Condition Monitoring for Nigerian Industries: A Review

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Abstract

This paper presents the necessity of adopting condition monitoring for machinery and plant maintenance, especially in the Nigerian public and industrial sector. It shows that the responsibilities required of maintenance schemes of our days goes beyond just repairing, it now involves ensuring availability, reliability and most importantly, financial profitability. Numerous maintenance works being performed and their financial costs can be avoided through the adoption of good condition based maintenance systems. Proper implementation of condition monitoring with adequate technical expertise and experience will guarantee good failure and integrity forecast as well as fault diagnosis. Condition monitoring thrives on consistent trending and analysis of certain measured parameters in providing insight into a state of fault or malfunction. Early knowledge of such faults is being highly useful in making or taking appropriate maintenance decisions. A condition monitoring program can have the same, or even much better, benefits for operation and maintenance as statistical process control is having for manufacturing.

Keywords: *Availability, reliability, financial profitability, integrity forecast and diagnosis.*

1. Introduction

Modern technological breakthroughs are considered not without their associated responsibilities in the form of development of appropriate maintenance philosophies and techniques that can ensure the continued availability and reliability of the system. Over the years, the studies of engineering design and maintenance have focused on the failure of systems, thereby forcing men to look in the direction of reaction to failure (as in breakdown or shutdown maintenance) or in the direction of failure prevention (as in preventive maintenance) (James 1992). Moreover, today in mechanical engineering, manufacturing, operation and installation of machines, the factor that stimulates the development of diagnostics is the ability to fulfill the intended function or mission.

The coming of condition monitoring as a maintenance philosophy is today calling for a focus of engineering design and maintenance systems to the 'condition' of the system under consideration, so that reactions can only be provided based on the current condition of the system. Condition based monitoring has, in the past, been referred to as an art, when quite clearly it is a science, and despite the cost of machine failure, surprisingly little attention has been devoted to this science from the viewpoint of understanding and modeling failure mechanisms (Bannister 1990). It is very tempting to think of deterioration and distress in a machine only in the macroscopic terms: overall increase in temperature, an increase in power consumption, a loss in processing performance, and so on. However, the origins of these changes are more likely to be localized transient processes operating on a microscopic scale, such as an impact that occur when inadequately lubricated surfaces are brought together (Holroyd *et al*. 1990).

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Nowadays, a lot of researches have been done on issues relating to 'failure of mechanical components and systems'. But it is pertinent to say here that little can be achieved unless the following issues are considered seriously:

i. Capacity to accurately tell the present state or quantify the integrity of the machine during its operation and life;.
ii. Ability to forecast the impending developments in the system within reasonable time ranges.
iii. Ability to diagnose with precision a fault and its causes in the system.
iv. Ability to generate easy to understand and interpret condition information, not mere data.
v. Ability to adequately recommend actions and corrective activities that are useful for effective maintenance planning process.
vi. Capacity to be driven by the basic needs of the system in terms of financial, operational and, or safety requirements, not necessarily technology.

2. Condition Monitoring

Condition monitoring, as defined by James (1992), is a maintenance philosophy that involves periodic measurement of the mechanical and process parameters that concerns a machine in order to gain a relative indication of the mechanical state of the machine.

Penman and McEwan (1990) put it this way: condition monitoring of an item of a plant means the continuous assessment of the health of the plant throughout its working lifetime by the collection and examination of signals that typify the performance of the plant whilst it is operating.

Condition monitoring exploits the use of various monitoring techniques, such as vibration monitoring, performance monitoring, lubrication monitoring, and so on, in conjunction with several analytical procedures, like Spectrometric Oil Analysis Procedure (SOAP), ferrography, fast Fourier transforms and spectral analysis, statistical analytical procedures and graphical trend analysis procedures (Dahunsi 2001).

In general terms and outlook, condition monitoring involves the trend study and analysis of selected measurable parameters linked with the operation of the machine while it is running. This is used as a basis for quantitatively gauging the condition of the machine against a previous condition or an established baseline or standard. The outcome of this comparison provides a basis on which efficient maintenance decisions can be taken.

The application of condition monitoring remains most prominent in rotordyamic machines where failures are easily and mostly diagnosed through vibration monitoring techniques. Other areas of application of condition monitoring include process plants, internal combustion engines, building services equipment, as well as machine and cutting tools.

2.1 Condition Monitoring vs. Health Monitoring

Machine health monitoring is a better way to refer to the activities in condition monitoring. In fact, the biggest use of condition monitoring is in confirming that the equipment is in good health.

