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METHOD OF PREDICTING, ESTIMATING AND IMPROVING MEAN TIME BETWEEN FAILURES IN REDUCING REACTIVE WORK IN MAINTENANCE ORGANIZATION

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ABSTRACT

Mean time between failures (MTBF) is a simple way of quantifying a repairable system, subsystem, or component's reliability. MTBF has been used for various decisions. Reliability of the system quantitatively determine by MTBF. Mathematical approach in quantifying MTBF is being used. Poisson distribution, Weibull model and Bayesian are the most popular approach used in developing MTBF model. MTBF is often confused with mean time to failure (MTTF), which MTTF applies to replaceable, rather than repairable. In current situation, most products designed as non-repairable unit, thus will eliminate varies level of repairing quality due to human error or level of competencies. This paper will explains the underlying complexities and misconceptions of MTBF and clarify in sequence what are the items and concerns that need to be consider in estimating MTBF.

Keywords: Mean time between failures, reliability, system failure, system failure

INTRODUCTION

Almost in every industries, MTBF plays a big role to drive the industries operates at lower cost, bigger profit and continuously to meet customer satisfaction. In any failures that repairable, MTBF able to indicates how often the unit being specified will have to be repaired when kept indefinitely in service. Ideas of implementing MTBF study mainly is to shift the unplanned maintenance or reactive maintenance regime to planned maintenance regime. Reactive maintenance seen to be one of the factor contributes to high manufacturing cost. Never ending struggle to reduce reactive maintenance, which consumes as much as 80% of the maintenance man-hours in plants. Their profits are eaten away by overtime labor costs and production losses due to unplanned maintenance (Broussard, 2008). MTBF study can be use as a bottom line for further improvement that needs to be done and as a monitoring tool to monitor the success of the improvement implemented. Maintenance of components time synchronization in a system can be done with MTBF study to avoid frequent shutdown especially in a single-stream process. In a single-stream process, every shutdown due to whatever reasons seen as a maintenance opportunity and it is necessary for maintenance personnel to know what are the value can be added to the losses. Therefore, equipment's MTBF has to be established and well-kept in record. MTBF based on definitions of failures and assumptions, which need a proper interpretation. Therefore, this study will clearly interpret all the related components in MTBF. MTBF is the most common means of comparing reliabilities. Solid understanding of MTBF is the key success in estimating it. Unclear failure definitions, misinterpretation and unrealistic estimations commonly are a factor of meaningless MTBF results. Field data measurement uses field failure data produces more accurate results than simulations. New design product or low volume productivity of product may not have sufficient field's data, thus field data measurement is more accurate. For the product that have long history in field service, past failure data may sufficient for simulation. Provided the product is not being upgraded that may improve the reliability.

Definitions

Availability is an ability of a component to be in state to perform a required function at a given instant of time or at any instant of time within a given to time interval, assuming that the external resources, if required, are provided.

Dependability is the ability to deliver service that can justifiably be trusted.

Reliability is an ability of a component to perform a required function under given conditions for a given time interval.

Fault is adjudge or hypothesized cause of a system malfunction.

Error is a deviation from the correct service state for a system or a subsystem.

Failure is a transition event that occurs when the delivered service deviates from the correct service state to an unwanted state.

Failure rate is the frequency with which an engineered system or component fails.

LITERATURE RIVIEW

MTBF as a tool for making decisions has been around for more than 60 years. At least 20 methods and procedures of estimating MTBF have been developed. Endless debate on method of estimating MTBF is going on since then (American Power Conversion, White Paper #78, 2004). As the demand on best-cost-producer getting higher, MTBF seems to be the most effective tool to be implemented. The monitoring is now not limited to the failures occurred for MTBF estimation but the implementation has been wider to monitor the reliability after improvement implemented (Jacob and Sreejith, 2008).

