Microcontroller Based Data Acquisition System For Electrical Motor Vibrations using VB software.

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Abstract **The electrical machine parameters under various operating conditions play a vital role in the considerations for the performance, efficiency, reliability and life of machine. Vibration signals measured at the external surfaces of a machine contain a great deal of information as to the internal processes. Hence it is considered as a very important parameter to monitor machine health. Hence such parameters should be constantly measured & monitored & its data acquisition should be carried out so that the data is available for the control of these parameters and also in the automation of different machine dependent processes.**

Also the data is to be stored so that it can be retrieved for future references & innovations.

There are different parameters of motor viz voltage , current , flux, torque, speed power factor, heat rise ambient temperature and vibrations that are needed to be measured & monitored under different operating conditions of motor.

This project focus on the measurement & monitoring of the parameter viz vibrations out of these parameters.

This parameter is very important in performance , reliability & life of machine and also play a vital role in the safety point of view.

The proposed system comprises of sensor, analog to digital converter , signal conditioning circuit, microcontroller 8051.These parameters will be constantly measured and displayed and if they cross a safety limit, the control action can be taken. Thus the future scope of the project is that more channels for measurement of more parameters such as temperature & humidity or 3-dimensional vibrations etc can be added & control methods for these parameters can be designed & developed as the further step of monitoring. Also hardware configuration can be changed to improve the speed.

INTRODUCTION

It is often very useful to measure the internal parameters of electrical machine under various operating conditions. The parameters like voltage, current, flux, torque, speed, power factor are usually measured & considered parameters to study the performance characteristics of the machine to study its efficiency and torque for different applications. But it is also important to measure & monitor one more parameter which is also important viz. vibrations of machine for the considerations of performance, efficiency, reliability & life of machine.

It is usually complicated to have constant monitoring & recording & storing results of these parameters using the traditional measuring apparatus like meters. Hence a system is designed to have a constant monitoring & storing
results of these parameters using sensor technology along with microcontroller. Also control of parameters can be achieved using relays.

In this project to achieve monitoring of different types of motors the following steps are taken. For the motors of specific ratings the circuit is to be designed.. The vibration are sensed and then this signal is conditioned into suitable format. Then the analog signals are converted to digital and

then they are given to the microcontroller and further to personal computer so as to achieve monitoring. The data is collected for different conditions of motor such as bearing misalignment, soft foot, unbalanced load etc. And hence this data can be analyzed and stored for future references.
The system proposed in this dissertation is based on sensor technology & microcontroller 8051. A sensitive real time monitoring can be achieved by this system and hence the performance characteristics and life of the machines can be improved.
The sensors will sense the parameter under study .Since the output signals of sensors cannot be directly processed by the electronic system a signal conditioning circuit is used for each sensor to condition the signal. This is an analog signal and it is converted to digital signal by using analog to digital converter.
The signals are further given to microcontroller to convert it in decimal form.
The output of microcontroller is given to level converter to manipulate between high and low levels of personal computer and microcontroller.
The level converter interface with personal computer which will display real time results and these can also be stored & retrieved for future references and can also be used for the comparison purposes in the form of graphs, charts and tables by processing it using personal computers.

1.1 Importance of Vibration Measurement

Vibration problems in induction motors can be extremely annoying and may lead to greatly reduced reliability. It is crucial, in all operations and manufacturing processes such that down time is avoided and/or minimized. If a problem does occur the source of the problem is quickly identified and corrected.. By using the proper data collection and analysis techniques, the true source of the vibration can be discovered. This includes Electrical imbalance ,Mechanical unbalance – motor, coupling, or driven equipment Mechanical effects – looseness, rubbing, bearings, etc. External effects - base, driven equipment, misalignment etc.[9]
Vibration problems can occur in the installation or operation of a motor. When they occur it is normally critical that one reacts quickly to solve the problem. If not solved quickly, there can be long term damage to the motor or immediate failure, which would result in immediate loss of production. The loss of production is oftentimes the most decisive concern. To solve a vibration problem cause and effect should be differentiated.
For this to happen, the root cause of the vibration must be understood.

Fig. 1 Damage Observed In Machines Due To Uncontrolled Vibrations

A proper routine vibration program using a portable data collector, or permanent on-line vibration monitoring, will become the foundation of any predictive maintenance proposal. Measuring, trending, alarming and analyzing fan and motor vibration will provide earlier warning of developing problems and allow replacement parts to be ordered. Bearings can be replaced during scheduled down times prior to non repairable damage occurring.

