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Maintenance techniques for infrastructural development

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Abstract

Maintenance practice is very important in engineering profession and every engineer is supposed to be acquainted with the basics of maintenance planning. In this paper the basic components of maintenance management is discussed and analysed. Planned, preventive and design out maintenances are also discussed. It was suggested that part of the reasons for poor performance of our utilities is as a result of poor maintenance culture. At the end ways to improve the performance of our ailing utilities, through good maintenance practice, is recommended.

Keywords: Engineering practice; maintenance; utilities; reliability; failure

1. Introduction

Maintenance is the process of keeping a system or equipment in good working condition (Ezechukwu, 2003) and maintenance management is a very important aspect of engineering practice. It involves training as an important tool more so when many equipment/systems are imported from various countries(Ezechukwu, 2008).

In the 60s the federal government of Nigeria realized the importance of maintenance and emphasized, among other things, that companies and parastatals should establish training schools for the training and retraining of engineering and technical manpower(Ezechukwu, 2003). Establishments like UAC, NEPA, P&T, Fed. Min. of Works, Dunlop, NNPC and others had their own training schools and when a new system/equipment is introduced, some engineers and technicians are sent out for special training on the new equipment. NNPC, NEPA, NITEL, and other Fed. parastatals trained many of their Engineers and technicians (locally and abroad) for particular systems(Shepherd, 2008).

Services of such parastatals were very good as compared to what they are now, when they have de-emphasized training(Ezechukwu, 2003). For example in NEPA there was mandatory two years training organized for new Engineers, technologists and system operators before they can work without direct supervision. Now such training is no more being seriously addressed to, one can compare the present performance of PHCN with that of NEPA of those days.

There are two main types of maintenance:- planned maintenance and unplanned or emergency maintenance. In planned maintenance, every item in the system is put into the maintenance schedule. A well planned schedule will provide for alternate supply when an important item is taken out for maintenance. The emergency maintenance results from errors that were not detected during the planned maintenance. In this case, the equipment has broken down. An emergency arrangement has to be made to put it back to service.

In all public utilities, consumers may not have prior notice of the outage and that can cause a lot of disorganization of plans and frustrations etc. Emergency maintenance can take an undetermined number of hours/days depending on the availability of spare parts, personnel and others. This type of maintenance is supposed to be avoided by good engineering maintenance management.

In every system, every component of the system must be put on maintenance schedule. Some may need daily attention, others may need weekly or monthly while some require annual maintenance, and so on.

2. Maintenance management

Maintenance management is an essential part of engineering practice. A well planned maintenance schedule depicts the quality of the maintenance engineer and knowledge of maintenance techniques brings about huge savings and smooth operation of the system(Ezechukwu, 2008).

Basically there are two major categories of maintenance, namely planned and unplanned or emergency maintenance(Ezechukwu, 2008).