Definition of Failure and Assumptions

Ss the use of MTBF is so wide, MTBF often quoted without providing a definition of failure. Definition of failure is crucial to determine where is the exact point that really needs to be focus on. Basic definitions of failure (American Power Conversion, White Paper #78, 2004):

1. Failure of the system as a whole to perform its required function.
2. Failure of any individual system (subsystem) to perform its required function but not to the system as a whole.

The definition of failure is not limited to above two, but it is actually infinite. Product characteristic plays a part i.e.: how the manufacture controls the product quality, how the product is being tested in term of population sample, burn-in environment and such. Additional questions are needed to accurately define a failure. Realistic assumptions have to be considered. Assumptions are required to simplify the process of estimating MTBF. It is almost impossible to collect the correct data and calculate the exact number. Assumptions may come from past experience, journals, hand book or proved previous similar project.

Predicting and Estimating MTBF

MTBF and service life is two different things. Service life can be described as expected number of operating hours before system fails. While MTBF can be describe as:

$$MTBF = MTTR + MTTF$$

MTBF consist of mean time to repair (MTTR) and mean time to failure (MTTF). Deep understanding of the product behavior will help us to focus at the right angle. To put a trial of the product while it is still in their "useful life" or "normal life" will gives high MTBF as a result. It is because; at this period it's experiencing the lowest and almost a constant failure rate. In reality, wear-out modes of the product would limit its life much shorter than its MTBF figure. There should be no coloration between MTBF and service life. A product can be extremely high MTBF (reliability) but a low service life. See Fig. 1.

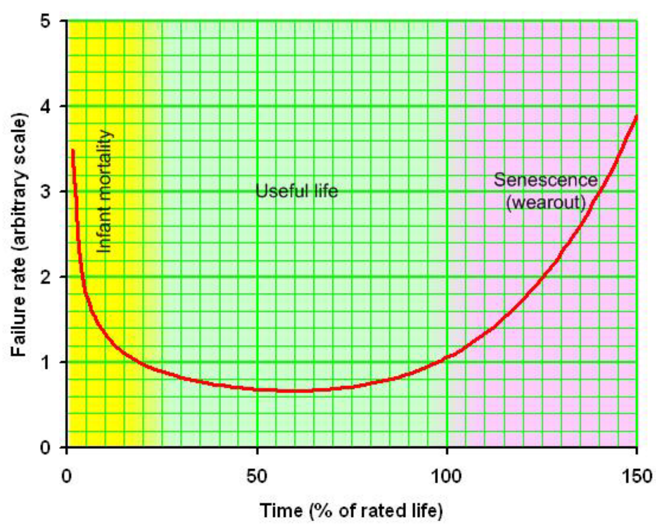

Figure 1: Bathtub curve illustrate consistent rate of failures

Useful life period is the stage, which a product in use in the field with a leveled product quality and results to a constant failure rate with respect of time. Source of failures at this stage could include:

1. Undetectable defects.
2. Low design safety factor.
3. Higher random stress than expected

4. Human factors.
5. Natural failures.

There are two ways to determine MTBF.

1. Reliability Prediction Method (Predict MTBF)
   The method is to calculate the value based on the system design, usually performed early in the product lifecycle. It is useful when field data is non-existent, for example; new product design. If field data does exist, this method should not be use.
2. Reliability Estimation Method (Estimate MTBF)
   The method is to calculate value based on observe sample of similar system. It could be done with large population of sample deployed in the field. It is most widely use as the product tested under a real working environment.

Determining MTBF by using estimate method is commonly use. MTBF is often confused with mean time to failure (MTTF), which applies to replaceable rather than repairable unit. To determine MTTF, burn-in process; is where the large number of units is put under test and run them until each and every one of it fails. Then average the length of time each unit lasted. The biggest challenge in implementation of Estimate MTFF is time. High reliability product will takes longer time. MTBF can be estimated in shorter time. Run the test with the population of units until long enough to have reasonably large number of failures. Replace the failed unit in the test population with a new unit. MTBF approximation can be obtained by multiplying number of units in the population by the total time, and dividing by the total failures. The larger the number of failures, the better approximation is to the actual MTBF.