1.2 Causes of Vibrations

There are many electrical and mechanical forces present in induction motors that can cause vibrations. Additionally, interaction of these various forces make identification of the root cause elusive. [13]

a. 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.

b. Broken Rotor Bar

If a broken rotor bar or open braze joint exists, no current will flow in the rotor bar .Hence this the field in the rotor around that particular 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 phenomenon (as in the case of a broken rotor bar) can exist.

c. 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.

d.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.

e. Weak Motor Base

If the motor is sitting 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.

f. Effect of resonance on Vibrations

Resonant frequency is the natural frequency of a component or an assembly or a structures. All structures have a resonant frequency. If impact is made on the structure with enough force to make it move, it will vibrate briefly at its natural frequency. A structure will have a resonant frequency in each of its 3 directional planes (x, y and z, or as we call them, horizontal, vertical and axial). Resonance serves to amplify the vibration due to whatever vibration force is present at (or near) that resonant frequency. It is important to note that resonance does not cause vibration - it amplifies it.

Critical speeds - occurs when a component rotates at its own natural frequency.

- A "critical speed" is simply when the rotational speed (rpm) coincides with the natural frequency of the rotor (cpm).
- The tiniest amount of residual unbalance (something that is always present) is enough to cause huge amounts of vibration when rotating at a critical.
- Rotors that are sped up or slowed down slowly are susceptible to this (i.e. turbines). In these cases, the critical speed is usually well known.
- The most common problem related to unknown critical speeds is probably belts. Belts rotating at their resonant frequency (or having a nearby source of excitation of that resonant frequency) can vibrate excessively and cause other problems. For example, if the natural frequency of the belts coincides with the rpm of the fan, the belts will vibrate at their natural frequency.
- 2nd and 3rd criticals also may occur if the rotor speed gets high enough.

1.3 Vibration Limits

Many publications of 'vibration limits' are available. Table 1 lists various industry vibration limits. Both current revisions, as well as older revisions of these standards are listed, as these older revisions are commonly referenced. Furthermore, these motor vibration limits are applicable to a motor mounted on a seismic mass, and either uncoupled, or coupled to a piece of equipment in such a way that any vibration influence from the driven equipment is totally eliminated.

As a motor ages, the vibration levels may slowly increase. There may be a multitude of reasons of why the levels may increase over time

• degradation of the bearings (sleeve bearings)
• loosening of rotor bars
• accumulation of debree 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 [13]

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	

Table 1: Vibration Limits According to Different Specifications

The factor limiting the vibration limits at these levels is the motor bearings. Generally, sleeve bearings (as compared to anti friction bearing motors) are more restrictive in terms of vibration limits. Sleeve bearing motors can operated continually at one-half their diametrical bearing clearance, without any damage. They can operate

at slightly higher levels for short periods of time as well, but these higher limits must be established with the motor manufacturers.
If the motor is sitting on a weak base, higher housing vibration limits and shaft vibration limits (if measured by shaft stick, and not by a proximity probe) can be tolerated. Effectively, the vibration measured at the motor feet can be subtracted from the vibration measured at the bearing. 4.System Design and Implementation

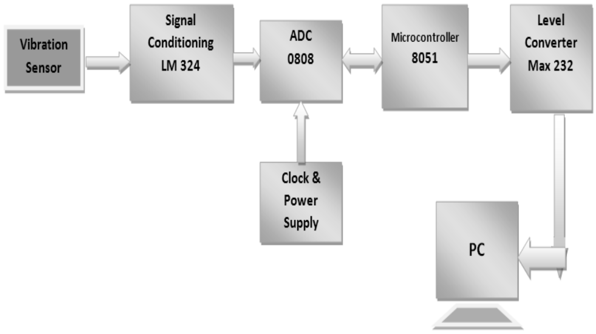


Fig.2 Block Diagram of Components

Vibration Sensor Signal Conditioning

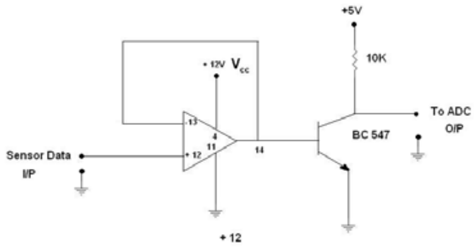


Fig. 3 Signal Conditioning Circuit for Vibration Sensor

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.

