Reliability

SMN 4842 20102011

Project Mgmt and Maintenance Eng.

Definition of Reliability

"Probability that a system or product will perform in a satisfactory manner for a given period of time when used under specified operating condition"

Reliability – 4 main elements

1. probability – numerical representation – number of times that an event occurs (success) divided by total number trials
2. Satisfactory performance – criteria established which describe what is considered to be satisfactory system operation

3. Specifed time – measure against which degree of system performance can be related – used to predict probability of an item surviving without failure for a designated period of time
4. Specified operating conditions expect a system to function – environmental factors, humidity, vibration, shock, temperature cycle, operational profile, etc.

LIFE CYCLE CURVE

- typical life history curve for infinite no of items – ‘bathtub curve
- comparison of failure rate with time
- 3 distinct phase – debugging , chance failure and wear-out phase

Life Cycle Curve

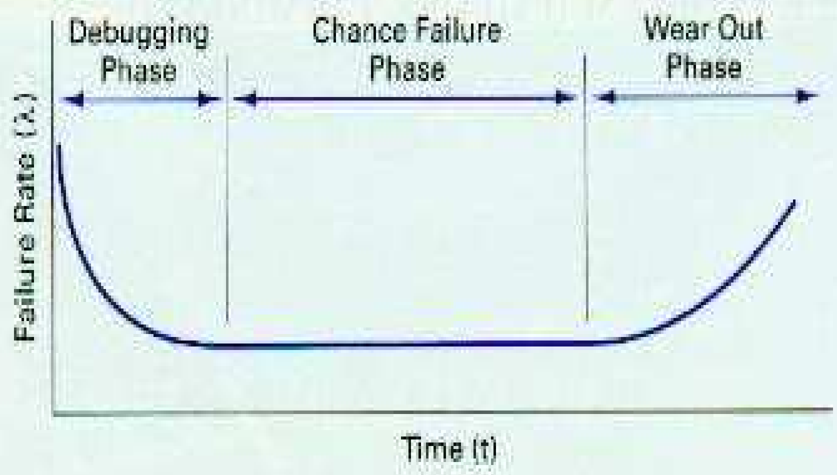


FIGURE 11-3 Typical life history of a complex product for an infinite number of items.

Debugging (Infant mortality) Phase

- rapid decrease in failure rate
- Weibull distribution with shape parameter $\beta < 1$ is used to describe the occurrences of failure
- Usually covered by warranty period

Chance failure phase

- Constant failure rate – failure occur in random manner
- Exponential and also Weibull with $\beta = 1$ can be used to describe this phase

Wear-out phase

- Sharp rise in failure rate – fatigue, corrosion (old age)
- Normal distribution is one that best describes this phase
- Also can use Weibull with shape parameter $\beta > 1$

Maintainability

- Pertains to the ease, accuracy, safety and economy in the performance of maintenance actions
- Ability of an item to be maintained
- Maintainability is a design parameter, maintenance is a result of design

Measures of Maintainability

MTBM – mean time between maintenance, include preventive and corrective maintenance

MTBR – mean time between replacement, generate spare part requirement

$\bar{M}$ – mean active maintenance time

$\bar{M}_{ct}$ – mean corrective maintenance time or mean time to repair

$\bar{M}_{pt}$ – mean preventive maintenance time

- Frequency of maintenance for a given time is highly dependent on the reliability of that item
- Reliability ↑ frequency of maintenance ↓
- Unreliable system require extensive maintenance

Reliability function [R(t)]

- $R(t) = 1 - F(t)$
- $F(t)$ = probability of a system will fail by time (t) = failure distribution function

  Eg. If probability of failure F(t) is 20%, then reliability at time t is

  $R(t) = 1 - 0.20 = 0.80$ or 80%

Reliability at time (t)

- $R(t) = e^{-t/\theta}$
- $e = 2.7183$
- $\theta = \text{MTBF}$

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

λ = failure rate

- So,

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

Failure Rate (λ)

