Technical Guide

"Mean Time Between Failure (MTBF) Measuring Reliability"

Small and Medium Enterprises Development Authority
Ministry of Industries & Production
Government of Pakistan

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1.1 Introduction to SMEDA:

The Small and Medium Enterprises Development Authority (SMEDA) was established in October 1998 with an objective to provide fresh impetus to the economy through development of Small and Medium Enterprises (SMEs).

With a mission "to assist in Employment Generation and Value Addition to the national income, through development of SME sectors, by helping increase the number, scale and competitiveness of SMEs", SMEDA has carried out 'sectoral research' to identify Policy, Access to Finance, Business Development Services, strategic initiatives and institutional collaboration & networking initiatives.

Preparation and dissemination of prefeasibility studies in key areas of investment has been a successful hallmark of SME facilitation by SMEDA.

Concurrent to the prefeasibility studies, a broad spectrum of Business Development Services is also offered to the SMEs by SMEDA. These services include identification of experts and consultants and delivery of need-based capacity building programs of different types in addition to business guidance through help desk services.

For more information on services offered by SMEDA, please contact our website:
www.smeda.org

1.2 Industry Support Program

In order to enhance competitiveness of SMEs and achieve operational excellence, SMEDA established an Industry Support Cell (ISC) for provision of foreign technical support and knowledge transfer in collaboration with International Development Organizations. SMEDA's Industry Support Program (ISP) initially launched with Japan International Cooperation Agency (JICA) and actively engaged in reducing energy inefficiencies and improving production and quality of products with the support of Japanese Experts. Later on, similar activities with other international partner organizations like German Corporation for International Cooperation (GIZ), Training and Development Centers of the Bavarian Employers' Association (bfz), Germany, and United Nations Industrial Development Organization (UNIDO) were also successfully implemented.

2. Understanding Key Terms?

Before we explain the concept of Mean Time Between Failure (MTBF) it is necessary to understand some basic concepts.

2.1 Failure Rate (λ)

Failure is defined as a situation in which a system (any machine) or part of system no longer runs or even produces the desired results i.e. expected quantity, quality etc. It means failure exists in varying degrees e.g. Partial or Total Failure.

Let say we have N number of Bulbs and after a time interval T, K number of bulbs have failed.

Failure Rate is measured using following formulae.

$$\textbf{Failure Rate } (\lambda) = \frac{\textbf{Total Number of Failures}}{\textbf{Total Operating Time}} \Rightarrow \frac{K}{T} \text{ using above example}$$

2.2 The Bathtub Curve:

The bathtub curve (Figure # 1) is used to describe the product failure rate over time. The bathtub curve does not illustrate the failure rate of single items but it is representative of the entire population/items over time scale.

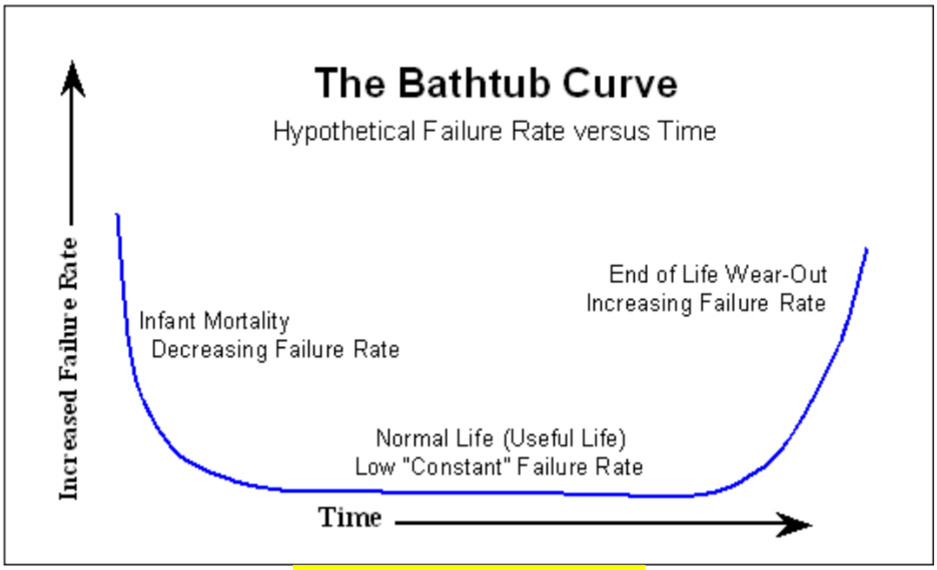

Figure 1: The Typical Bathtub Curve

There are three distinct zones:

1. Infant mortality; decreasing failure rate
2. Constant (random) failure; Normal / Useful Life
3. Wear-out failure; Increasing Failure Rate

Zone 1: Infant Mortality zone represents the failure of the weak items. The earlier failure rate starts high but decreases gradually.