1.4 Analog to Digital Conversion

In physical world parameters such as temperature, pressure, humidity, and velocity are analog signals. A physical quantity is converted into electrical signals. We need an analog to digital converter to translate the continuous analog signals to discrete digital numbers so that the microcontroller can read them. Thus, an analog-to-digital converter (ADC) is an electronic circuit that converts continuous signals to discrete digital numbers. Analog to digital converters are the most widely used devices for data acquisition.

Experiment: Experiment was Performed at

1] Sinhgad Institutes, Pune at Electrical Engineering Laboratory.

2] Bharati Vidyapeeth College of Engineering. Electrical Machines Laboratory

Procedure: For the motor under running conditions vibrations in the vertical direction i.e along vertical axis can be measured by keeping the piezoelectric sensor i.e. vibration sensor on its frame. An insulation tape was used for fixing it. If necessary it can be fixed up there by epoxy glue or similar adhesive. The system is connected to PC by its serial communication port.

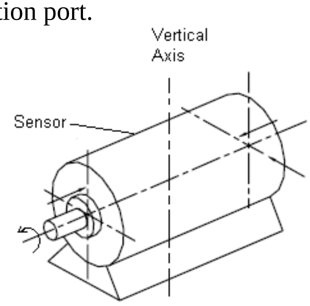


Fig 4 Sensor Position on Motor

Description of The Motors:

Sinhgad Institutes, Pune at Electrical Engineering Laboratory.

1] D.C. Shunt motor with brake pulley arrangement 3HP, 220V DC, 1500rpm. ARWA make.

2] D.C. Shunt motor with brake pulley arrangement 3HP, 220V DC, 1500rpm, having mechanical looseness. [ARWA make]

3] Alternator coupled with D.C.shunt Motor 5Hp ,415V ,1440rpm ,
3KW ,220V,1500rpm with faulty damaged bearing. [ARWA make]

Bharati Vidyapeeth College of Engineering. Electrical Machines Laboratory

D.C. Shunt motor. Healthy Condition. 3 HP, 220V DC, 1500rpm , Kirloskar Make.7.1 ARWA Make D.C. Shunt Motor Tests

Case A: Healthy Machine

1] The vibration pattern of the healthy motor i.e. motor without any faults was carried out at three different speeds viz. N_1 = 1000rpm , N_2 = 1250rpm N_3 = 1500rpm.

Armature current control method was used to control the speed.

At Speed N_1 = 1000rpm

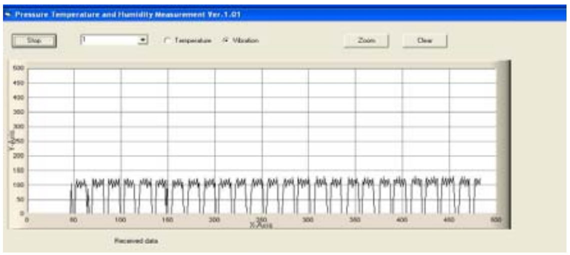


Fig 5 Healthy Machine at N = 1000rpm.

Peak Vibrations are approximately equal to 100 to 125 µm with vibration frequency as seen in the pattern. Thus vibrations of 125 µm are occurring 3 times within 5 sec.

[In the duration of 25 to 30 sec]

Formula: (no. of vibrations x amplitude of vibrations in µm)/ 5sec = µm/sec

Hence rate of vibration is (3 x 125)/5 = 75 µm/sec.

At Speed N_2 = 1250rpm

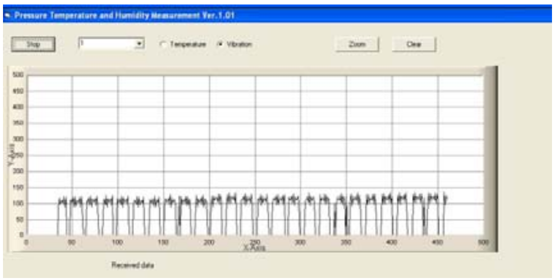


Fig 6 Healthy Machine at N = 1250rpm.