- Rate at which failure occur in a specified time interval

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

- Can be expected in terms of failures per hour, % of failure per 1,000 hours or failures per million hours

Example 1

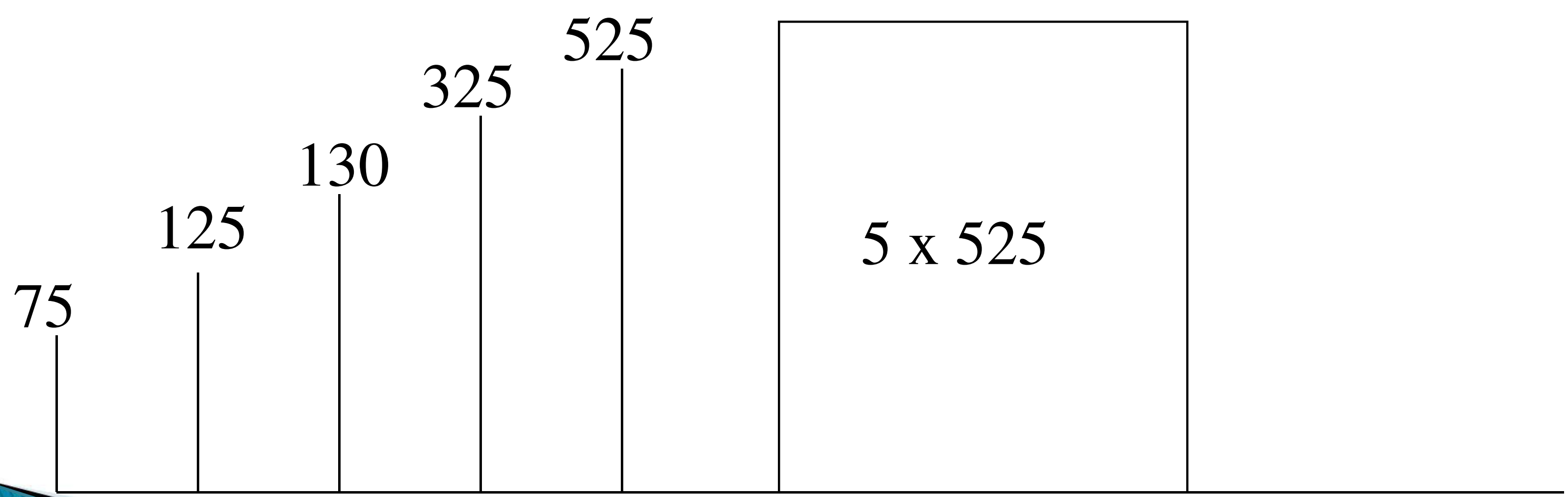
- 10 components were tested. The components (not repairable) failed as follows:

✓ Component 1 failed after 75 ours
✓ Component 2 failed after 125 hours
✓ Component 3 failed after 130 hours
✓ Component 4 failed after 325 hours
✓ Component 5 failed after 525 hours

Determine the MTBF

Solution:

Five failures, operating time = 3805 hours



Solution

$\lambda = 5 / 3805 = 0.001314$

Example 2

The chart below shows operating time and breakdown time of a machine.

20.2	2.5	6.1	7.1	24.4	4.2	35.3	1.8	46.7

Operating time (blue): 20.2, 6.1, 24.4, 35.3, 46.7 — Down time (red): 2.5, 7.1, 4.2, 1.8

Operating time   Down time

a) Determine the MTBF.

Solution:

Total operating time = 20.2 + 6.1 + 24.4 + 4.2 + 35.3 + 46.7

= 136.9 hours

Solution

$\lambda = 4 / 136.9 = 0.02922$

Therefore;

$\theta = MTBF = 1/\lambda = 34.22$ hours

b) What is the system reliability for a mission time of 20 hours?