Zone 2: Constant Failure zone represents the normal/ usable life of the product or system. Normal life failures are caused by external forces for example overload etc.

Zone 3: Wear-out failure zone represents the steadily increasing rate indicating the end of products life.

2.3 Service Life:

It is the expected lifetime or period of use of a machine or system in the field. It is the amount of time a machine or system is in service. Service life is specified as median by the manufacturer.

2.4 Useful Life:

It is time after the machine or system has crossed the infant mortality zone refer to Figure # 1 and before the wear out failure starts. In this timeframe the lowest failure occurred in the system.

2.5 Reliability:

It is defined as the probability that a device will perform its required function subject to stated conditions for specific time duration. Product reliability is quantified as Mean Time Between Failure (MTBF) for repairable products. Reliability focuses on preventing failures during the useful lifetime of the machine or system.

Reliability function is theoretically defined as the probability of success.

Reliability = 1 – Probability of Failure

Or as R(t), the probability of Failure at time t

$$R_{(t)} = e^{-\lambda t}$$

Where λ is the intrinsic failure rate, excluding early failures (infant mortality) and wear-out failures (end of life) refer to Figure # 1 (Typical Bathtub Curve).

Hence reliability is the probability of failure in the flat central part of the familiar bathtub curve (Figure # 1).

2.6 B10 Life:

B10 Life tells us the 90% reliability or 10% failure of a product / items at a specific point in its lifetime. B10 life is particularly useful in establishing warranty periods for a product.

3. What is Mean Time Between Failure (MTBF)?

Managing failure can help reduce its negative impacts on the system performance and efficiency. One of the key metrics to monitor failure data is Mean Time Between Failure (MTBF).

We can define Mean Time Between Failure in a number of ways.

1. Mean Time Between Failure is a key indicator that is used to check the status of failure of your asset to evaluate the reliability and to further plan the maintenance strategies in order to improve it.

2. Mean Time Between Failure is a reliability indicator used to define the mean working time of equipment between failures for a repairable system. For non-repairable system we use different metrics like Mean Time To Failure (MTTF).

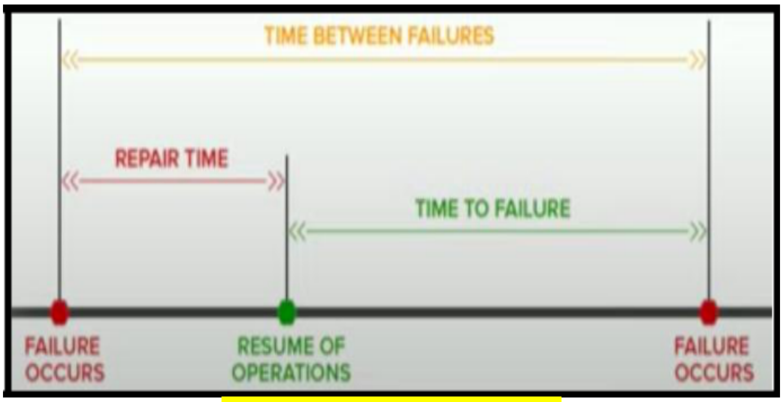

Figure # 2: Concept of MTBF

3. MTBF is the total average time under which during normal operating conditions the system/equipment works well before next failure.

4. MTBF is the reciprocal of Failure Rate i.e. M.T.B.F. = (1/Failure Rate)

MTBF indicates how reliable the system/equipment is so that we can plan and manage the activities properly without losing the performance or efficiency.

MTBF is measured in units of hour. MTBF does not account for planned shutdowns like (cleaning, inspection, lubrication, adjustments, routine parts replacement etc.). It focuses on sudden/unplanned breakdowns due to which it is necessary to stop the system/equipment and cannot be run without proper repair and maintenance work.

4. Common Misconceptions Regarding MTBF?

MTBF is commonly misinterpreted with Service Life. MTBF and the Service Life are both explained in detail in heading # 3 and 2.3 above. There is no correlation between Service Life and MTBF.

You can get a very high value of MTBF number in hour (not very uncommon). High MTBF is because it is mostly based on the assets rate of failure in the useful life or constant failure rate zone (refer to bathtub curve explanation in heading 2.2).

Considering this scenario, one can assume that system or machine can operate this long without a failure which is wrong assumption. We can have practical scenarios in which system or machines have a very high MTBF but a low expected or Service Life as explained above.

MTBF is a measure of reliability it doesn't equal to Expected Life, Useful Life & Average Life Etc.

5. MTBF Vs MTTF Vs MTTR?

In order to get the clarity, three important terms which are usually misunderstood by the business owners and production staff are defined below:

1. **MTBF** - Mean Time Between Failures: It is commonly used to determine average time between failures for repairable products. Refer to Heading # 3 for further details.

