POSTAL Book Package 2023

Mechanical Engineering

Conventional Practice Sets

Industrial Engineering

Contents

MADE EASY Publications

11 CHAPTER Maintenance Engineering

Practice Questions : Level-I

Q.1 A module of an automatic machine has 10 components in series. Each component has an exponential time to failure distribution with a constant failure rate of 0.05 per 4000 hours. What is the reliability of each component and the module after 2000 hours of operation? What is the mean time to failure of the module?

Solution:

The failure rate of each component (λ) is given by

$$\lambda = \frac{0.05}{4000} = 1.25 \times 10^{-5} \text{ per hour.}$$

The reliability (r) of each component after 2000 hours of operation:

$$r = e^{-\lambda t} = e^{-0.0000125(2000)} = 0.975$$

The reliability (R) of the module is given by

$$R = r^{10} = (0.975)^{10} = 0.779$$

The mean time to failure of the module $= \frac{1}{n\lambda} = \frac{1}{10} \times \frac{1}{(1.25 \times 10^{-5})} = 8000$ Hrs.

Q.2 A electronic circuit consists of 15 valves, 20 resistors and 10 capacitors all connected in a series. The components in each category are identical and their failure times are found to follow exponential distribution with the following mean failure times:

	Valves	Resistors	Capacitors
Mean failure time (hrs.)	10000	20000	20000

What is the mean time between failure of the system? What is its reliability for 100 hours?

Solution:

Let the failure rates of valves, resistors and capacitors be denoted by λ_1, λ_2 and λ_3 respectively, which are the parameters of exponential distribution. So, we have

$$\lambda_1 = \frac{1}{10000},\ \lambda_2 = \frac{1}{20000} \text{ and } \lambda_3 = \frac{1}{20000}$$

$$\text{MTBF} = \frac{1}{[15\lambda_1 + 20\lambda_2 + 10\lambda_3]} = \left[\frac{15}{10000} + \frac{20}{20000} + \frac{10}{20000}\right]^{-1}$$

$$= \frac{20000}{(30 + 20 + 10)} = 333.33 \text{ hours}$$

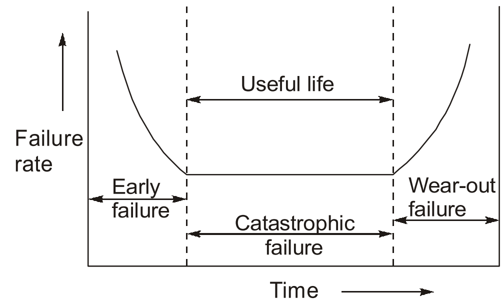
the reliability R(t) of the system for 100 hours is

$$R(t) = e^{-100/333.33} = e^{-0.33} = 0.74082$$

Q.3 Draw the "bathtub curve" and indicate various failure regions. List the major causes of failure in mechanical components/system. Draw the flowchart for failure modes and effects analysis (FMEA).

Solution:

Phase of failure/Bathtub curve:



Early failure: These failure occur at the beginning due to defective design, manufacturing, or assembly work warranty is based on the concept of early failure.

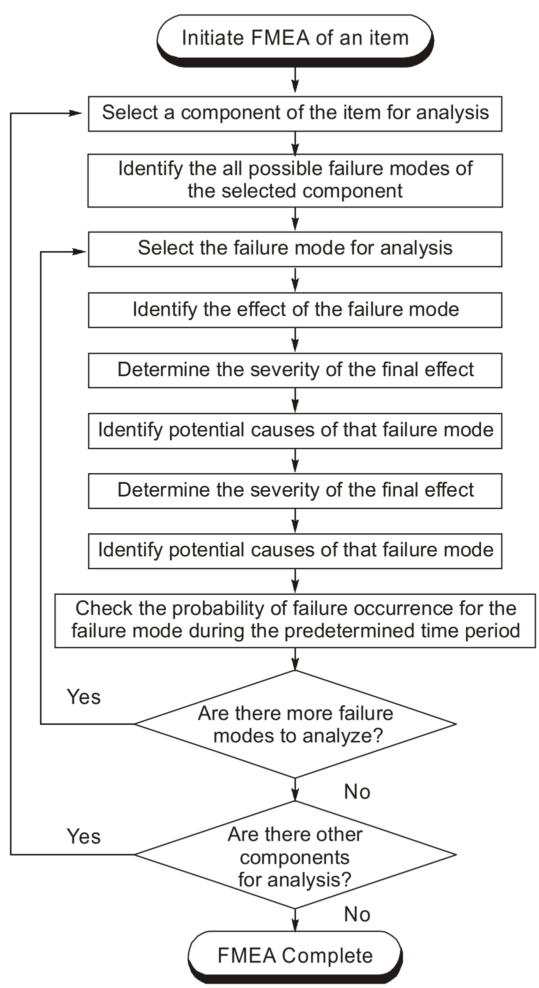
Catastrophic failure: These failure occur during actual working of product, they occur randomly and suddenly. These are caused due to sudden stress accumulation beyond the designed limit.