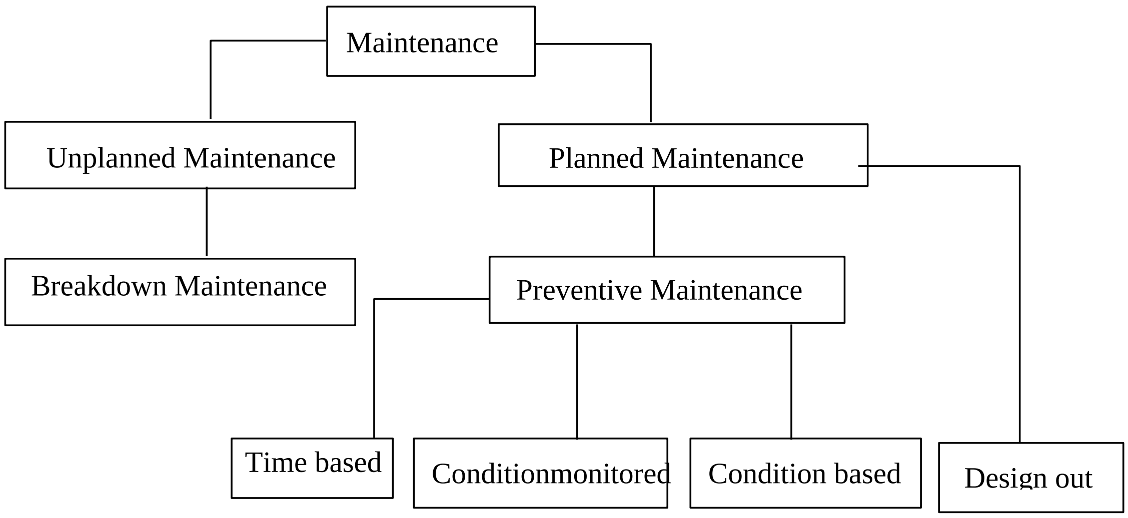

Fig. 1. Maintenance components.

2.1. Planned maintenance

Under planned maintenance, we have
a. Preventive maintenance
b. Design-out or improved maintenance.

Preventive maintenance
The preventive maintenance can also be broken down into:
1. Condition-based (preventive) maintenance
2. Time-based (preventive) maintenance and
3. Condition-monitored maintenance.

2.1.1. Condition-based maintenance

This is the maintenance resulting from observed change/s in the monitored parameter. Such monitored parameters could be one or more of the following.
1. Temperature: abnormal temperature change e.g. motors, generator, electronic components etc.
2. Sound: Abnormal sound e.g. in machines.
3. Acoustic: Abnormal change in tunes and reproduction e.g. musical cassette/ disc player.
4. Corrosion: Corrosion attack e.g. structures.
5. Vibration: Unusual vibration e.g. rotating machineries.
6. Viscosity: Change in viscosity e.g. lubricant oil.
7. Color: Change in normal color e.g. silica gel, water etc.
8. Shock: The experiencing of shock e.g. in electrical appliances.

More parameters can be monitored or developed to suit a particular application provided the parameter being monitored has direct bearing on the general well being of the equipment. Condition based maintenance is capable of doing the following:
a. Giving early warning of fault development.
b. Giving good indication when the system is working smoothly and
c. Providing reliable basis for diagnosing developing fault. Condition based maintenance when properly applied will :-
i. Eliminate or reduce the down-time of a system and therefore increase system availability and so enhance productivity.
ii. It reduces the down-time/repair time since major damage is avoided and all necessary arrangement concluded before shut down.
iii. Reduces the spare parts stock (and savings in procuring spare parts at all cost on event of sudden break down), by scheduling maintenance with good knowledge of required spare parts.
iv. Elimination of component waste since only unserviceable components will be replaced.
v. Elimination of secondary damage (e.g. A faulty break pad not detected early enough could result in the damage of the wheel drum).

vi. Improvement in safety, quality of the product and customer satisfaction.

2.1.2. Time-based maintenance

This is the type of scheduled maintenance which is carried out at stipulated time intervals, sometimes recommended by the manufacturer. The time interval recommended for maintenance of a system could change as the equipment gets older and requires more frequent maintenance. Also maintenance intervals could be determined by other factors like; distance covered, environment, duty cycle etc.

2.1.3. Condition monitored maintenance

In this method statistical approach is adopted and probability theory is used in determining where and how to replace an item. Trend detection through data analysis exposes failure cause and preventive actions that can be taken to avoid such failures in future. Statistical approach is most effective where there are large numbers of similar items. For example church lights burnout within interval of time. This interval of time can be determined statistically giving a standard deviation around an average life time. It has been found that it is more economical to change all bulbs at such predetermined life time or soon after a certain percentage of the bulbs has burnt-out than replacing them as they get burnt(Bones, 1977).

