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Research Paper

A Case Study on Sensors for Advanced Condition Monitoring systems

K. Raghavendra Pai* and Narasimha Marakala
Mechanical Engg. Dept., NMAMIT, Nitte, Udipi, Mangalore 574110
*Email: pai_7raghu@yahoo.in

Abstract

In the recent past a great deal of research efforts have been directed towards the development of an effective condition monitoring system. For this reason a polysilicon based sensor was used in a hexagonal architecture design and the readings or signals were obtained from the ic-engine. Sensors and their supporting instrumentation, used for recording various variables such as temperature, vibration, efficiency and other process parameters, have generated new possibility in achieving an effective design for a condition monitoring system. The prime objective of the paper is to revolutionize thinking in the selection of sensors, to help achieve a multivalent system for condition monitoring applications. With rapid advancement in the sensor technology in past few years, there is a good future in the field of condition monitoring of equipments.

Keywords: Condition monitoring, sensors, polysilicon sensor, hexagonal architecture, sensor configuration.

1 Introduction

A condition monitoring system is an advanced maintenance technique that helps to identify the problem, before the actual failure occurs. There are different types of parameters based on which condition monitoring can be accomplished. Some of them are pressure, temperature, sound, wear debris, vibration etc. all of these require a sensor to sense the above mentioned parameters. Non-availability of the sensor can lead to decreased efficiency to establish an effective condition monitoring system. Thus it is necessary to have a sensor which can be used with high degree of flexibility [1,2].

It has been found that in most of the cases it is not possible to get a sensor as per the required location due to its present specification constraints. Hence, if a sensor is scaled down in its size without affecting its functionality then it is possible to establish an effective condition monitoring system [3,4].

2 Sensor selection and placement

The major constraint in vibration measurement of IC-engine vibration is the dimension of the sensor, and difficulty in presenting the sensor in the working area of the cylinder. The two major issues can be resolved by scaling down the existing sensors to 1:50 ratio in average. Different materials are found in market that are presently used in the automotive electronics, manufacturing sectors etc; some of the commonly used materials are SU-8, pollysilicopn etc. The use of the nano sensors with wireless technology can further improve the hexagonal architecture described here.

Macroscopic properties of materials may be changed dramatically with nano-ingredients. For example, by reducing the grain size from about 100 nm to about 10 nm, the strength of certain metals may be increased by about ten-fold. Also, certain newer requirements necessitated the use of extremely small sensing elements thus leading us to the direction of NEMS/MEMS. For example, the need to detect a few molecules of narcotics or explosives or markers in biotechnology applications mandate the use of similarly sized sensing elements. Consider the monitoring of a generator; in this case it is important to monitor the magnetic field of the equipment. Optical current field sensor are better than the conventional sensors.

Nano magnetic fluid is a colloidal solution with finely dispersed Ferro-magnetic materials which is carried by a suitable liquid. This is high-end technology but when used properly it is possible to obtain very high accurate results. The behaviour of this nano-magnetic fluid is largely dependent on the external magnetic field. This is because the refractive index of the nano-magnetic fluid is directly proportional external magnetic field. Hence, use of this fluid can help to identify the faults in a rotary machine which produces a magnetic field of sufficient and constant density.

The nano magnetic fluid that is commonly used is the water-based Fe_3O_4 fabricated with the chemical co-precipitation technique. The average diameter of magnetic nano-particles is approximately 12 nm, and their volume fraction in the original nano-magnetic uid is 7.9%. However, the accuracy of the sensor is largely dependent on the concentration of the nano-materials. Hence, an ideal concentration has to be maintained. Hence a sensor made of polysilicon was selected.

Sensor placement plays an important role in results that are obtained from the condition monitoring system. Sensor placement depends on type of sensor used, type of

system being monitored, and the surface characteristics of the machine. In general, the effective and reliable condition monitoring system depends on two major factors:
a) Locations of the sensors;
b) The signal processing algorithms.
Sensor location can be identified by going through designs to find a "sweet spot". It can also be obtained by using structural analysis, by identifying all the centres of gravity of the equipment. Also a structural dynamic technique can be used. Environment surrounding (magnetic field, noise, electric field) the sensor must be given equal importance to avoid any interference with the sensor functionality.

3 Sensor operation

There are different ways through which we can use the sensor. Several online as well as off-line methods have been discovered. Here we will be discussing multiple sensors connected in a web to carry out on-line monitoring.