A machine that is in good health refers to a machine with a good level of availability and reliability. Availability means continued production to a manufacturer, while reliability is accompanied with a whole host of connected benefits, such as confidence, assurance, continuity, output, security, safety, and value. The provision of condition monitoring does not cost too much and results in a good financial return.

According to Hunt (1993), reliability, though a major objective of the 70s and 80s was not a practical reality until condition monitoring was accepted (that is, accepted as the major feature of maintenance). He went further to propose the following analogies between mechanical monitoring parameters (as in the mechanical systems) and medical monitoring parameters (as in the medical systems) as shown in Table 1.

Table 1. Analogies between mechanical monitoring parameters and medical monitoring parameters.

Steady State		
No.	Mechanical Monitoring	Medical Monitoring
i	Appearance	Appearance
ii	Crack testing	X-ray
iii	Energy consumption	Appetite
iv	Leakage	Loss of fluid
v	Performance	Work done
vi	Pressure	Blood pressure
vii	Speed	Movement
viii	Temperature	Temperature
Dynamic State		
No.	Mechanical Monitoring	Medical Monitoring
i	Acoustic emission	Heartbeat
ii	Noise	Breathing
iii	Pressure pulses	Pulse
iv	Response rate	Reflexes
v	Ultrasonic	Brain and Heart Scan
vi	Vibration	Shaking (Shivering)
Fluid State		
No.	Mechanical Monitoring	Medical Monitoring
i	Content	Blood test
ii	Particle count	Output fluid test

2.2 Condition Monitoring Parameters

The choice of the parameters to be measured and monitored is highly important when it comes to condition monitoring. Mostly, the parameters are quantities whose features are related to the outputs of the machine.

Fig. 1 shows an illustration used by Cempel (1991) to demonstrate the interaction and relationship between the input quantities (these are in terms of: energy, materials, control and disturbances), the machine, and the output quantities (these are in terms of: the desired product, product quality, dissipated energy and associated diagnostic elements).

From Fig. 1, it is evident that as the product is being produced or manufactured, certain measurable characteristic parameters are in accompaniment in such a way that apart from the quality features of the desired product, these accompanying parameters can be monitored with the intention of discovering or estimating the condition of the machine.

The types of parameters that can be adopted for condition monitoring depend largely on the type of plant or machine under consideration and its operation. However, condition monitoring parameters can generally be classified as follows:

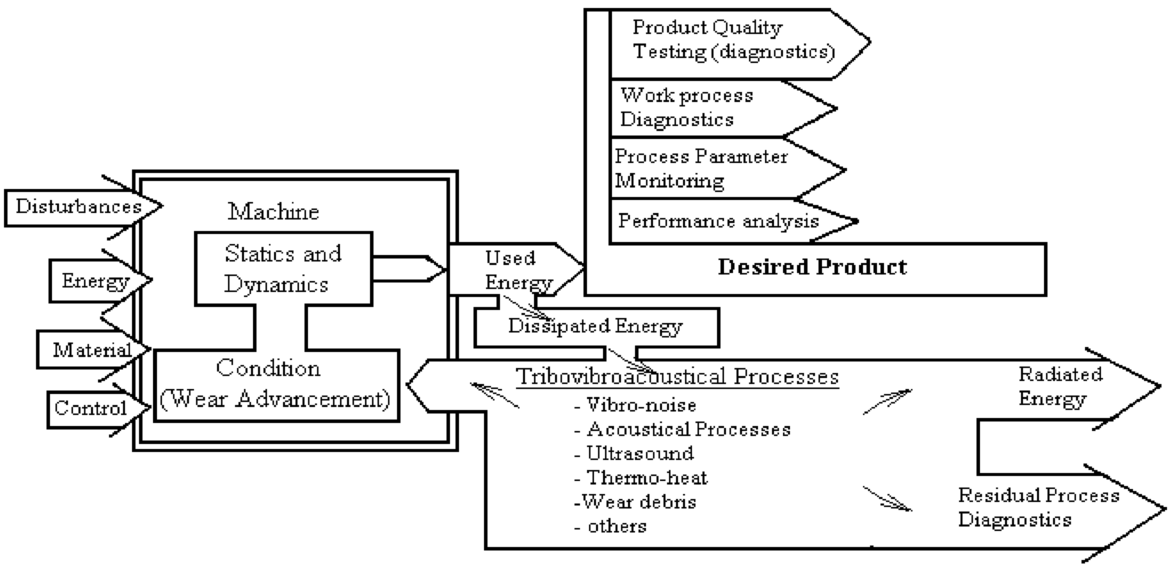

Fig. 1. The machine as an operating system with energy and information flow with the possibility of diagnostic observation (Cempel 1991).

