Reliability Engineering

Notes 1

Reliability History

- Reliability as a subject gained importance after World War II because a high failure rate of electronic equipment was observed during the war.
- More complicated products were produced, composed of an ever-increasing number of components (television sets, electronic computers, etc.). With automation, the need for complicated control and safety systems also became steadily more pressing.
- The first journal on the subject, Institute of Electrical and Electronics Engineers (IEEE) Transactions on Reliability, came out in 1963. A number of textbooks on the subject were published in the 1960s.

- Industries are increasingly introducing automation for producing goods ranging from the simplest to highly complex systems. However, all processes and products are prone to failure. For example, a television remote control may stop functioning or a malfunction may occur in any other household appliance; an automobile engine starter may fail, an aeroplane may crash due to the failure of some of its component(s), credit card transactions may fail

Reliability

- The reliability of a product (or system) can be defined as the **probability** that a product will perform a **intended function** under **specified conditions** for a certain period of **time**.
- In effect, reliability is a probability .

- The Reliability definition has four important elements:
- **Probability** When a number of identical components operate under similar conditions, the failure times of components generally vary from component to component and we cannot predict their failure times exactly. advance. But we can describe the phenomenon of failure in probabilistic terms. reliability of a component/system at time t is the probability that it performs its function without failure. Being a probability, its value lies between 0 and 1. (A value between 0 and 1, number of times that an event occurs (success) divided by total number trials)
- Suppose that the reliability of the refrigerator of a particular company at 10 years is R(t) = 0.9452. Then this can be interpreted as follows: Out of 10000 refrigerators of this particular company, approximately 9452 refrigerators worked without failure for 10 years.

- **Intended Function:** The intended function of a product must be described in unambiguous terms early on in the design process so that the expected requirements of the customers can be ensured/addressed. Thus, intended function of a product is the function/work/job which it is expected to perform when we put it in operation under stated conditions.
- For example, if a pump is designed to deliver at least 300 gallons of water per minute, the intended function of the pump is to deliver 300 gallons or more water per minute.

- **Time:** Reliability can be meaningful only if it is related to a time interval or period of time. For example, we can say that the reliability of a component is 0.98 for a mission time of 100 hours. But the statement ‘reliability of a component is 0.95’ is meaningless since the time interval is unknown.

$$R(t) = \frac{\text{Number of components performing intended function at time 't'}}{\text{Number of component at start (i.e., when 't' = 0)}}$$

In the above definition, time ‘t’ means the interval $[0, t]$.

- **Operating conditions**: The performance of the product should be observed under normal stated conditions in which it is expected to perform. The environmental conditions (such as temperature, humidity, shock, vibration, altitude, etc.), design loads (such as voltages, pressure, etc.) and operating conditions (such as maintenance,storage, etc.) affect the reliability of a product. So a product will perform better in the field if its design takes into account and is representative of how it is actually used by the customers. For example, a car which is designed for smooth roads will not perform well if a customer uses it on rough roads. These describe the operating conditions (environmental factors, humidity, temperature cycle, operational profile, etc.) that correspond to the stated product life.

iPhone 14 and iPhone 14 Plus are splash, water and dust resistant and were tested under controlled laboratory conditions with a rating of IP68 under IEC standard 60529 (maximum depth of 6 metres up to 30 minutes). Splash, water and dust resistance are not permanent conditions. Resistance might decrease as a result of normal wear.

Reliability Engineering

- Reliability engineering is an engineering field that deals with the study, evaluation, and life-cycle management of reliability.
- Reliability is often measured as probability of failure, frequency of failures, or in terms of availability.
- Maintainability and maintenance are often important parts of reliability engineering.
- Reliability Engineering is concerned with analyzing failures and providing feedback to design and production to prevent future failures.

Reliability Engineering

- Reliability engineers address 3 basic questions:
- • When does something fail?
- • Why does it fail?
- • How can the likelihood of failure be reduced?

Reliability

- Reliability of a product or part is used in two ways.
- 1. Reliability when activated.
- 2. Reliability for a given length of time.
- First one is often used when a product or part must operate for one time, such as an air bag in a car.
- The second of these focuses on the *length of service* , such as most other products e.g., a car.

Reliability Engineering

- The important applications and benefits of reliability engineering may be summarized as follows:
- Implement an integrated reliability engineering and product assurance program in purchasing, engineering, research, development, manufacturing, quality control, testing, packaging, shipping, installation, start up, operation, field service or inspection, and performance feedback.

Reliability Engineering

- Study the types of failures and determine the time-to-failure distribution of parts, components, products and systems in order to minimize failures and be prepared to cope up with them.
- Study the effects of age, mission duration and operation stress levels on reliability to see if the established goals can be met.
- Indicate areas in which design changes would be most beneficial from the reliability improvement and cost reduction point of view. Provide a basis for comparing two or more designs and choosing the best one from the reliability point of view.

