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RELIABILITY – INTRODUCTION

- The probability that a system or component will perform its desired function without failure under stated conditions for a stated period of time.
- For systems with repairable components, repairs must be considered in the calculation of reliability. This parameter can be calculated for specific points in time
- *Reliability* is a time dependent characteristic.
- It can only be determined after an elapsed time but can be predicted at any time.
- It is the probability that a product or service will operate properly for a specified period of time (design life) under the design operating conditions without failure.

AVAILABILITY– INTRODUCTION

- The probability that a system or component is in an operable state at a specified time.
- Logistic delay times and administrative downtime for maintenance are not included in the calculation of availability.
- If you want to include these times, you would choose to calculate operational availability instead
- *Availability* is used for repairable systems
- It is the probability that the system is operational at any random time t.
- It can also be specified as a proportion of time that the system is available for use in a given interval (0,T).

RELIABILITY PARAMETERS

The basic terms/parameters required to be studied in reliability are as under: -

Reliability

The probability that a system or component will perform its desired function without failure under stated conditions for a stated period of time. For systems with repairable components, repairs must be considered in the calculation of reliability. This parameter can be calculated for specific points in time. Lower and upper confidence levels for this parameter can also be calculated for the system.

Unreliability

The probability that a system or component will fail under stated conditions during a stated period of time. This parameter can be calculated for specific points in time. Lower and upper confidence levels for this parameter can also be calculated for the system.

MTTF

The MTTF (Mean Time To Failure) is the expected time to failure of the system. Lower and upper confidence levels for this system parameter can also be calculated.

Failure Rate

The probability of system failure within time t and $t + 1$ units, given that the system is continuously operational until time t this system parameter can be calculated for specific points in time.

AVAILABILITY PARAMETERS

The basic terms/parameters required to be studied in availability are as under: -

Availability

The probability that a system or component is in an operable state at a specified time. Logistic delay times and administrative downtime for maintenance are not included in the calculation of availability. If you want to include these times, you would choose to calculate operational availability instead. Availability can be calculated for specific points in time. Lower and upper confidence levels can also be calculated.

Operational Availability

The probability that a system or component is in an operable state at a specified time. Logistic delay times and administrative downtime for maintenance are included in the calculation of operational availability. If you want to exclude these times, you would choose to calculate availability instead. Operational availability can be calculated for specific points in time. Lower and upper confidence levels can also be calculated.

Unavailability

The probability that a system or component is not in an operable state at a specified time. Inclusion of logistic delay times and administrative downtimes in this parameter is dependent upon whether availability or operational availability is calculated. This parameter can be calculated for specific points in time.

Mean Availability

The average availability (or operational availability) of the system or component over time.

Steady State Availability

The availability of the system at time infinity. This system parameter can be calculated for the steady state. Lower and upper confidence levels can also be calculated.

MTBF

The MTTF (Mean Time Between Failures) is the expected time between failures of a repairable system. This system parameter can be calculated for the steady state. Lower and upper confidence levels for this parameter can also be calculated.

BATH-TUB DISTRIBUTION

Many differing batches of mechanical and electrical industrial components have been tested to determine if it is possible to predict when they will fail. These tests have revealed that during their normal working life, they do not reach a point of wear-out at some likely time that could be called "old age". On the contrary a given item is as likely to fail in a given week shortly after installation as in a given week many months later. This probability of failure that is known as the failure rate (symbolized by the Greek letter lambda) can go through three distinct failure patterns. Batches of components can display one, two or all three (Figure 2.2 Bath Curve) of these patterns (stages) through their lifetime.

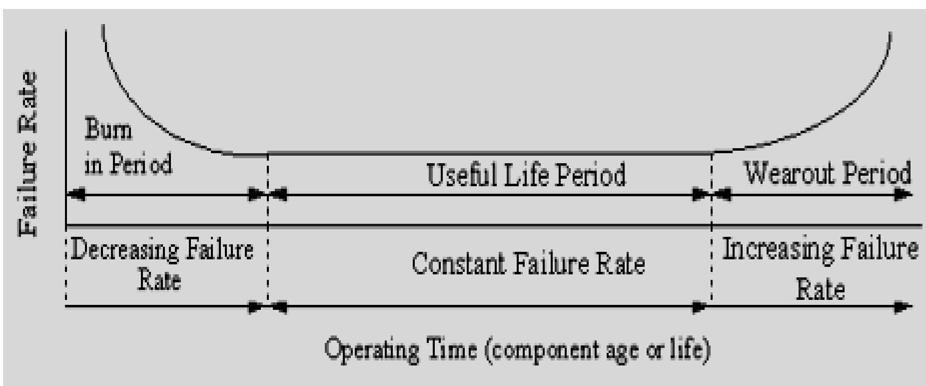

FIG BATHTUB CURVE

In the first of the three stages, the failure rate plunges downward rapidly from a very high starting point - this is "infant mortality". Failure during this stage can be attributed almost entirely to manufacturing & installation defects. Failure caused by manufacturing defects or poor installation tends to show up almost immediately, accounting for the high starting point. The term "Burn In" which can also be used to describe this period comes from the computer industry where new machines are run in a hot environment before dispatch. Any hardware faults will show up quickly in this elevated temperature. Once a machine passes it shall have a long trouble-free life. Equipment can also return to the infant mortality stage after maintenance intervention (Figure 10). For various reasons, equipment can suffer problems as a result of maintenance. Planned maintenance can actually reduce its availability.

Example: a group of similar bearings are changed every year as part of a planned maintenance activity. If they were condition monitored and changed on showing signs of imminent failure, it would be found that these bearings have an average life of 2.5 years. This over maintaining then results in increased probability of failure due to the infant mortality after each maintenance activity.