$R = e^{-\lambda t}$ $t = 20$ hours

$R = e^{-(0.02922)(20)}$

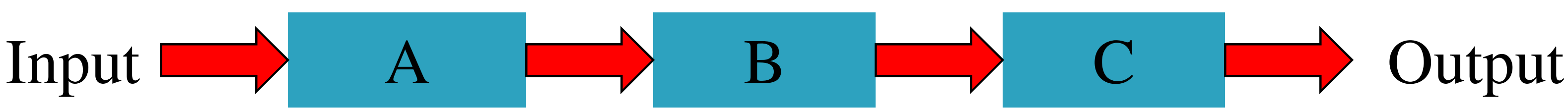
$R = 55.74\%$

Reliability
Component Relationship

- Application in series network, parallel and combination of both

Series Network

- Most commonly used and the simplest to analyze



All components must operate if the system is to function properly.

$$R = R_A \times R_B \times R_C$$

- If the series is expected to operate for a specified time period, then

- R_s (t) = $e^{-(\lambda_1+\lambda_2+\lambda_3+...+\lambda_n)t}$

Example

- Systems expected to operate for 1000 hours. It consists of 4 subsystems in series, $MTBF_A$ = 6000 hours, $MTBF_B$ = 4500 hours, $MTBF_C$ = 10,500 hours, $MTBF_D$ = 3200 hours. Determine overall reliability.

  $\lambda_A = 1\ /MTBF_A = 1/6000 = 0.000167$

  $\lambda_B = 1/MTBF_B = 1/4500 = 0.000222$

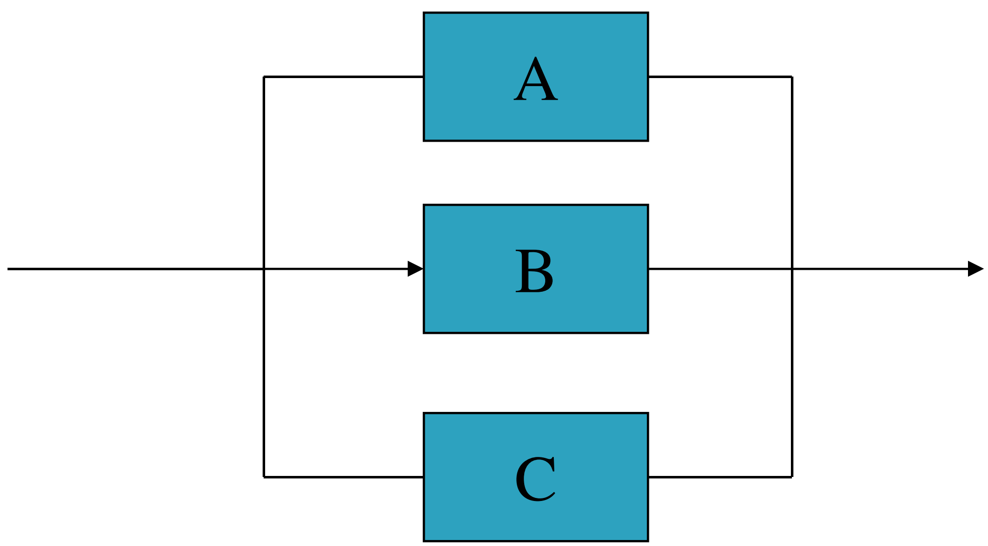
  $\lambda_C = 1/MTBF_C = 1/10500 = 0.000095$

  $\lambda_D = 1/MTBF_D = 1/3200 = 0.000313$

  Therefore; $R = e^{-(0.000797)(1000)} = 0.4507$

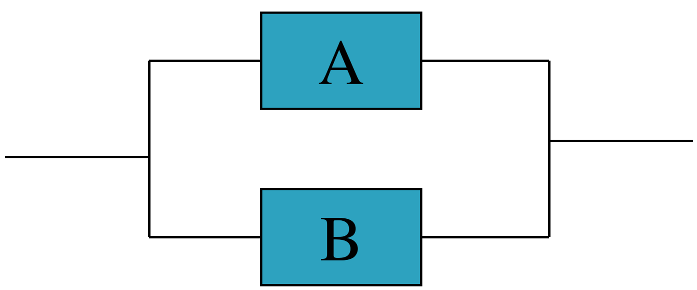
Parallel Network

- A number of the same components must fail order to cause total system failure



Example

- Consider two units A and B in parallel. The systems fails only when A and B failed.