2. **MTTF** - Mean Time To Failure: It is commonly used for measuring the amount of time a non-repairable or replaceable asset operates before failure.

3. **MTTR** - Mean Time To Repair: It is commonly used to determine how long it will take to get a failed product running again

6. How to measure MTBF, Failure Rate and Reliability?

The formula used to calculate MTBF is as follow.

$$\textbf{MTBF} = \frac{\textbf{Total Operating Time}}{\textbf{Total Number of Failures}}$$

If MTBF is known, we can calculate the Failure Rate which is the reciprocal of MTBF and is measured as follow.

$$\textbf{Failure Rate } (\lambda) = \frac{\textbf{Total Number of Failures}}{\textbf{Total Operating Time}}$$

Or We can say that

$$\lambda = \frac{1}{MTBF}$$

We have MTBF and Failure rate calculated as shown using the above formulae. If we want to know that what is the probability that how many units of particular machine or system will be working at time equal to MTBF. We use following formula.

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

Or

$$R(t) = e^{-t/MTBF.}$$

If,

t= MTBF

$$R(t) = e^{-1} = 0.3677$$

$$\mathbf{R(t) = 36.8\%}$$

Thus from the above data we came to a conclusion, if t = operating time = MTBF in that scenario the probability that any one particular module will survive to its calculated MTBF is only36.8%

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Example Case # 1:

Let suppose we have 10 repairable devices tested for 500 hours. During the test 2 devices failed out of 10. Estimate the MTBF, Failure Rate and Reliability.

Solution:

1. **Calculating MTBF:**

$$\mathbf{MTBF} = \frac{\textbf{Total Operating Time}}{\textbf{Total Number of Failures}}$$

Total Operating Time for 10 Devices =10* 500 => 5000 Hours

Total Number of Failures = 2 Devices Failed

$$\mathbf{MTBF} = \frac{5000}{2} \Rightarrow \textbf{2,500 hour}$$

2. **Calculating Failure Rate:**

$$\textbf{Failure Rate } (\lambda) = \frac{\textbf{Total Number of Failures}}{\textbf{Total Operating Time}}$$

Or

Failure Rate (λ) = $\frac{1}{MTBF}$

Failure Rate (λ) = $\frac{1}{2500}$

= **0.0004 Failures/hour**

3. **Calculating Reliability:**

$R_{(t)} = e^{-\lambda t}$

λ = 0.0004, t = 5,000 hour

$R_{(t)} = e^{-\lambda t}$

$= e^{-(0.0004)(5000)}$

$R_{(t)} = 13.53\%$

The result tells us that there is only probability of 13.53% devices will be found operating for total operating hours of 5,000 without failure.

Example Case # 2:

A car manufacturer sells *400,000* cars of a certain model in one year. During the the first three years the owners of *50,000* of these cars experience major failures. Estimate the MTBF, Failure Rate and Reliability.

Solution:

1. **Calculating MTBF:**

MTBF = $\frac{\textbf{Total Operating Time}}{\textbf{Total Number of Failures}}$

Total Operating Time for 400,000 Cars = 400,000 * 3 Years => 10,512,000,000 Hour
Total Number of Failures = 50,000 Cars Failed

MTBF = $\frac{400,000 * 3(365*24)}{50,000}$ **=> 210240 hour/car failure**

2. **Calculating Failure Rate:**

$$\textbf{Failure Rate } (\lambda) = \frac{\textbf{Total Number of Failures}}{\textbf{Total Operating Time}}$$

Or

$$\textbf{Failure Rate } (\lambda) = \frac{\textbf{1}}{\textbf{MTBF}}$$

$$\textbf{Failure Rate } (\lambda) = \frac{\textbf{1}}{\textbf{210240}}$$

= **0.000004756468 Failures/hour**

3. **Calculating Reliability:**

$$R_{(t)} = e^{-\lambda t}$$

λ = **0.000004756468 Failure/hour, t = 3 Years => 26,280 Hour**

$$R_{(t)} = e^{-\lambda t}$$

$$= e^{-(0.000004756468)(26280000000)}$$

$$R_{(t)} = 88.25\%$$

The result tells us that there is probability of 88.25% cars will be found operating for total operating hours of 3 Years or 26,280 Hours without failure.

7. How to improve MTBF?

In order to improve MTBF it is necessary to reduce the Machine Failure Rate. Machine Failure not only results in lost production targets like quantity and quality but also increases the time and cost spent on machine maintenance. The best way is to analyse the root cause of the failure and take countermeasures and check the results. If the results are fine implement to the whole group. There are few tips how to improve the MTBF of your system/machines.

1. Improvement in Operating Conditions
2. Improve Preventive Maintenance Processes
3. Conduct Root Cause Analysis of Failures
4. Implement Countermeasures & Measure the Results
5. Establish Condition Based Maintenance
6. Reduce Load/ Stresses on Machine/System
7. Make design improvements