Reliability Engineering

Notes 2

Repairable and Non-repairable Items

- Items in a system can be classified into two groups – Repairable items and non-repairable items.

- Repairable items are components which can be repaired upon failure and thus their life histories consist of alternating operating and repair periods.

- For items which are repaired when they fail, reliability is the probability that failure will not occur in the period of interest, when more than one failure can occur.

- Repairable system reliability can also be characterized by the mean time between failures (MTBF), but only under the particular condition of a constant failure rate.

- Non-repairable components are components that cannot be repaired or the repair is uneconomical.

- For a non-repairable item such as a light bulb, reliability is the survival probability over the item's expected life, or for a period during its life, when only one failure can occur. During the item's life the instantaneous probability of the first and only failure is called the hazard rate.
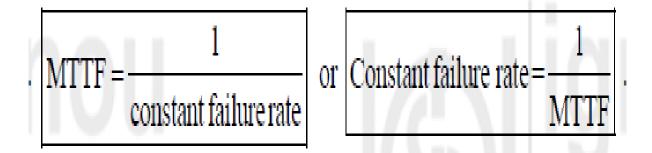
- Life values such as the mean life or mean time to failure (MTTF) can be used as reliability characteristics.

Basic Terms

- MEAN TIME TO FAILURE (MTTF): The term is used for non-repairable items or devices. MTTF is a measure that tells us on an average how long the product/component performs its intended function successfully before failure.

- It is calculated by taking the mean of the lifetimes obtained on the basis of results of a sample of such identical products/components tested under stated conditions.

In general, if n components are put to test and $t_i, (i = 1, 2, 3, ..., n)$ denotes the time for which the ith component performs its intended function, then mean time to failure (MTTF) of such components is given by
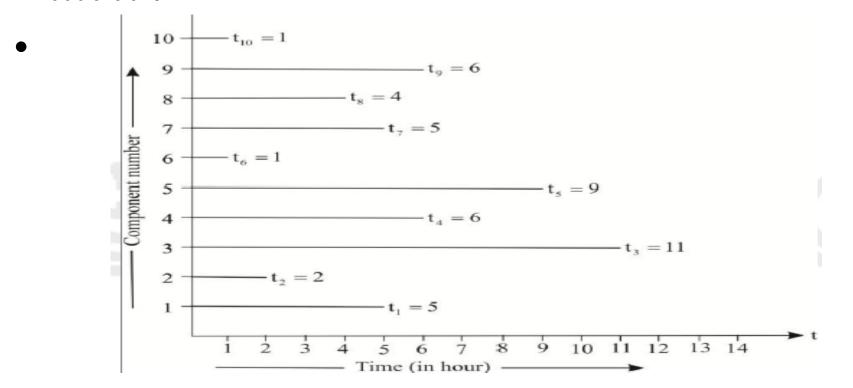
$$\text{MTTF} = \frac{1}{n} \sum_{i=1}^{n} t_i$$

- If the failure rate is constant,

$$\text{MTTF} = \frac{1}{\text{constant failure rate}} \quad \text{or} \quad \text{Constant failure rate} = \frac{1}{\text{MTTF}}$$

- For example, four items have lasted 3,000 hours, 4000 hours, 4000 hours and 5,000 hours before failure.
- MTTF is 16,000/4 or 4,000 hours.

Example

- Times for which of each of the 10 components operates successfully are given. What is MTTF?

-

$$\text{MTTF} = \frac{1}{10} \sum_{i=1}^{10} t_i = \frac{1}{10}(5+2+11+6+9+1+5+4+6+1) = \frac{50}{10} = 5\,\text{hr}$$

Mean time between Failures (MTBF)

- The MTBF is used for repairable products.
- MTBF is the average time from the uptime after the repair following a failure to the next failure.
- Mean time between failures is often used as a synonym for MTTF.
- MTTF and MTBF can often be modelled
- by the Exponential distribution.

$$\text{MTBF} = \frac{\text{Total operating hours for specified units}}{\text{Total failures for those units in a measurement interval}}$$

Basic Terms

- Failure: This is the inability of an item to function within the initially defined guidelines.

- Downtime: This is the time period during which the item is not in a condition to carry out its stated mission.

Basic Terms

- Human reliability: This is the probability of completing a job/task successfully by humans at any required stage in the system operation within a defined minimum time limit (if the time requirement is specified)

Basic Terms

- MEAN TIME BETWEEN MAINTENANCE (MTBM): The average time between all maintenance events that cause downtime, both preventative and corrective maintenance, and also includes any associated logistics delay time.

$$MTBM = \frac{\text{Total number of life units expended in a given time}}{\text{Total number of scheduled and unscheduled maintenance events due to that item}}$$

- MEAN TIME TO REPAIR (MTTR) : A measure of system maintainability equal to the average system repair time, and this value is the reciprocal of repair rate in the exponential case.

$$MTTR = \frac{\text{Total diagnose, repair, and test hours for specified units}}{\text{Total number of completed repair actions for those units}}$$

Maintainability

- Maintainability is a measure of the speed with which loss of performance is detected, diagnosed and repaired. Maintainability is the probability that a unit or system will be restored to specified conditions within a given period when maintenance action is taken in accordance with prescribed procedures and resources.

- This is the probability that a failed item will be repaired to its satisfactory working state.