i. Performance monitoring parameters, these are parameters that are linked with the operation of the machine. Examples of such parameters include: fuel flow rate, temperature and thermal monitoring (thermography), pressure, speed, and so on.
ii. Vibration monitoring, this includes the parameters that indicate the amount of energy dissipated in the machine in the form of vibrations and acoustic emissions.
iii. Lubrication monitoring, this includes all the parameters that relate to wear debris quantity and sizes, film thickness and oil temperature.
iv. Visual monitoring, this includes all visual external inspection and internal inspection using special tools like borescope.
v. Non-destructive test technique, these techniques include magnetic particle testing, fluoroscopy, and so on. They are used to examine components for flaws and crack initiation as a means of ascertaining their integrity.

2.3 Condition Monitoring Measurement and Analysis

The success of a condition monitoring program lies in the quality of the sensors, transducers, pick-up and gauges used for the measurements, adequate data management and analysis for proper interpretation, and lastly, manpower with reasonable experience and expertise sufficient to make diagnoses based on the interpretation of the information acquired.

Fig. 2 is a schematic diagram showing how condition monitoring arrangement can be executed manually. The main feature involved is the manual reading out of measured values and their recording. This arrangement is quite prone to human errors, especially when handling a large volume of data.

When computer use is integrated into the condition monitoring arrangement, as shown in Fig. 3, all the inadequacies due to the manual operation are automatically cleared. Although cases where direct on-line computers are linked directly with the sensors might be expensive and somewhat cumbersome, the system operates better, especially when suitable software tools prepared specifically for the purpose are installed.

2.4 Condition Monitoring within the Framework of Modern Facility Maintenance Programs

The advent of terotechnological practices in Europe after the Second World War, with emphasis on ensuring optimum economic life cost, brought to the fore the issue of reliability of equipment and facilities more than ever before. This was probably laying the good foundation required for the entry of condition monitoring, which was already being practiced in some forms in the United Kingdom since 1960s (Lilly 1984).

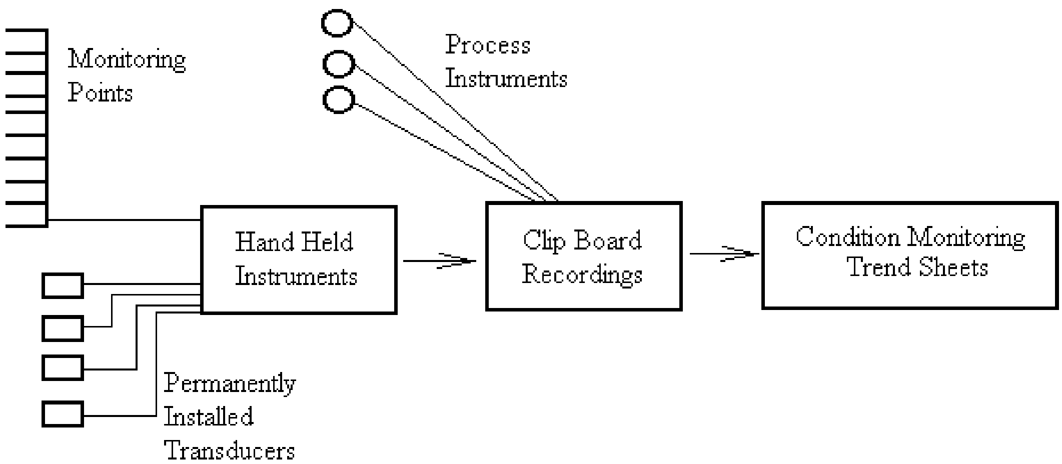

Fig. 2. Manual condition monitoring arrangement.