At N_3 = 1500rpm

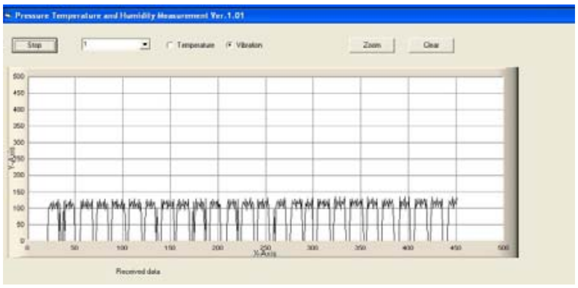


Fig 7 Healthy Machine at N = 1500rpm.

Case B : Unbalanced Load

Now the same motor is subjected to the unbalanced load & patterns are observed. Tensions on both sides are in kg. For creating unbalanced load Tension on tight side & Tension on slack side are kept at different values.

1] T_1 = 3 kg & T_2 = 5 kg [i.e. T_1 = 29.43N & T_2 = 49.05N]

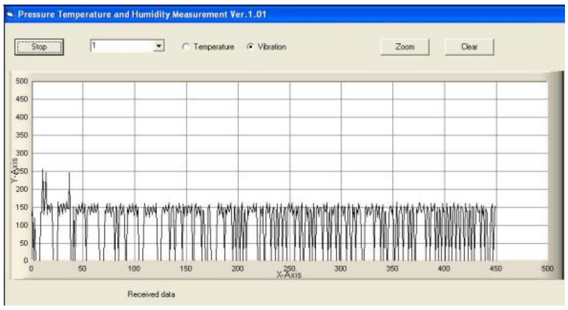


Fig 8 Unbalanced Load 3 kg & 5 kg.

Thus the vibrations are more intense at start & further their frequency is observed to increase.2] 2] T_1 = 2 kg & T_2 = 5 kg [i.e. T_1 = 19.62N & T_2 = 49.05N]

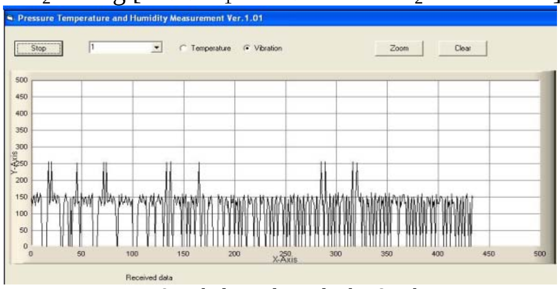


Fig 9 Unbalanced Load 2 kg & 5 kg.

Thus amplitude of vibrations is observed to increase more frequently. Also frequency of vibrations is observed to increase after 15sec as compared to that at start.

3] T_1 = 1 kg & T_2 = 5 kg [i.e. T_1 = 9.81 N & T_2 = 49.05N]

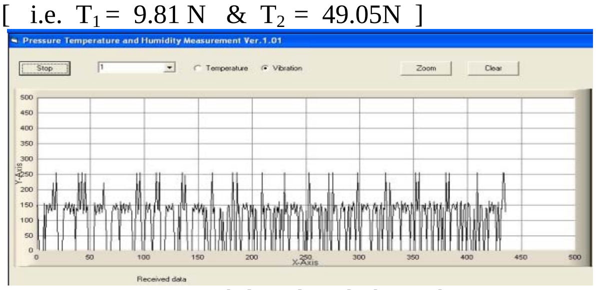


Fig 10 Unbalanced Load 1 kg & 5 kg.

Thus amplitude of vibrations is observed to increase still more frequently. Also frequency of vibrations is observed to increase as compared to that at start.

Case C : Armature current fluctuation & Fault

For the same motor the rheostat by which field current was adjusted was faulty within a definite patch . Hence the current was constantly fluctuating & finally decreased to very low value hence speed was increased & vibrations were also observed to increase to a large extent as shown in the following pattern.

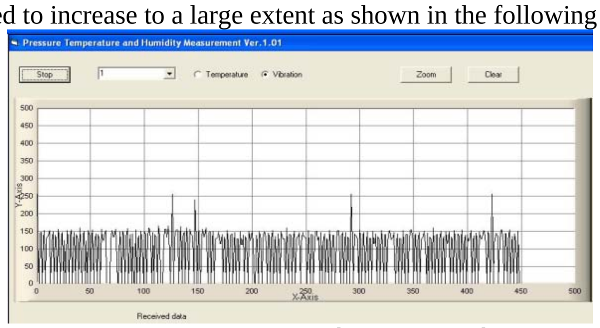


Fig 11 Armature Current Fluctuation & Fault

Thus the frequency of vibrations is very high & amplitude is also increasing frequently.

