second are the vibrations.

4.4 Motor under faulty condition-3 i.e. Unbalanced load -1:

The motor shaft is mounted with the load that has an arrangement to create un unbalance by inserting the bolts unevenly so as to create an unbalance. In the first case of unbalance only one bolt is inserted on only one side. Hence a slight unbalance is created and the vibration pattern is observed as follows:

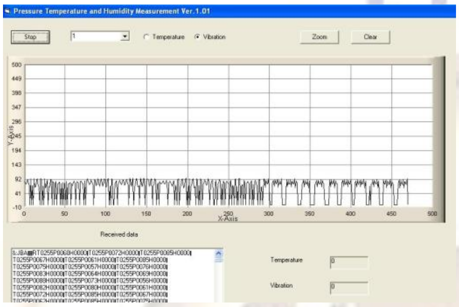


Here vibrations are occurring 9 times and of amplitude 45 micrometers during 5 sec. Hence per second vibrations can be calculated as

9 x 45/5 = 81 micrometers [µm] per second are the vibrations.

4.5 Motor under faulty condition-3 i.e. Unbalanced load -2:

In the second case of unbalance two bolts are inserted on only one side. Hence a more unbalance is created and the vibration pattern is observed as follows where the vibrations are observed to be increased in the velocity.

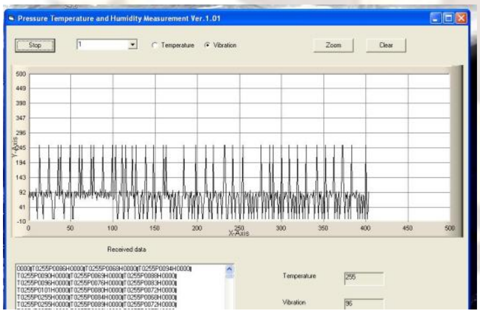


Here vibrations are occurring 8 times and of amplitude 92 micrometers during 5 sec. Hence per second vibrations can be calculated as

8 x 92/5 = 147.2 micrometers [µm] per second are the vibrations.

4.6 Motor under faulty condition-4 i.e. Unbalance 2 and speed 1800 rpm:

In addition to the second unbalance condition when the speed is increased from 1500 rpm to 1800 rpm the higher vibrations are observed of which the pattern is as shown below.



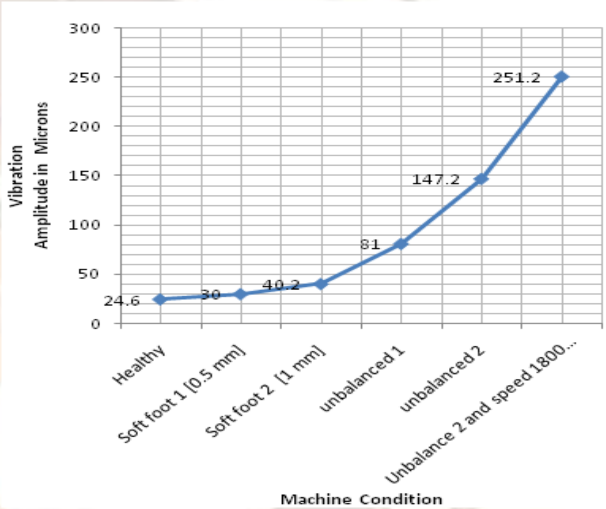
Here vibrations are occurring 3 times and of amplitude 92 micrometers and also of 245 micrometers 4 times during 5 sec. Hence per second vibrations can be calculated as[3 x 92 + 245 x 4] /5 = 251.2 thus maximum among all the conditions.

V. RESULT

The results are summarized in the table below :

Machine Condition	Vibration Velocity in Microns/sec
Healthy	24.6
Soft foot 1 [0.5 mm]	30
Soft foot 2 [1 mm]	40.2
unbalanced 1	81
unbalanced 2	147.2
Unbalance 2 and speed 1800 rpm	251.2

The graph can be plotted as below:



VI. CONCLUSION

Vibration measurement is possible using this microcontroller based data acquisition system for all types of motors out of which the d.c. motor vibrations are studied. In the case study it is observed that healthy motor is showing the least vibrations whereas they are increasing with the different types of faults the most being at increased speed plus under fault condition.

Though the system has certain drawbacks such as need of additional manual measurement, the vibrations can be broadly estimated at a glance and also in a cost effective way as is cost is very less than FFT and accelerometers..

Thus this can be used in all types of Electrical motors as well as mechanical Engineering machinery that uses electrical motors for measurement of vibrations and then storing Data. From previously stored data causes and faults can be predicted and thus corrective action can be taken. Also maintenance schedule can be decided.

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There is future scope of automated further calculations in this project but there can be increase in the cost. The system will also help in deciding the maintenance schedule of the machinery and also suggesting the troubleshooting procedures in the same.

VII. ACKNOWLEDGEMENT

First of all I would like to express my thanks to my guide and PG coordinator Prof. Holmukhe for his invaluable suggestions and constant guidance.

I would thank Prof. Mrs. S.S. More Head of Department and Dr. A.R. Bhalero Principal, and all the faculty members of department of Electrical Engineering at Bharati Vidyapeeth University for their guidance and support.

I would also thank the management committee of SKNCOE and colleagues of Electrical Department for their co-operation which made me possible to complete my work.

I would like to express my gratitude to my family members and friends for their constant encouragement, support, help and co-operation. Without their encouragement my work would have been just a dream.

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