Knowledge of failure pattern is a viable asset to condition monitored maintenance programme. Detecting a failure pattern helps to arrest failure modes before they spread to other similar items. If four items out of ten similar items develop identical faults in quick succession, it will be advisable to have a closer look at the other six and carry out preventive maintenance to avoid their break down.

2.2. Design-out maintenance

The design-out maintenance, sometimes called improvement maintenance where applicable, is the most effective of all other methods described in terms of scientific approach and overall cost implications. While the previous methods strive to minimize the effect of failure, design-out maintenance strives to eliminate the cause of failure(Ezechukwu, 2008).

No matter the reliability of equipment, no matter how perfect the installation is, operation of the equipment in an environment not covered by the reliability specification will definitely affect its performance. In such a case the design-out maintenance is necessary to improve the reliability and maintainability of such equipment. For example an electric motor designed to be used at the dry and housed location must have to be drip-proofed if it is to be used in an area that contains moisture.

2.3. Unplanned maintenance

This is a maintenance that is not envisaged. It is not expected but the system/equipment has failed forcing the maintenance to be taken. It is also called emergency maintenance.

2.3.1 Break-down maintenance

This is an unplanned maintenance which nobody wants to have. It results from unanticipated break down of the system. It waste material and resources since the system has to be put back to service at all cost in other to meet the required production target(Ezechukwu, 2008). Some factors determine the serviceability of an item. One is the reliability. High reliability equipment will have good maintainability. Reliability of an item is its ability to perform the required functions under stated conditions for a specific time. High reliability material may be expensive but its services and maintainability makes it cheaper at the long run(Bones,1977). The graph of reliability is exponential as shown in (Fig. 2).

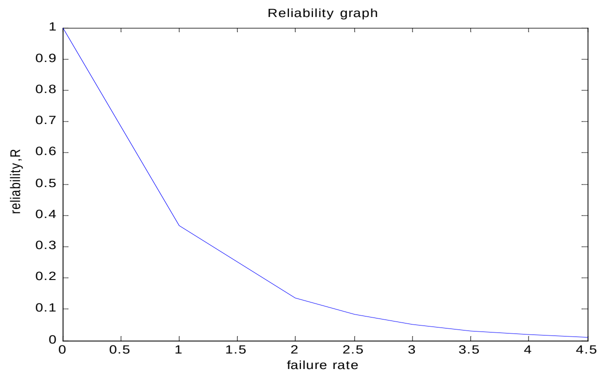

Fig. 2. Exponential reliability function (for constant failure rate period).

Reliability can be assessed from the producer's point of view and from the customers view point. From the producers view point, before delivery, increasing reliability increases cost. After delivery, cost of warranty, claims and repairs etc, will decrease with increasing reliability(Bones, 1977) (Fig. 3). The cost of delivering the services is thus the sum of the costs before and after delivery. From the customers point of view, the after delivery cost falls with increase in reliability of the system. So the total cost is the sum of the purchase cost and after delivery cost and this is minimum (Fig. 4). The total cost shifts to the right and thus indicating that the customer seeks higher reliability without additional cost.

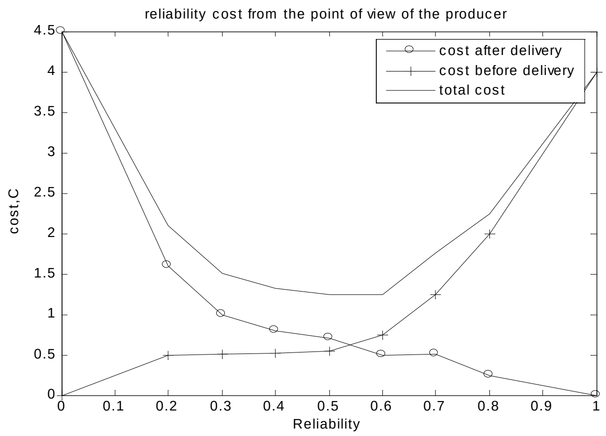

Fig. 3. Reliability and Cost from producer's view point.