For a repairable system, run a small number (as small as one) of units until they have experienced a number of failures (repair each failed unit and put it back into the test). Then take the total running time and divide by the number of failures. Formula for calculating the MTBF is (Scott Speaks, Vicor Reliability Engineering):

$$MTBF, (\theta) = \frac{Total\ Time, (T)}{Number\ of\ Failures, (R)}$$

Formula for calculating the MTTF is:

$$MTTF, (\gamma) = \frac{Total\ Time, (T)}{Number\ of\ Units\ Under\ Test, (N)}$$

Limitation of MTBF and MTFF

Aging is the main issue that deviate unit’s MTBF results. Each component in the unit has its special age-related degradation mode. Wear and tear effects at components are commonly detectable and been replaced during repair. Non-replaceable components i.e.: unit’s casing, is repeating entering MTBF cycle after repair and the non-replaceble components will experience fatigue. Various effects, such as corrosion, slowly take their roll. As these phenomena goes on, unit will begin to fail at increasing rate where they have passed the useful lives. See Fig. 1.

Realistic assumptions are always the key of the success of the MTBF estimation. Annual failure rate (AFR), has two scenarios that need to be considered (American Power Conversion, White Paper #112, 2004). Scenario 1, makes the following 2 assumptions: (1) the products operates 24 hours a day, 365 days a year; (2) all the products in the populations begins at the same time. It is relevant for products that are continuously running. Scenario 2, for products are known to run intermittently.

Scenario 1,

$$AFR = \frac{Failures\ in\ the\ sample\ period\ \left(\frac{52\ weeks\ per\ year}{Number\ of\ weeks\ in\ sample\ period}\right)}{Number\ of\ units\ in\ population}$$

Scenario 2,

$$AFR = \frac{Failures\ in\ the\ sample\ period\ \left(\frac{52\ weeks\ per\ year}{Number\ of\ weeks\ in\ sample\ period}\right)}{Commulative\ of\ operating\ years\ of\ population}$$

Scenario 1 and Scenario 2 is actually the same equations but with different sets of assumptions. Wrong assumption will lead to wrong result of MTBF since MTBF can be calculate with:

$$MTBF = \frac{Hours\ in\ a\ year}{AFR}$$

Improving MTBF

Jacob and Sreejith (2008) introduced minimum mean time between failures (MMTBF) that is another approach to improve MTBF. The improvement does not mean the improvement of MTBF results. It is the way of determining value of improvement that sufficiently needed. This mean MTBF will be further improve by two key components; a specified MMTBF and a maximum acceptable probability of premature failure, P_f. P_f is the probability that the time to failure smaller than MMTBF. This approach is to determine the value of reliability that need to be improve. The value can be decided based on the control chart. The control chart also can be used to monitor improvement in reliability for necessary action to be taken if the improved system is not reflecting the desired result. The control chart must have upper control limit (UCL), central limit (CL) and lower control limit (LCL). Assuming false alarm probability α, which the control limits can be obtained from the following equations:

$$LCL = \left(\frac{1}{MTBF}\right)^{-1} ln\left(\frac{1}{1-\frac{\alpha}{2}}\right)$$

$$CL = \left(\frac{1}{MTBF}\right)^{-1} \ln 2$$

$$UCL = \left(\frac{1}{MTBF}\right)^{-1} \ln\left(\frac{2}{\alpha}\right)$$

The limits imposed are to observe when the process is said to be out of control, above UCL and less than LCL. There are chance to experience false alarm during process. False alarm occurred when there is excessive number of failures, the chart will signal in such an out of control situations, called false alarm. Although false alarm probability anticipated in the process, the probability of alarm plotted without any changes to the process is 0.27% by a traditional chart but it could be any number. False alarm probability will be much higher if the number of failures if Poisson distributed. Failure plotted on the chart can be translated depends on where the plotted points fall. If the plotted points fall:

1. Between calculated limits; it indicates the process in the state of statistical control and no action warrant
2. Above UCL limits; it indicates the failure occurrence rate may have decrease, which results in an increase of MTBF. Action to investigate why such things happen and maintain it.
3. Below LCL limits; it indicates the failure occurrence rate may have increase, which results in decrease of MTBF. It means process has deteriorated, thus action should be taken to identify and remove them.