$$F_s(t) = F_a(t)\,F_b(t)$$
$$= [1-R_a(t)][1-R_b(t)]$$
$$= 1-R_a(t)\,R_b(t) + R_a(t)\,R_b(t)$$
$$R_s(t) = 1- F_s(t)$$
$$= R_a(t) + R_b(t) - R_a(t)\,R_b(t)$$

- If A and B are constant failure rate units, then:

- $R_a(t) = e^{\lambda_a t}$ $R_b(t) = e^{-\lambda_b t}$

And $R_s(t) = \int_0^{\infty} R_s(t)dt = \frac{1}{\lambda_a} + \frac{1}{\lambda_b} - \frac{1}{\lambda_a + \lambda_b}$

$\theta_s = \text{MTBF}$

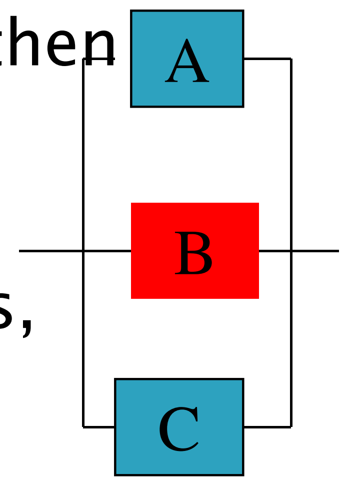
Consider 3 components in parallel

- $R_s = 1 - F_s$
- $F_a = 1 - R_a$ $F_b = 1 - R_b$ $F_c = 1 - R_c$
- $R_s = 1 - (1-R_a)(1-R_b)(1-R_c)$
- If components A, B and C are identical, then the reliability,