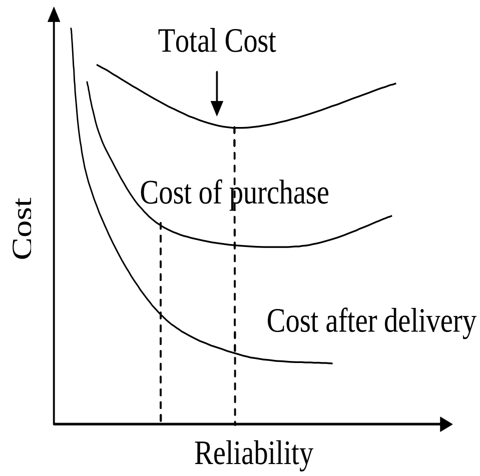

Fig. 4. Reliability and cost from customer's view point.

Table 1
Classification of failure

Category	Failure	Remark
Cause	Inherent failure	
	Misuse failure	
	Wear-out failure	
Degree	Complete failure	Catastrophic failures
	Partial failure	Degradation failure
	Intermittent failure	,, ,,
Priodicity	Sudden failures	Catastrophic failures
	Gradual failures	Degradation failure
Consequence	Critical failure	Catastrophic failures
	Major failure	Catastrophic failures
	Minor failure	

Reliability engineering deals with statistics of failures. Failure is defined as the termination, for any reason and to any degree, of the ability of an item or system to perform its required function(Bones, 1977). Failure can be categorized into periodicity, degree, cause and consequence etc. (table 1). There are some failures for which the designer/producer will be held responsible for and there are some in which the customer is liable to. Some of the failures which the designer/producer will not be held responsible are:

1. Faults due to lack of adherence to maintenance procedures and instructions.
2. Faults caused by adjustment after handover.
3. Faults caused by human intervention. For example, damages due to land dispute.
4. Replacement item from the customer, immediately faulty when used.
5. Faults caused by external influences outside the designed systems specifications.
6. Fault due to failure of the component/system operating beyond its designed life.
7. Secondary failure of the system caused by faulty test equipment or avalanche effect.
8. Fault analysis pending due to insufficient information.
9. No system or component fault found.

Failure is a statistical event. We can not say exactly the time it will occur but we can predict that in a given period of time there will be on average, a certain number of failures, and we can even set confidence limits to that. The failure rate is also not a constant. A plot of failure rate against time gives the familiar "Bath-tub" diagram. (See Fig 5). It is called the bath-tub diagram because of the shape which is similar to that of bath-tub.

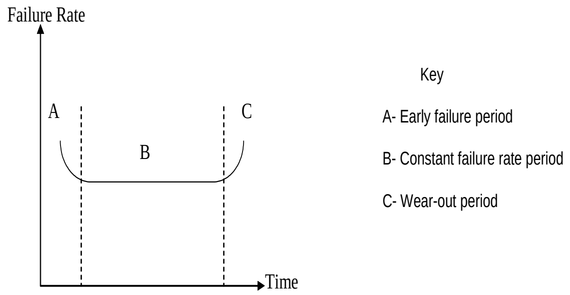

Fig. 5. The bath-tub diagram

Figure 5 is made up of the early failure period, the constant failure rate or useful life period and the wear-out period.

i. The early life period is where high failure rate and defects which escaped the quality control or supervision are exposed. The failures should be eliminated before delivering to the customer. It can also be called the "burn-in-period". This includes to some extent, the guarantee period of the producer and the free service period.
ii. The constant failure rate or the useful life period. This is the period during which the reliability of the system is usually assesed. It is the period when the rate of failure of components is almost constant.
iii. The third period is the wear-out period. This is the period in which part of the system or equipment fail from wear and degradation. At this point replacement of the part is considered necessary.