PROBLEM STATEMENT

Reduce Reactive (Unplanned) Maintenance

Planned maintenance supposed to take place before the occurrence of MTTF. There are few factors contributes to the failure of achieving higher rate of man-hours in proactive (planned) maintenance as shown in Figure 2.

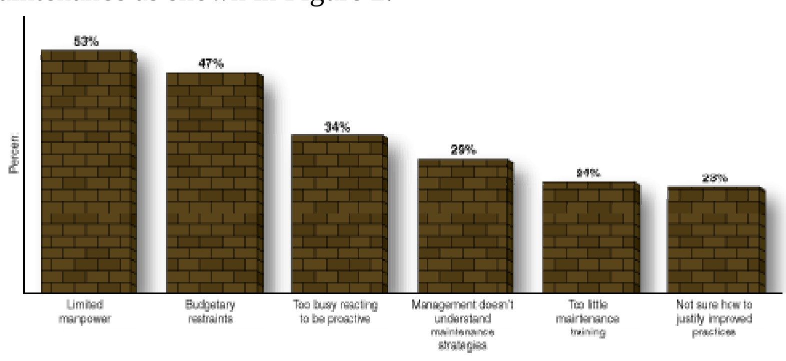

Figure 2: Planned maintenance barriers

In Plant Asset Management (PAM), there are three main characteristics to generate planned work in time to avoid costly and unnecessary breakdowns, or to keep process equipment running at target efficiency:

1. Potential problems are identified before they effect the process;
2. The health of the plant assets is assessed using a combination of products and services; and,
3. Maintenance activity is driven by problem severity, potential causes, and operator options.

In PAM criteria no.1; can be translated to the same failure monitoring method in MTBF, which is to identify potential failure before the occurrence of MTTF. In other words, MTBF can be considered as one of the tool for PAM. Reactive maintenance is synonym with unplanned maintenance. Reactive job always been done with extra cost, poor quality and lack of safety precaution. The impact of having high rates of reactive maintenance is huge. Maintenance material costs are related to the frequency and size of repairs made to the equipment. Maintenance of unpredictable failure required high level of spares. Annual holding costs for spares will impacts Company's profitability. That is why there is constant pressure on maintenance organizations to reduce spare parts. In doing reactive work, pressure to complete the job in no time will directly impact the quality of work. It will become worst if it's happen during odd time where the alertness of human getting weaker. This will lead to double handling due to poor quality of work, thus will increase the overall of repair cost. Safety aspect always been neglected during doing urgent reactive work. Lost time injuries always happen and this will affect company's image. All in all, by reducing reactive work, will gives benefits to the organizations. MTBF analysis is one of the tools that can help the organization to reduce reactive or unplanned work.

RESEARCH METHADOLOGY

Plant's MTBF Base Line

MTBF analysis will be carried-out on every section's main component across Tioxide Malaysia Sdn. Bhd plant. It will only limit to equipment that fails under reactive mode. Current MTBF situations will then be use for improvements.

Type of Improvement

There are few types of improvement:

1. Improvement on components MTBF by:
    a. Improvement on component design
    b. Replace to high-reliable product
    c. System adjustment
2. Sufficient number of spares

Instrumentation

For complex engineering design improvement Finite Element Analysis (FEA) will be use.

Data Collection

Historical data for parts replacement or maintenance will be drill out from SAP system.

Limitation of Study

This study is limited to single streamed Titanium Dioxide manufacturing, which uses Sulfate process.

CONCLUSION

Reactive maintenance is one of the main pulling factors that limit the organization from being best-cost-producer. Its affect the organizations in many ways. Annual manufacturing cost, customer satisfaction and company's image are put into jeopardize if the organization's maintenance mode is not been shifted from reactive regime to predictive regime. This study will point out the

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