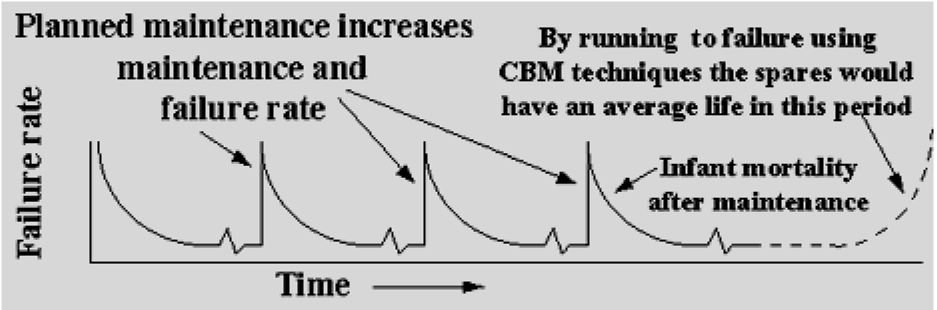

FIG AVERAGE LIFE AND PLANNED MAINTENANCE INTERVALS

As the curve levels off, it enters the second stage that is a straight segment indicating an essentially constant failure rate. In the final stage, the failure rate climbs sharply as spares wear out.

In reality the bath curve has little application in industrial process. Very simple components can follow this failure pattern such as a light bulb where faulty manufacture may result in very short life. A rare example of a more complex system that follows the bath curve is a petrol engine. Engines have to be taken care of in their early life to allow them to "bed in". Following this they go through a period of constant failure. Most petrol engines then fail following a life of 100,000 to 150,000 miles. Even this so called wear out period can cover a significant part of the engine's life.

MEASURE OF RELIABILITY:

- MTBF = Uptime (U_t)/ No. of frequency of failure (N)
- Hazard rate (H_r)

  = No. of frequency of failure (N)/Uptime (U_t)

  = 1/MTBF

- MDT = Downtime (D_t)/ No. of frequency of failure (N)
- MTTR = 0.3 X MDT
- A_{op} = MTBF/(MTBM + MDT)
- A_{in} = MTBF/(MTBF + MTTR)
- Suppose n_0 identical units are subjected to a test. During the interval (t, t+Δt), we observed $n_f(t)$ failed components. Let $n_s(t)$ be the surviving components at time t, then the MTTF, failure density, hazard rate, and reliability at time t are:

$$MTTF = \frac{\sum_{i=1}^{n_0} t_i}{n_0}, \qquad \hat{f}(t) = \frac{n_f(t)}{n_0 \Delta t}$$

$$\hat{\lambda}(t) = \frac{n_f(t)}{n_s(t)\Delta t}, \qquad \hat{R}(t) = P_r(T > t) = \frac{n_s(t)}{n_0}$$

The unreliability $F(t)$ is; $F(t) = 1 - R(t)$

Example: 01

- The powder manufacturing unit of dairy plant runs 24 hrs/day with one day as shut down/month. Calculate the following reliability parameters for month of January; if total down time is 82 hrs. (i) MTBF (ii) Hazard Rate (iii) MDT (iv) Operational Availability (v) MTTR (vi) MTBM (vii) Inherent Availability.

Solution:

Total 31 days for January so;
Total Running Time = 24 x 30 = 720 Hrs (Considering one day as shut down period)
Total Down Time = 82 Hrs (Given)
Effective Up Time = 720 – 82 = 638 Hrs

(i) Calculation of MTBF:

MTBF = Uptime (U_t)/ No. of frequency of failure (N)

MTBF = 638/5

= 127.6

(ii) Calculation of Hazard Rate (H_r):

Hazard rate (H_r) = No. of frequency of failure (N)/Uptime (U_t)

= 1/MTBF

= 1/127.6

= 0.0078

(iii) Calculation of MDT:

MDT = Downtime (D_t)/ No. of frequency of failure (N)
= 82/05
= 16.4

(iv) Calculation of MTTR:

MTTR = 0.3 X MDT

= 0.3 X 16.4

= 4.92

(v) Calculation of MTBM:

MTBM = [Total Time (T_t)/N] – MDT

= [720/5] – 16.4

= 127.6 = MTBF

(vi) Calculation of operational availability:

A_{op} = MTBF/(MTBM + MDT)
= 127.6/(127.6 + 16.4)

= 0.886

(vii) Calculation of inherent availability:

A_{in} = MTBF/(MTBF + MTTR)

= 127.6/(127.6 + 4.92)

= 0.962

Example: 02

200 light bulbs were tested and the failures in 1000-hour intervals are;

Time Interval (Hours)	Failures in the interval
0-1000 1001-2000 2001-3000 3001-4000 4001-5000 5001-6000 6001-7000	100 40 20 15 10 8 7
Total	200

Solution:

Time Interval (Hours)	Failures in the interval
0-1000 1001-2000 2001-3000 3001-4000 4001-5000 5001-6000 6001-7000	100 40 20 15 10 8 7
Total	200

Time Interval	Failure Density $f(t) \times 10^{-4}$	Hazard rate $h(t) \times 10^{-4}$

0-1000	$\frac{100}{200 \times 10^3} = 5.0$	$\frac{100}{200 \times 10^3} = 5.0$
1001-2000		
2001-3000	$\frac{40}{200 \times 10^3} = 2.0$	$\frac{40}{100 \times 10^3} = 4.0$
……		
6001-7000	$\frac{20}{200 \times 10^3} = 1.0$	$\frac{20}{60 \times 10^3} = 3.33$
	……..	……
	$\frac{7}{200 \times 10^3} = 0.35$	$\frac{7}{7 \times 10^3} = 10$

Time Interval	Reliability $R(t)$
0-1000	200/200=1.0