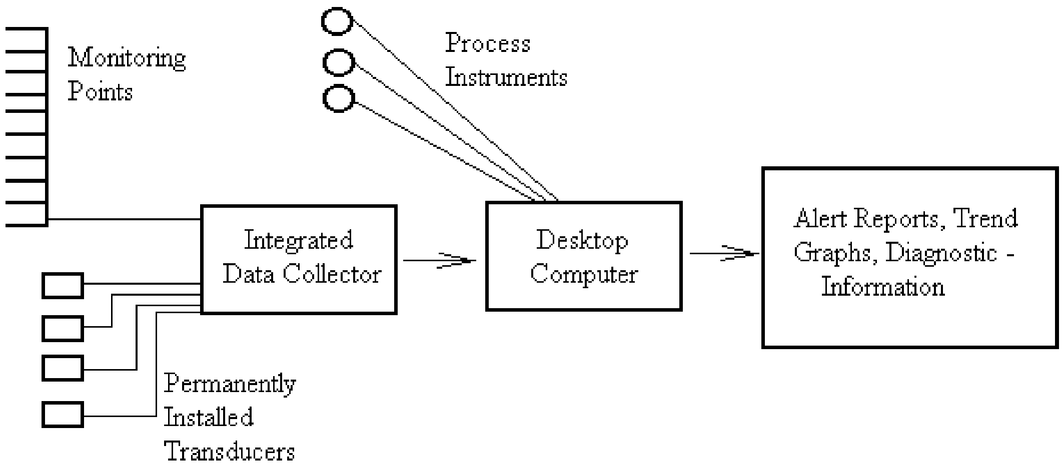

Fig. 3. Computer integrated condition monitoring.

As maintenance costs ballooned, a maintenance optimization procedure, called ‘Reliability Centered Maintenance’, was developed in the late 70s to help reduce the ever-increasing volumes of work resulting from the implementation of computerized scheduling.

The early reliability centered maintenance procedures were heavily influenced by safety issues, since they had their origin in the air industry. The aviation industry is also one of the earliest to adopt condition monitoring in its overall maintenance program. At about the same time (i.e., late 70s), Total Productive Maintenance started to gain momentum among the Japanese manufacturers. Total productive maintenance was then prominent among other industrial management philosophies like ‘Asset Management’ and ‘Total Quality’ in Japan (Watton 1992).

The targets of total productive maintenance and condition monitoring are unified in the following goals they both seek to achieve:

1. Total productive maintenance is an equipment improvement effort; it targets creating the ideal equipment state.
2. Total productive maintenance is achieved by developing a sound maintenance regimen focused at continually restoring the deterioration in the machines, thereby keeping the performance of the machine consistent from one day to another.
3. Total productive maintenance implementation creates an opposite attitude about equipment aging from the common attitude. The total productive maintenance attitude is: the more we operate and maintain a piece of equipment, the more we learn about it. This knowledge is used to continually improve the maintenance plan and the productivity of the machine.

Haines (1984) reported that between 1980 and 1984 alone, more than 500 papers with original contributions to rotating machinery dynamics, mostly with emphasis on reducing vibration amplitudes by means of condition monitoring or vibration monitoring, have been published. This was still in the era of reliability centered maintenance and total productive maintenance.

Condition based maintenance (otherwise known as predictive maintenance) was the basis for the development of ‘proactive maintenance’, as well as the currently most popular maintenance philosophy, reliability based maintenance. Today, condition monitoring and its activities are not only fully embedded, but are also cardinal to the functionality and foundation of both proactive and reliability based maintenance.

3. Maintenance Practices in the Nigerian Public Sector

A highly productive plant is a plant that is adequately and properly maintained. Only such plants can be profitable, because profitability and efficiency have been found to be highly related. Consequently, one of the reasons for low profitability and productivity in the Nigerian public sector is the poor maintenance practices and management in the constituent organization.

Although the standard of the workshops available at the various Nigerian public sector organizations like Nigerian National Petroleum corporation (NNPC), National Electric Power Authority (NEPA), Nigerian Telecommunica-tions Limited (NITEL), Iron and Steel industries (for example, in Aladja, Ajaokuta), and so on are comparable to those of similar organizations providing the same services in the developed countries, there exist a high level of inconsistency between reliability of the maintenance work done by these big organizations and the standard of workshops and facilities available to them.

According to Onubogu (1999), while specific practices vary from one organization to the other, the following general characteristics can be found in almost all of the public sector organizations:

i. No clear policy on which job should be done in-house and which should be out-sourced.
ii. A belief that the more the percentage of work done in-house, the more efficient their workshop is.
iii. No clear policy on when to apply predictive maintenance (that is, condition based maintenance) in preference to breakdown maintenance.
iv. Where preventive maintenance policies exist, they are hardly adhered to.
v. Importation of expatriate craftsmen and technicians to handle difficult jobs.
vi. Lack of in-house capacities to maintain systems, such as central air conditioners, elevators, forklifts and cranes.
vii. Insufficient emphasis on the training of craftsmen, technicians and engineers.
viii. Overall under-utilization of the installed capacities of most of the workshop equipment.