In this method the sensors are connected in the form of hexagonal architecture with two sub stations within the outer hexagon. The two sub stations are provided to act as data back-up unit and data reduction units. Data is reduced by filtering non useful or non- redundant information given by each sensor. The use of non-contact sensor helps to reduce the breakdown of the entire system. This is achieved when one of the sensors fails it leads to zero input to the hexagon substation. This leads to activation of adjacent sensor to carry out its operation temporally. The same is communicated to the central hexagonal architecture. This sends the information, enabling the change of the faulty sensor. Having a structured monitoring system helps to reduce the cost of data processed by algorithm.

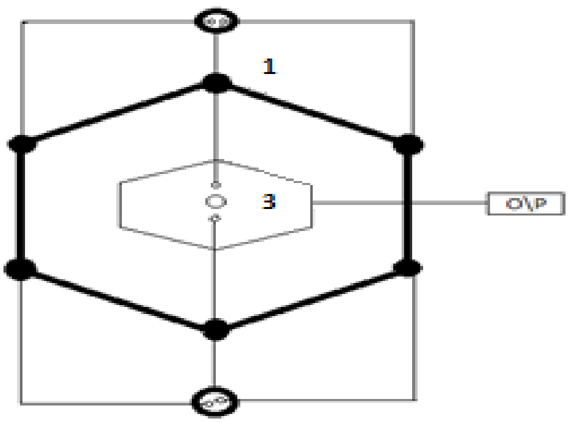

Figure 1: Proposed Hexagonal architecture for standardization of sensor operation, ver.1

In Figure 1, "1" represents the primary sensors; these primary sensors are used to measure vibration. There are two loops of sub-stations, the function of this is to reduce the quantity of the unwanted signal in a data. "3" represents the central processing unit in Figure 1.

In case of hardwired sensors the overall uses will be Limited. This limitation can be overcome by integration approach in placement of the sensor. With the integration approach the architecture becomes complex. Multiple algorithms will be required to get the useful data. A diagram representing the same is as shown in Figure 2.

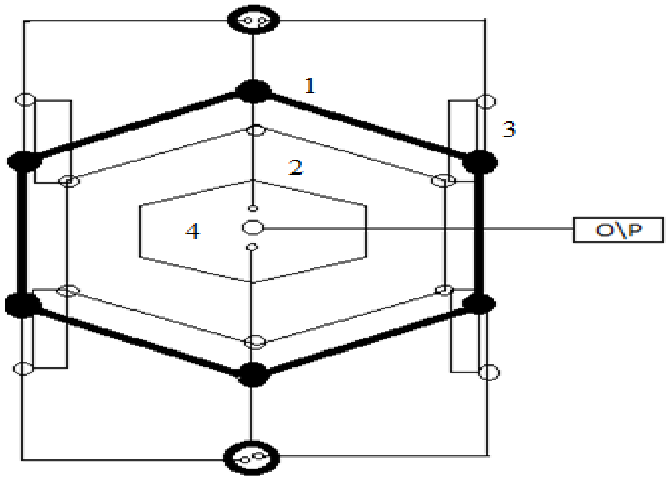

Figure 2: Proposed Hexagonal architecture for standardization of sensor operation, ver.2.

In Figure 2, "1" represents the primary sensors; these primary sensors are used to measure vibration. "2" represents the secondary sensors which act as back-up sensors as well as sensors to refine the output given to "3" substation. There are two loops of sub-stations, the function of this is to reduce the quantity of the unwanted signal in a data. "4" represents the central unit which is responsible for delivering the final output of the measured quantity to the user.

In this system the vibration data is primarily obtained from the primary sensors. However, the secondary sensors also collect the vibration data. Now the data is subjected to signal processing where any data that is seen to be in-appropriate will be removed. By increasing and decreasing the hanning window it is also possible to obtain desired output.

This type of sensor configuration can be used on any type of equipment i.e. rotary and reciprocating. In case of rotary engines there are variety of methods to establish a highly accurate and reliable system. Reciprocating engines however, do not have any standard techniques to gain the vibration. Once the sensors have been placed in, as above mentioned method; it is possible to acquire the vibration signal. The vibration signal has to be then subjected to advanced digital processing methods, a major part of it being the ways to minimize the stray signals. One simple method to eliminate the stray signal might be to place one or two sensors to act as a calibrating sensor. The signal from this calibrating/reference sensor is linked with the active sensors.

The type of nullification to be carried out depends on type and purpose of the sensor used. However, this project requires a large scale investment. If successfully developed then this will be successful implementation of the predictive maintenance on the reciprocating engines.

4 Signal processing

Signal processing is a method to extract useful data from the machine or structure by employing a sensor to get the information. The information obtained can be processed in different methods or techniques:
• Mathematical;
• Statistical;
• Computational;
• Heuristicand Linguistic Representations;
• Formalisms, and Techniques for Representation;
• Modeling, Analysis and Synthesis;
Mathematical method is one of most used methods in the field of signal processing.