2.4. Endurance test

The endurance test is usually done during the useful life period of a system. A good number of the specimens are subjected to normal stress and their failure rates are plotted against time base. During this period the exponential law of failure dominates other distributions, and the probability of no failures occurring in a given time, i.e. the reliability is given by

$$R = e^{-\lambda t} \qquad (1)$$

Where; R= reliability, λ= failure rate (No of failures per unit time) and t= time.

But λ is the reciprocal of the mean-time-between-failures (MTBF),m.

$$m = \frac{\text{Total survivial hours}}{\text{Total population}} = \frac{\text{Total operating hours}}{\text{No of failures in time}} \qquad (2)$$

$$=1/\lambda \qquad (3)$$

Substituting value of λ in equation (1)

$$R=e^{-t/m} \qquad (4)$$

The ability of an item to be put back to service after break down is called maintainability. Some factors determine the maintainability of an item. They are:-
a. Method of determining that fault exist : It may be easy to note that a loud speaker is faulty immediately you use it but it may not be easy to recognize that the clock is faulty unless there is means for comparison.
b. The method of quickly identifying the faulty component. The solution to this problem is training of service men, acquisition of test instruments and apparatus and knowledge of procedures. The designer who considers maintainability will always provide test points for wares. This will help to identify the faulty components.
c. Rectification of the fault, which may include replacement of the parts that are defective. Again good designing ensures that the components with high failure rate are easily accessible. However where multiple soldering is required for disconnection of faulty parts, care must be taken that fault is not introduced during the process of soldering/desoldering.
d. Reset buttons must be placed where they can not be touched accidentally.
e. Finally it will be very important to check if the system operates very well after the repair. Thus maintainability is a statistical feature and can still be defined as the probability that the item will regain its operational status after repair, under normal condition(Bones, 1977).
f. Availability of the spare parts.

'Availability' is the probability that an equipment can perform its functions at the required time(Simpson, 1976). Availability, A, is expressed as:

$$A=m/ (m + t) \qquad (5)$$

m= Meantime between failures (for repairable items) and t= down time or maintenance time. Alternatively

$$A= (1 - U) \qquad (6)$$

Where U is the unavailability (due to break down) and can be expressed as

$$U= MTTR/(m + MTTR) \qquad (7)$$

MTTR (for non-repairable item) is the mean time to repair of the equipment or item.

2.5. Upgrading

Some engineers do not update themselves in the fields of their profession. An engineer must take all necessary steps to maintain and develop his professional competence by paying attention to new developments in science and engineering relevant to his field of professional activities and shall encourage his subordinates to do so. An up-to-date engineer is one who understands modern concepts and can readily apply them.

Courses, seminars and workshops help professionals to update themselves in his area of specialization. Fortunately, organizations like The Nigerian Society of Engineers, Nigerian Institution of Electrical and Electronic Engineers, NIEEE, and the host of others, organize seminars and workshops from time to time. Engineers should avail themselves such opportunities.

3. Conclusion

- The best approach to good maintenance management is to list all components of the system and allocate maintenance periods to them.
- It is always better to avoid brake-down maintenance as much as possible.
- High reliability items do not break down very often unless when they approach the wear-out period.
- The time-based preventive maintenance has the advantage of improved availability and better inventory control than the break-down maintenance but condition based maintenance maximizes the benefits of preventive maintenance. Generally it is advisable to do all possible maintenances during a single access. Activities like modifications and minor repairs can be delayed until during the planned shut-down of the item.

4. Recommendations

It is believed that the performance of our utility boards will improve if they adhere to:

1. Reactivating their training schools for the training and retraining of engineering and technical personnels.
2. Keep enough spare parts of essential items.
3. Always keep broad based maintenance schedule to cover all items in the system.
4. Individuals should be sensitive to condition changes in their environments and
5. Be maintenance conscious.
6. Engineers should always endeavour to upgrade themselves from time to time.

Although these recommendations are made to the utilities, they are also applicable to individuals and other establishments.

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