It is naturally expected that plants, machines and other infrastructures be subjected to deterioration due to use and exposure to process and environmental conditions. Moreover, the purpose of maintenance activities is to ensure that the systems operate continually at a level close to the design value such that profitability is ensured. Condition monitoring exposes any deterioration in the machine as it comes, thereby sustaining the life of the machine.

There is no alternative to the adoption of condition based maintenance (predictive maintenance) philosophy as the foundation of the maintenance policies in use in the Nigerian public sector organizations and industries. Too much has been expended already on various scheduled and reactive turn-around maintenance activities, whose basis does not agree with modern maintenance ideologies and practices. Maintenance activities are not to be merely reactive or preventive, they must be proactive.

5. Benefits of Condition Monitoring Activities

Modern process industries are more or less in continuous production with high speed, ‘high dollar’ machineries. But even the initial cost of these machineries is modest when compared to the daily loss during an unscheduled shutdown (Wowk 1991).

Today, there are so many reports from various corporations and plants about the financial savings made on maintenance through the adoption of condition monitoring. For example, Lilly (1984) reported that savings in unscheduled downtime could contribute up to 20% increase in gross profit with proper condition monitoring practice.

Stanford (1999) reported that a UK oil and gas platform has been able to defer some 60% of its routine maintenance work following the introduction of a condition monitoring program, while another Canadian natural gas production facility was able to avoid maintenance costs due to catastrophic failures estimated at approximately $2 million.

The biggest use of the condition monitoring systems is in confirming that the equipment is in good health and so the amount of routine work to be done at the next plant shutdown can be reduced or even eliminated altogether. Stanford (1999) listed the benefits of condition monitoring as follows:

i. Reduced environment and safety risk because risks of catastrophic failures are reduced.
ii. Increased plant up-time.
iii. Reduced maintenance expense.
iv. Increased manpower efficiency.
v. Reduced depreciation charges.
vi. Deferred replacement capital charges.

6. Challenges of Condition Monitoring

The execution of condition monitoring programs aims at ensuring availability and reliability of plants and machines. The presence of these two factors guarantees improved productivity and profitability, but not without the following challenges for the Nigerian engineer:

i. Need for perpetual consciousness of the fact that target capabilities cannot be attained if equipment cannot start-up on schedule or operate throughout its scheduled run without failure.
ii. The cost effectiveness of condition monitoring depends largely on the experience and expertise of the diagnostician, although attempts are currently being made to replace or support the diagnostician with expert systems. An in-depth understanding of heuristics associated with machine component distress is highly required.
iii. There is usually no particular measured parameter that singly guarantees success, rather it is common for the initial faults to give rise to a succession of further faults, calling for the use of a number of diagnostic tools.
iv. Awareness of the fact that the risks and consequences of maintenance decisions are greater than design decisions or purchase decisions, because maintenance decisions are made when the equipment is in service or is needed for production.

These challenges also point to the following requirements for adequate engineering training:

i. Engineering training curriculum ought to show that the relationships or links between equipment maintenance and manufacturing are financial profitability goals and sustained productivity goals.
ii. Engineering trainees must be made to understand that the modern equipment maintenance and reliability philosophies must be applicable to all realms of engineering, from the manufacturing oriented sectors to the service oriented sectors.
iii. Appreciation of the fact that poor maintenance and reliability leads to reduced profits, higher costs in labour and inventory, dissatisfied customers and poor product quality.

7. Conclusion

Condition monitoring or its principles and practices have been found to be integrated directly or indirectly into every successful maintenance scheme in the developed world since its discovery. Its strength lies in its diagnostic capacities, which is of great assistance in making maintenance decisions.

Although the cost of automating and acquiring the right sensors, transducers and computers for effective running of condition monitoring is enormous, this cost is borne only once and for all if done properly. Moreover, the costs incurred each time there in scheduled or unscheduled shutdown will eventually outweigh the cost of putting a good condition monitoring program in place on the long run in situations where it is not being used.

It is time for Nigeria to embrace the modern day proactive maintenance activities and principles, especially in the form of condition based maintenance, in its public and industrial sector.

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