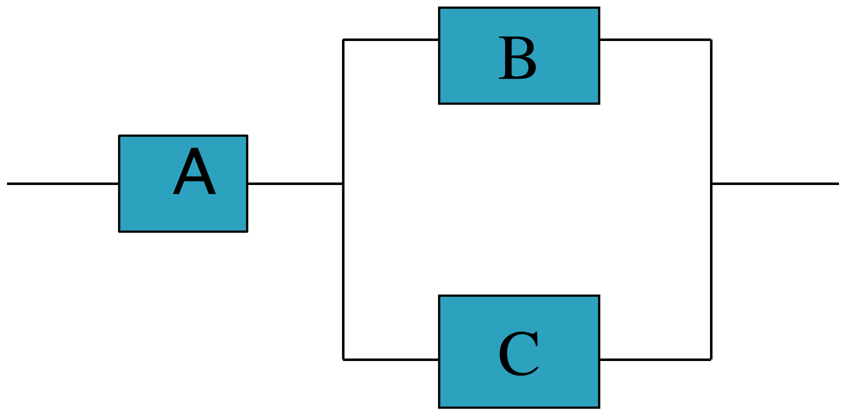
$$R_s = 1 - (1 - R)^3$$

- For a system with n identical components,

$$R_s = 1 - (1-R)^n$$

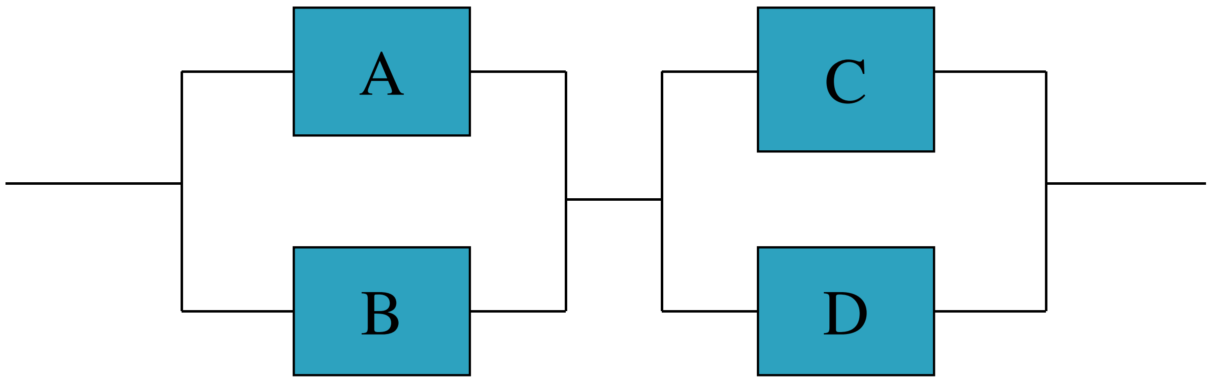


Combined series parallel network



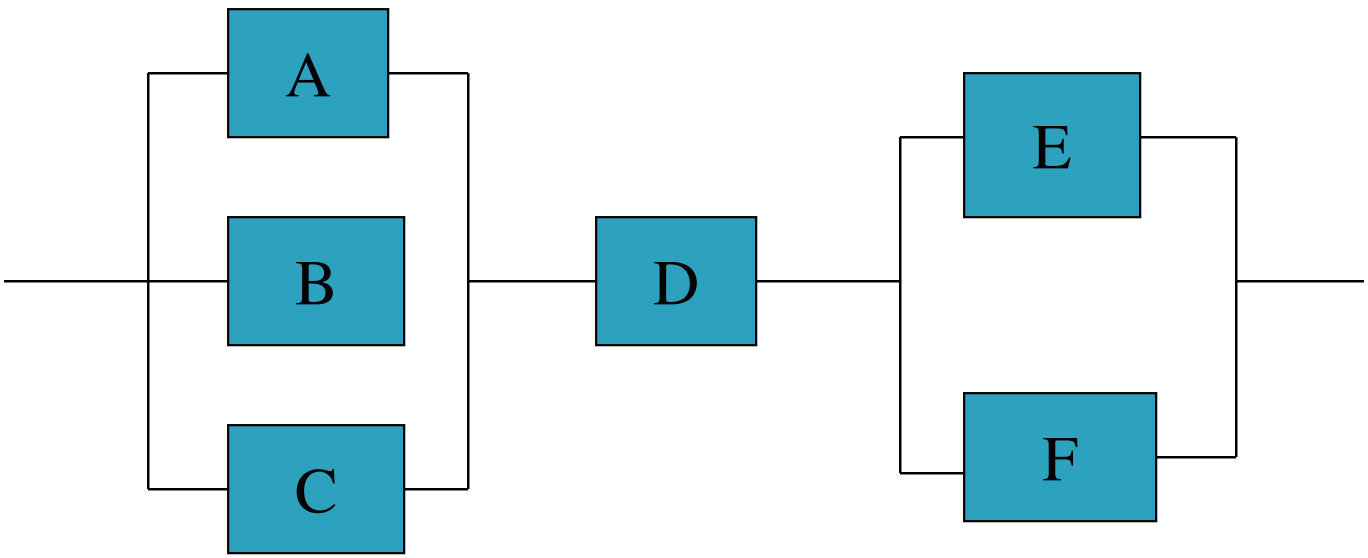
$$R_s = R_A\,[R_B + R_C - R_B R_C]$$

Combined series parallel network



$$R_S = [1-(1-R_A)(1-R_B)][1-(1-R_C)(1-R_D)]$$

Combined series parallel network



$$R_S=[1-(1-R_A)(1-R_B)(1-R_C)][R_D] \times [R_E+R_F-(R_E)(R_F)]$$

Combined series parallel network

- For combined series-parallel network, first evaluate the parallel elements to obtain unit reliability
- Overall system reliability is determined by finding the product of all series reliability