Wearout failure: It is a typical aging problem and product is more likely to fail due to wear and tear. Proper care and maintenance can delay the failure.

Major causes of failure in mechanical systems component:

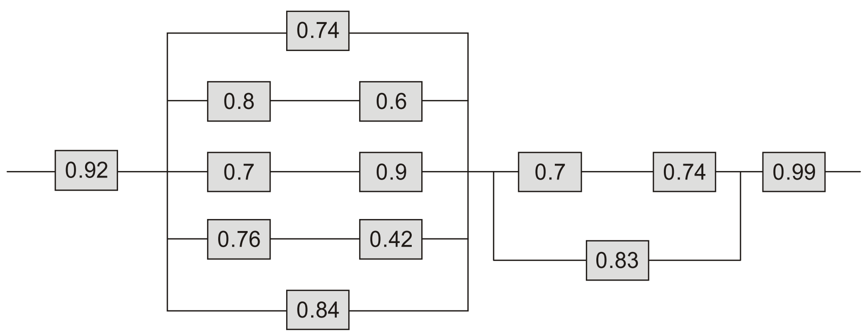
1. Excessive deflection (e.g. in beam), angular misalignment (e.g. in shaft), excessive elongation (e.g. belt)
2. Creep failure.
3. Corrosion or deterioration of material
4. Fatigue failure
5. Wear
6. Thermal shock
7. Brittle and ductile failure
8. Buckling of component
9. Impact load
10. Material bond failure.

Flow chart for failure modes and effects analysis (FMEA):



Practice Questions : Level-II

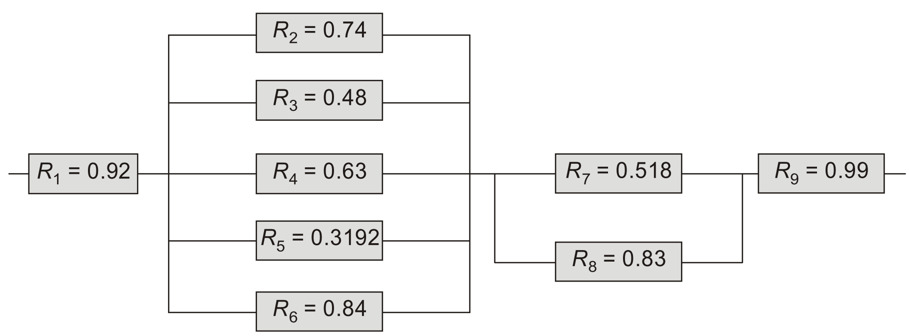
Q.4 Reliability of individual component is shown in figure.



What will be the reliability of the system?

Solution:

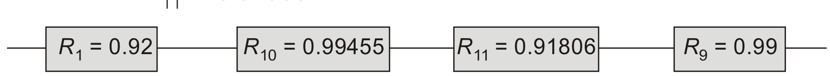
The system can be replaced by an equivalent diagram as shown in figure.