7.1.4 Case D: Mechanical Looseness

When the same motor was subjected to the mechanical looseness by slightly loosening some of the nut bolts following pattern was observed.

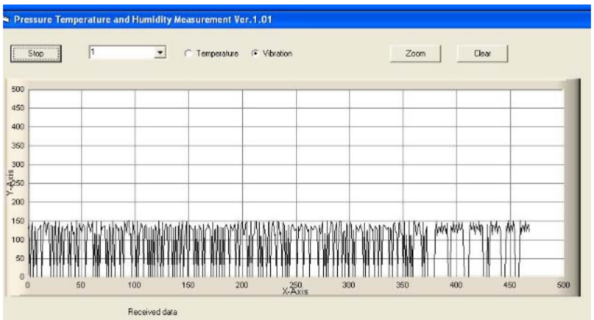


Fig 12 Mechanical Looseness

Thus the frequency of occurrence of vibrations is more in the starting & middle region.

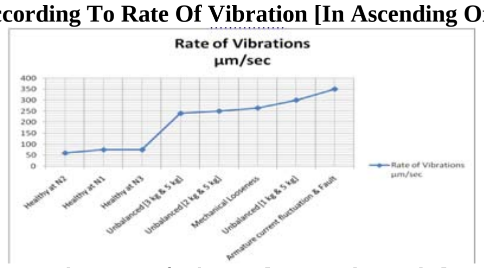
Result analysis for ARWA Make D.C. Shunt Motors.

Result when arranged in ascending order of rate of vibrations is obtained as below.

Condition	Rate of Vibrations µm/sec
Healthy at N2	60
Healthy at N1	75
Healthy at N3	75
Unbalanced [3 kg & 5 kg]	240
Unbalanced [2 kg & 5 kg]	250
Mechanical Looseness	264
Unbalanced [1 kg & 5 kg]	300
Armature current fluctuation & Fault	350

Table 2 : Conditions Arranged in Ascending Order of Rate of Vibrations

2] According To Rate Of Vibration [In Ascending Order]



Graph 1. Rate Of Vibration [In Ascending Order]

Thus most severe vibrations are observed in case of armature current fluctuation & Fault. All vibrations are found to be well below limit i.e 0.06 inch/sec = 1524 µm/sec
(conversion factor : 1 inch = 25,600 µm) according to IEEE standard 841 -1994 Interpretation.

Faulty/ Damaged Bearings at Coupling between Alternator & D.C. Shunt Motor [ARWA Make : Sinhgad Institutes]

An alternator coupled with D.C. Shunt motor having faulty bearings is run at three different speeds by adjusting the lamp load

N_1 = 1013 rpm

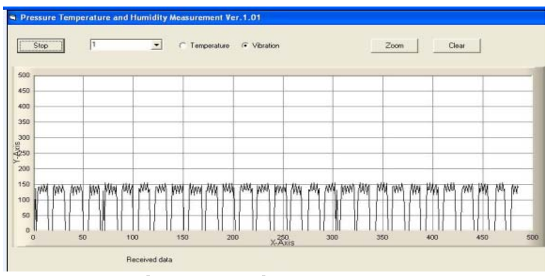


Fig 13 Faulty / Damaged Bearings at N = 1013 rpm

Thus the vibrations of medium amplitude & frequency of occurrence are observed.

At N_2 = 1255 rpm

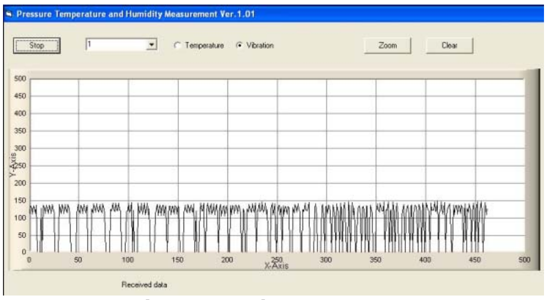


Fig 14 Faulty / Damaged Bearings at N = 1255 rpm

Thus the vibrations of medium amplitude & frequency of occurrence are observed &frequency is observed to increase after 30 sec.