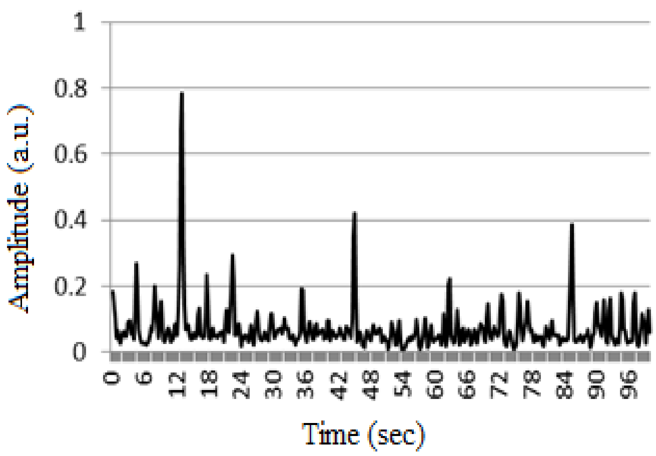

Figure 3: The signal from vibro-meter representing vibration.

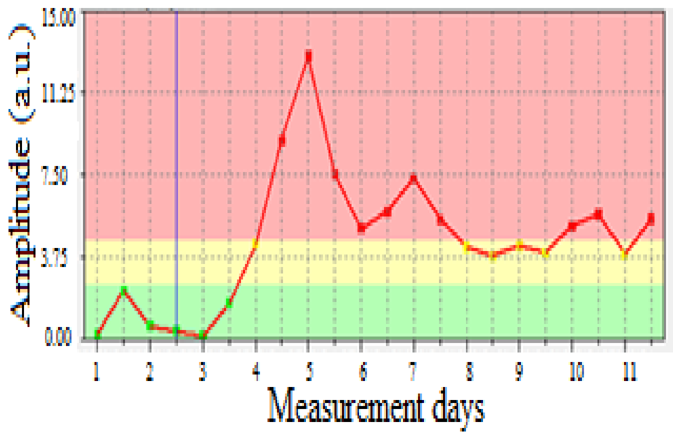

Figure 4: Vibration trends of an IC-engine after the implementation of hexagonal architecture.

These signals basically consist of set of numbers which are subjected to various mathematical operations using MATLAB to obtain the desired results. Using this it was possible to identify various problems in IC-engines; the trends of vibration after the counter measures are as shown in Figure 3. Given in Table 1 are Data from a typical sensor. Shown in Figure 4 are vibration trends of an IC-engine after the implementation of hexagonal architecture.

Table 1: Data from a typical sensor.

Nos.	Measuring date	mm/s RMS	Alarm status	Envelope
1	22-Jul-15	0.08	Ok	0.01
2	23-Jul-15	0.08	Ok	0.01
3	25-Jul-15	0.04	Ok	0.01
4	27-Jul-15	0.08	Ok	0.01
5	28-Jul-15	0.86	Ok	0.02
6	29-Jul-15	0.10	Ok	0.01
7	30-Jul-15	0.07	Ok	0.00
8	31-Jul-15	1.42	Ok	0.01
9	03-Aug-15	2.91	Warning	0.02
10	04-Aug-15	2.99	Warning	0.01
11	05-Aug-15	3.70	Warning	0.01
12	06-Aug-15	1.95	Ok	0.02
13	07-Aug-15	1.81	Ok	0.01
14	08-Aug-15	3.09	Warning	0.04
15	10-Aug-15	5.79	Danger	0.01
16	11-Aug-15	1.23	Ok	0.01
17	12-Aug-15	3.24	Warning	0.01
18	13-Aug-15	2.29	Ok	0.01
19	14-Aug-15	3.91	Warning	0.01
20	17-Aug-15	3.59	Warning	0.18
21	18-Aug-15	2.80	Warning	0.01
22	19-Aug-15	3.06	Warning	0.35
23	20-Aug-15	3.31	Warning	0.01

From Table 1 we can see that alarm status gives an idea whether the IC engine requires some corrective measures or not. Based on the alarm status in the corresponding vibration signal (Figure 3) we can decide what action must be taken for the given problem.

5 Conclusion

Application of condition monitoring systems will increase rapidly in the coming years. As the demand increases for more reliable and accurate technologies the hexagonal architecture will be a good choice. The use of this architecture and the sensor will help to refine the overall implementation structure of the sensor in the field of the condition monitoring.

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