Reliability Engineering

- Some of the benefits are as follows:
- a) Reduce warranty costs and reduce inventory costs through correct prediction of spare parts requirements.
- b) It helps in increase of sales as result of increased customer satisfaction and promote them on the basis of reliability indexes and view-points through the sales and marketing departments.
- c) Increase profits or for the same profit we can get more reliable products and systems.

Reliability Engineering

- A reliability engineering department may have various kinds of responsibilities.
- Establishing reliability policy, plans and procedures
- Reliability allocation
- Reliability prediction
- Specification and design reviews with respect to reliability
- Reliability growth monitoring
- Providing reliability related inputs to design specifications and proposals
- Reliability demonstration
- Training reliability manpower and performing reliability-related research and development work

Reliability Engineering

- • Monitoring the reliability activities of subcontractors, if any
- • Auditing the reliability activities
- • Failure data collection and reporting
- • Failure data analysis

Reliability Engineering

- In industry for the control of processes, in computers, in medical electronics, atomic energy, in defence equipments, communications, navigation at sea and in the air, and in many other fields, it is essential that these equipments should operate reliably.

Why Do Engineering Products Fail?

- There are many reasons why a product might fail.
- The reliability engineering effort, during design, development and in manufacture and service should address all of the anticipated and possibly unanticipated causes of failure, to ensure that their occurrence is prevented or minimized.

- The design might be inherently incapable. It might be too weak, consume too much power, suffer resonance at the wrong frequency, and so on.
- The item might be overstressed in some way. If the stress applied exceeds the strength then failure will occur. An electronic component will fail if the applied electrical stress (voltage, current) exceeds the ability to withstand it.

- Failures can be caused by wearout. We will use this term to include any mechanism or process that causes an item that is sufficiently strong at the start of its life to become weaker with age. Well-known examples of such processes are material fatigue, wear between surfaces in moving contact, corrosion, the wearout mechanisms of light bulbs and fluorescent tubes.

- Failures can be caused by errors, such as incorrect specifications, designs or software coding, by faulty assembly or test, by inadequate or incorrect maintenance, or by incorrect use.

$$R(t) = \frac{number\ of\ survivors\ at\ time\ t}{number\ of\ items\ put\ on\ test\ at\ time\ t = 0}$$

At time t = 0, the number of survivors is equal to number of items put on test. Therefore, the reliability at t = 0 is

$$R(0) = 1 = 100\%$$

$$R(t \to \infty) = 0$$

- After this, the reliability, R(t), will decline as some components fail

Unreliability

- **Unreliability:**The probability that a device will fail to perform a required or intended function under stated conditions for a specified period of time. It is the complement of reliability
- We denote reliability and unreliability of a component by R and Q, respectively
- $R+Q = 1$

- Failure Distribution Function
- Define the function F(t)
- $F(t) = 1 - R(t)$
- $F(0) = 0$ $\qquad F(\infty) = 1$

- Cumulative failure distribution function and gives unreliability of the component up to time t. So if we want to calculate the probability of failure of a component at time t (known as unreliability of the component), then we have to simply obtain the value of the function F(t).

Failure Rate (λ)

- Rate at which failure occur in a specified time interval.
- Reliability of a system is often specified by the failure rate λ

$$\frac{\text{number of failures}}{\text{total operating hours}}$$

Example

- 10 transformers were tested for 500 h each, and four transformers failed after the following test time periods:
- One failed after 50 h , one failed after 150 h , two failed after 400 h
- What is the failure rate for these types of transformers?