At N_3 = 1497 rpm

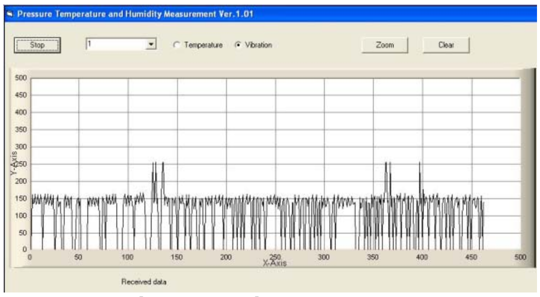


Fig 15 Faulty / Damaged Bearings at N = 1497 rpm

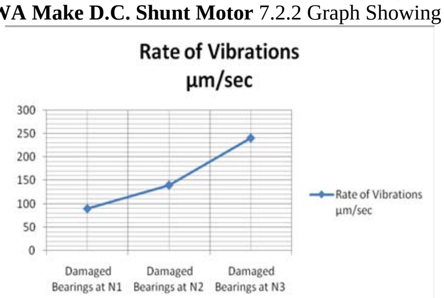
Thus the vibrations of medium amplitude & frequency of occurrence are observed &frequency is observed to increase after 15sec. Also amplitude is increasing at some instances of time till 250µm.

In the duration of 25 to 30 sec , vibrations of amplitude 150 microns are occurring 5 times within 5 sec. Hence rate of vibrations = (150 x 5)/5 = 240 µm/sec

Summary Of Results For Rate Of Vibrations [Velocity Of Vibrations] For ARWA Make D.C. motor coupled to alternator Within The Duration of 25 To 30 Sec.

Case No	Condition	Amplitude 1 µm	No. of Vibrations of Amplitude 1	Amplitude 2 µm	No. of Vibrations of Amplitude 2	Total Amplitude µm	Time in sec	Rate of Vibrations µm/sec
1	Damaged Bearings at N1	150	3	0	0	450	5	90
2	Damaged Bearings at N2	140	5	0	0	700	5	140
3	Damaged Bearings at N3	150	8	0	0	1200	5	240
	Maximum limit for vibrations for 3 hp motor according to IEEE std. 841 -1994 is 0.06 Inch/sec i.e. 1524 micrometers/sec							
	Thus these vibrations are found to be well below limit with maximum vibrations at case-3							

Table 3 : **Summary Of Results for ARWA Make D.C. Shunt Motor** 7.2.2 Graph Showing Rate Of Vibrations At Different Speeds.



Graph : 2 Rate Of Vibrations At Different Speeds of D.C. Shunt Motor

Kirloskar Make D.C. Shunt Motor Tests

Healthy Motor [3 HP, 220V DC, 1500rpm , Kirloskar Make.]

1] On Motor Surface

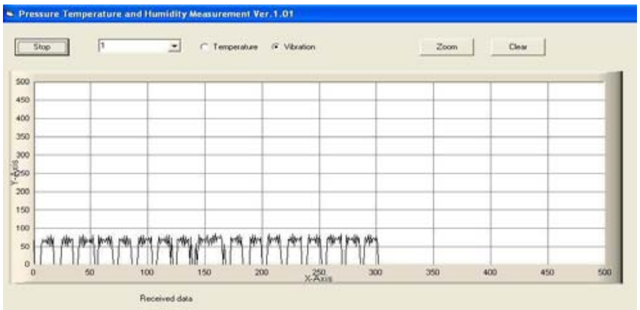


Fig16: On Motor Surface [Kirloskar Make Motor]

2] Near Shaft:

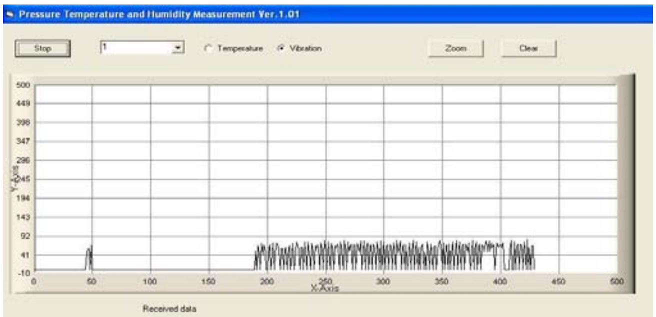


Fig17 Near the shaft [Kirloskar Make Motor]

3] On Foundation:

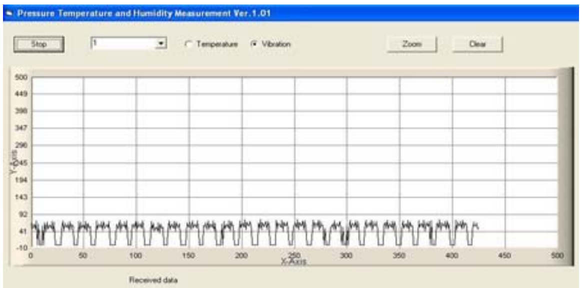


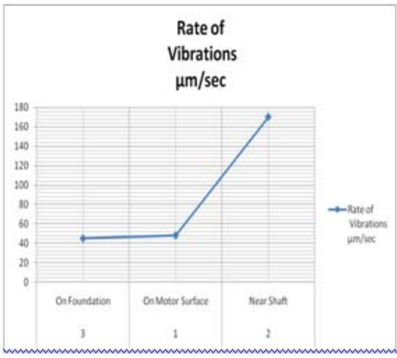
Fig 18: On Motor Foundation [Kirloskar Make Motor]

7.3.1 Summary of Results For Rate of Vibrations [Velocity Of Vibrations] For Kirloskar Make D.C. Shunt Motor Within The Duration of 25 To 30 Sec.

A	B	C	D	E	F	G	H	I
Case No	Condition	Amplitude 1 µm	No. of Vibrations of Amplitude 1	Amplitude 2 µm	No. of Vibrations of Amplitude 2	Total Amplitude µm	Time in sec	Rate of Vibrations µm/sec
1	On Motor Surface	80	3	0	0	240	5	48
2	Near Shaft	85	10	0	0	850	5	170
3	On Foundation	75	3	0	0	225	5	45
Maximum limit for vibrations for 3 hp motor according to IEEE std. 841 -1994 is 0.06 Inch/sec i.e. 1524 micrometers/sec								

Table 4: Summary of Results For Kirloskar Make D.C. Shunt Motor

Graphs Showing Rate Of Vibrations At Different Conditions



Graph : 3 Rate Of Vibrations At Different conditions of D.C. Shunt Motor

All vibrations are found to be well below limit   i.e 0.06 inch/sec = 1524 µm/sec

All above patterns of vibrations on PC screen along with their analysis can be used to get a quick guideline for mechanical & electrical fault detection & hence for repair by using this low cost & portable device so that the repair work & vibration dampening arrangements can be carried out or arrangements can be made to dampen these vibrations. Also analysis for more case of known faults for different motors can be carried out. This will provide a detailed guideline for fault detection & hence will be useful for quick repair to minimize the downtime of different processes.

Advantages & Disadvantages

Advantages

1] Cost of project is less.
2] Scan time is very less of the order of 1 to 5 ms
3] The system is portable, sensors can be placed at peripheral as well as in the inner regions i.e. inside the frame.
4] Computer interfacing is available hence analysis & storage of data is available.
5] Due to real time monitoring control automation becomes easy

Disadvantages

1] Limit in the range of vibration of sensor
2] Wirelss communication is not possible.
3] Conversion time & system restore time is more than some advanced controllers.

Applications

1] To detect the cause of vibration from the analyzed and stored data so as to take the necessary corrective action.
2] Industrial parameter control.
3] Engine testing
4] Automotive engineering
5] biomedical instrumentation
6] mass spectrometry
7] power quality measurement

In most cases, the data acquisition system provides the much needed real time data for the analysis of a particular fault. It can also provide the required data to optimize a control system in a given process industry.

9. Conclusion

The electric motor parameters can be constantly monitored and hence can be further controlled by using data acquisition and control system. The constant monitoring can produce data-base for scheduling of the motor servicing, troubleshooting and also for future references. Hence motor life can be improved . Also downtime of the industrial process can be minimized. Due to use of microcontroller the computing needs of the task can be handled most effectively. Hence the proposed system can be widely used in automotive engineering, biomedical, instrumentation and power quality monitoring and control applications. This data acquisition system provides advantages of design simplicity, portability and less cost.

In this work the most severe vibrations are observed in case of armature current fluctuation & Fault. All obtained patterns of vibrations along with their analysis can be used to get a quick guideline for mechanical & electrical fault detection & hence for repair by using this low cost & portable device Hence the repair work can be carried out or arrangements can be made to dampen these vibrations. Also analysis for more case of known faults for different motors can be carried out. This will provide a detailed guideline for fault detection & hence will be useful for quick repair to minimize the downtime of different processes.

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