- If the reliability is high, frequency of maintenance is low.

Availability

- Availability is defined as the percentage of time that a system is available to perform its required function(s). It is measured in a variety of ways, but it is principally a function of downtime.
- This is the probability that an item is available for application or use when needed.
- Availability can range from zero (never available) to 1.00 (always available). Companies that can offer equipment with high availability have a competitive advantage over companies that offer equipment with lower availability.
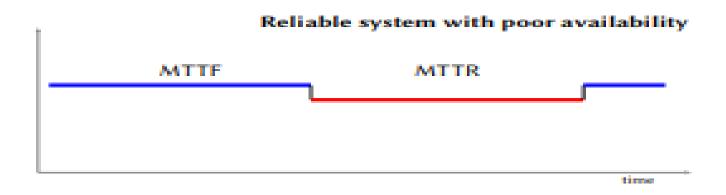
$$= \frac{\text{Time available for a specified use during a stated period}}{\text{Total length of stated period}}$$

$$\text{Availability} = \frac{\text{Uptime}}{(\text{Uptime} + \text{Downtime})}$$

$$\text{Availability} + \text{Unavailability} = 1$$

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$
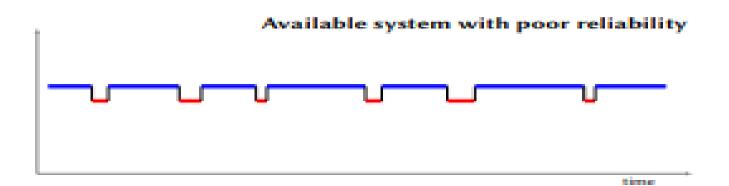
- Maintainability together with reliability determine the availability of a machinery system. Availability is influenced by the time demand made by preventive and corrective maintenance measures.

- To increase availability, designers increase MTBF but also decrease MTTR.

Reliability ≠ availability

- Availability measures proportion of time system is alive and well

- Reliability measures probability for failure free operation

Reliability ≠ availability

Reliable system with poor availability

MTTF   MTTR

time

Available system with poor reliability

time

Example

- A copier is expected to operate for 200 hours after repair, and the mean repair time is expected to be two hours. Determine the availability of the copier.

- MTBF = 200 hours, and MTTR = 2 hours

- Availability = MTBF/MTBF + MTTR

- $\quad\quad\quad\quad = 200/(200 + 2) = 0.99$

Example

- Equipment is required to meet an availability of $Ai = 0.985$ and a mean time between failures (MTBF) = 100 hr. What is permissible mean time to repair (MTTR).

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

- 0.985 = 100/(100+MTTR)
- MTTR= 1.52 hours

Example

- 300 cars have accumulated 45000 hours, 10 failures are observed. What is the MTBF? What is the failure rate?

- MTBF = 45000/10 = 4500 hours.
- Average Failure rate = 1/4500 = 0. 00022 per hour.

Example

- Five oil pumps were tested with failure hours of 45, 33, 62, 94 and 105.

- What is the MTTF and failure rate?

- MTTF = (45+33+62+94+105) / 5 = 67. 8 hours
  Failure rate = 1 / 67.8
- = 0. 0147 per hour.

Example

- 10 components were tested for 525 h. The components (not repairable) failed as follows: Component 1, 2, 3, 4, 5 failed after 75, 125, 130, 325, 525 hours.

- Find the failure rate and mean time till failure.

- No. of failures = 5
- Total operating time
- = 75 + 125 + 130 + 325 + 525 + 5*525 = 3805
- Failure rate = 5 / 3805 = 0. 001314
- Mean time to failure =1/0. 001314 = 761. 04 hours.

Resources

- Introduction to reliability (Portsmouth Business School, April 2012)
- https://canmedia.mheducation.ca/college/olcsupport/stevenson/5ce/ste39590_ch04S_001-019.pdf, Supplement to Chapter 4 Reliability
- Reliability Engineering Lecture Notes, Vardhaman College of Engineering
- https://www.slideshare.net/CharltonInao/reliability-engineering-chapter1csi
- https://extapps.ksc.nasa.gov/Reliability/Documents/210624%20Probability%20Formulas.pdf
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- https://slideplayer.com/slide/5235890/
- http://slideplayer.com/slide/9536322/, Introduction to Reliability Engineering, e-Learning course, CERN
- https://slidetodoc.com/1-introduction-to-reliability-engineering-elearning-course-n

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- https://bbec.ac.in/wpcontent/uploads/wpforo/default_attachments/1627099565-chap1-reliability-word.pdf, Reliability Engineering, BE 8th Semester EE Department BBEC, Kokrajhar

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Resources

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- and ANDRE KLEYNER, 2012, Fifth Edition, John Wiley & Sons, Ltd
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- https://slideplayer.com/slide/4707809/
- https://mathshistory.st-andrews.ac.uk/Extras/reliability_history/
- Ignou The People's University, Unit 11 Reliability Lecture Notes
- Ignou The People's University, Unit 13 Introduction to Reliability Lecture Notes
- Introduction to Reliability Fundamentals, Donald G. Dunn, 2019 D2 Training
- Power System Reliability, Lecture Notes DR. AUDIH ALFAOURY, 2017- 2018, Al-Balqa Applied University