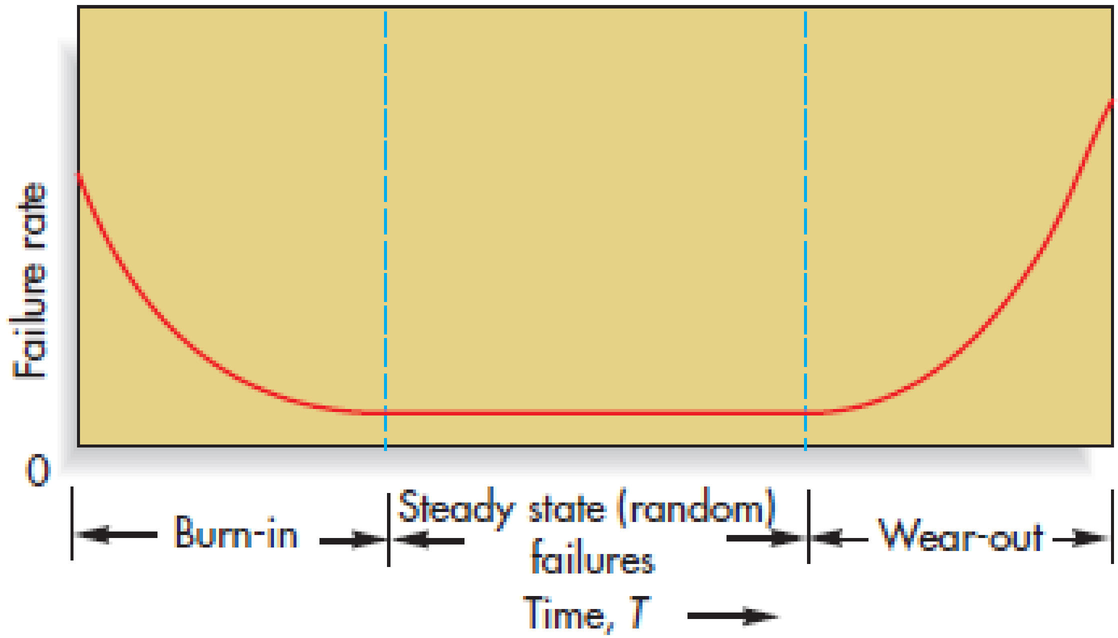
Solution

$$\text{Total operating time of units} = (1 \times 50 + 1 \times 150 + 2 \times 400 + \underset{\text{10-4=6}}{6} \times 500)\ \text{unit h}$$

$$= 4000\ \text{unit h}$$

$$\lambda = \frac{4}{4000} = 0.001\ \text{failures/unit h}$$

Bath tub Curve



Bath tub Curve

- A typical profile of failure rate over time is called the bath tub curve.
- The first period is called burn-in period. Usually, a number of products or parts fail shortly after they are put into service. It is also called infant mortality phase.
- The failures in the beginning are mainly due to defects in design and due to the improper manufacturing techniques, etc.

Bath tub Curve

- During this period, failures occur because engineering did not test products or systems or devices sufficiently, or manufacturing made some defective products.
- Therefore the failure rate at the beginning is high and then it decreases with time after early failures are removed by burn-in or other stress screening methods. Some of the typical early failures are:
- • poor welds
- • poor connections
- • contamination on surface in materials
- • incorrect positioning of parts, etc.

Bath tub Curve

- Second phase is called as the useful life period. During the second phase, random failures occur. In many cases, this phase covers a relatively long period of time (several years).
- In this period the failures are chance failures or random failures.

Bath tub Curve

- Third phase is called the wear-out period and the failures are mainly due to aging effect or lack of maintenance. These failures are called wear-out failures and the failure rate increases. When the failure rate becomes high, repair, replacement of parts etc., should be done.

Bath tub Curve

- The Bath tub curve can be divided into three regions namely
- i) Decreasing hazard rate region
- ii) Constant hazard rate region
- iii) Increasing hazard rate region

Understanding Reliability Keyboard Example

- How might a keyboard key fail? (mechanisms)
- – Material that gives tactile “click” might fatigue and break
- – Electric contacts might corrode or become blocked with dirt
- What might cause these fails? (stresses)
- – Being pressed too many times (wearout)
- – Heat, humidity, dust, dirt, being pressed too hard

- How can we test a key’s entire life? (stress test)
- – Use a machine to press it 1,000,000 times
- – Before that, heat it and shake it with dirt and water
- How can we make it more reliable? (design for rel.)
- – Find what breaks and make that (and only that) stronger

Resources

- Introduction to reliability (Portsmouth Business School, April 2012)
- https://canmedia.mheducation.ca/college/olcsupport/stevenson/5ce/ste39590_ch04S_001-019.pdf
- https://www.slideshare.net/CharltonInao/reliability-engineering-chapter1csi
- http://slideplayer.com/slide/9536322/, Introduction to Reliability Engineering, e-Learning course, CERN
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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
- https://risk-engineering.org/static/PDF/slides-reliability-engineering.pdf, Overview of reliability engineering, Eric Marsden

Resources

- Reliability Engineering Lecture Notes, Vardhaman College of Engineering
- Practical Reliability Engineering, PATRICK D. T. O'CONNOR
- and ANDRE KLEYNER, 2012, Fifth Edition, John Wiley & Sons, Ltd
- https://www.slideshare.net/CharltonInao/reliability-engineering-chapter1csi, Reliability Engineering
- http://cs.uok.edu.in/Files/79755f07-9550-4aeb-bd6f-5d802d56b46d/Custom/SE_UnitIII.pdf
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- http://web.cecs.pdx.edu/~cgshirl/Documents/QRE_ECE510/Lecture_pdfs/ECE%20510%20Lecture%201,%20Introduction,%20Monte%20Carlo%20Rev%202.pdf, Quality and Reliability Engineering Lecture Notes, Scott Johnson, Glenn Shirley
- https://slideplayer.com/slide/4707809/
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- Ignou The People's University, Unit 13 Introduction to Reliability Lecture Notes
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- https://www.apple.com/uk/iphone-14/
- Introduction to Reliability Fundamentals, Donald G. Dunn, 2019 D2 Training
- Power System Reliability, Lecture Notes DR. AUDIH ALFAOURY, 2017- 2018, Al-Balqa Applied University