Now,
$$R_3 = 0.8 \times 0.6 = 0.48$$
$$R_4 = 0.7 \times 0.9 = 0.63$$
$$R_5 = 0.76 \times 0.42 = 0.3192$$
$$R_7 = 0.7 \times 0.74 = 0.518$$

This system can be replace by an equivalent diagram.

$$(1 - R_{10}) = (1 - R_2)(1 - R_3)(1 - R_4)(1 - R_5)(1 - R_6)$$
$$= (1 - 0.74)(1 - 0.48)(1 - 0.63)(1 - 0.3192)(1 - 0.84)$$
$$(1 - R_{10}) = 5.45 \times 10^{-3}$$
$$R_{10} = 0.99455$$
$$(1 - R_{11}) = (1 - R_7)(1 - R_8)$$
$$(1 - R_{11}) = (1 - 0.518)(1 - 0.83)$$
$$(1 - R_{11}) = 0.08194$$
$$R_{11} = 0.91806$$



Hence, reliability of system, $R_S = R_1 \times R_{10} \times R_{11} \times R_9 = 0.92 \times 0.99455 \times 0.91806 \times 0.99$

Reliability of system, $R_S = 0.831612$

Q.6 A machine is to be designed to have a minimum reliability of 0.9 and minimum availability of 0.97 over a period of 5000 hour. Calculate the following:

1. Mean time to repair.
2. Probability that machine will fail after 9000 hour.

Solution:

Given data: Time, t = 5000 hour; Reliability, R = 0.9 Availability, A = 0.97

1. We know that, Reliability is exponential function of time.

$$R = e^{-\lambda t}$$
$$0.9 = e^{-\lambda \times 500}$$
$$0.9 = e^{-5000\lambda}$$
$$\ln 0.9 = -5000\lambda$$
$$\text{Failure rate, } \lambda = 2.1072 \times 10^{-5} \text{ per hour}$$

Mean time between failure, $\text{MTBF} = \frac{1}{\lambda} = \frac{1}{2.1072 \times 10^{-5}} = 47456.34$ hour

We know that, Availability, $A = \frac{MTBF}{MTBF + MTTR}$

$$0.97 = \frac{47456.34}{47456.34 + MTTR}$$
$$0.97(\text{MTTR}) = 47456.34 - 0.97 \times 47456.34$$
$$\text{MTTR} = 1467.722 \text{ hour}$$

2. Reliability that machine will run for 9000 hour,

$$R(t) = e^{-\lambda t}$$
$$R(9000) = e^{-2.1072 \times 10^{-5} \times 9000} = 0.82725 = 82.725\%$$

Q.7 Explain the following types of non-destructive testing techniques.

(i) Magnetic-particle inspection technique.

(ii) Acoustic-emission technique.

(iii) Eddy-current inspection

Solution:

(i) Magnetic-particle inspection technique: The magnetic-particle inspection technique consists of placing fine ferromagnetic particles on the surface of the part. The particles can be applied either dry or in a liquid carrier such as water or oil. When the part is magnetized with a magnetic field, a discontinuity (defect) on the surface causes the particles to gather visibly around it. The collected particles generally take the shape and size of the defect.

(ii) Acoustic-emission technique: The acoustic-emission technique detects signals (high-frequency stress waves) generated by the workpiece itself during phenomena such as plastic deformation, crack initiation and propagation, phase transformation, and rapid reorientation of grain boundaries. Bubble formation during boiling and friction and wear of sliding interfaces are other sources of acoustic signals. Acoustic emissions are detected by sensors consisting of piezoelectric ceramic elements. The acoustic emission technique is typically performed by stressing elastically the part or structure, such as bending a beam, applying torque to shaft, and pressurizing a vessel. It is particularly effective for continuous surveillance of load-bearing structures.

(iii) Eddy-current inspection: The eddy current inspection method is based on the principle of electromagnetic induction. The part is placed in, or adjacent to, an electric coil through which alternating current flows at frequencies ranging from 6 to 60 MHz. This current induces eddy currents in the part. Defects existing in the part impede and change the direction of the eddy currents, causing changes in the electromagnetic field. These changes affect the exciting coil (inspection coil), whose voltage is monitored to detect the presence of flaws.