Predicting Reliability During Design

Procedure:

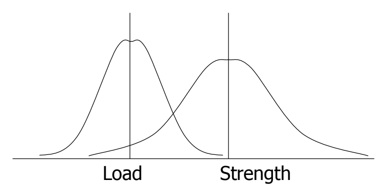
- Define the product and its function
  - Functional block diagram
- Prepare a reliability block diagram
  - Shows redundancies
- Develop probability model
- Collect part reliability info
  - Not available readily
  - Tests, Part manufacturers data, Other publications
- Combine all the above,
  - include growth models if appropriate

Why does failure occur?

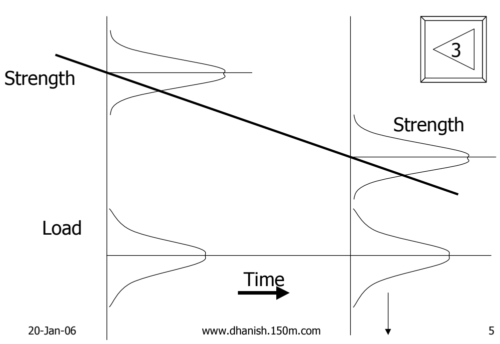
- Design not capable
- Overstress
- <u>Variation</u>
- Wearout
- <u>Time dependent mechanisms</u>
- Sneaks
- Errors

Variation

- Mean load less than Mean strength, but...



Time dependent mechanisms



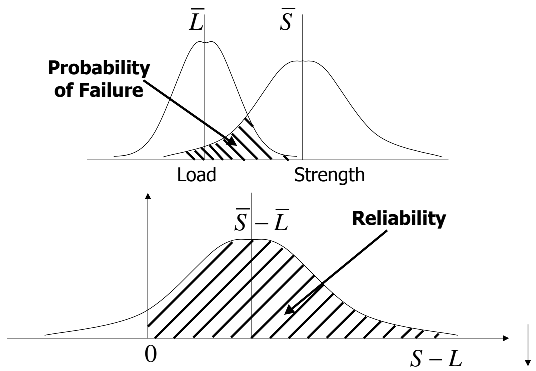
Reliability from Load and Strength

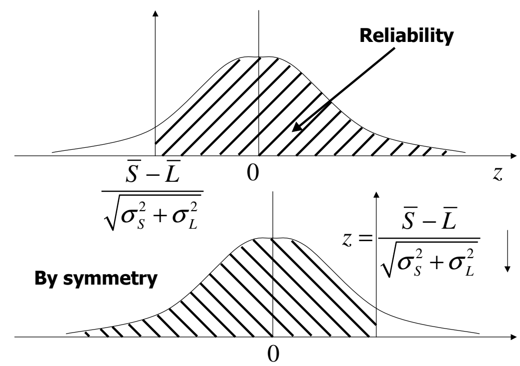
- Let L represent the Load and S the strength
- Failure occurs when S<L, or S-L<0

Let S be $N(\bar{S},\sigma_S^2)$ and L be $N(\bar{L},\sigma_L^2)$

Reliability = P(S-L)>0

S-L will be $N(\bar{S}-\bar{L},\sigma_S^2+\sigma_L^2)$





Thus,

Reliability is the area under the standard normal from -infinity to $\bar{S}$ - $\bar{L}$

$$\text{Reliability} = \phi\left[\frac{\bar{S} - \bar{L}}{\sqrt{\sigma_S^2 + \sigma_L^2}}\right]$$

The above analysis does not show the effect of time

NOTE:

- It can be shown that
  - constant failure rate results from loading variability,
  - increasing failure rates from the combined effects of loading variability and product deterioration,
  - decreasing failure rates from loading and initial capacity variability
- Ref: Lewis, E.E., "Introduction to Reliability Engineering Second Edition", John Wiley & Sons, Inc, 1994

Problem:

- For an electronic component, the operating temperature is a critical parameter. The maximum expected temperature is 70°C with a standard deviation of 3°C. The material shows a strength distribution with mean 80°C and standard deviation of 4°C
- Predict the reliability of the component

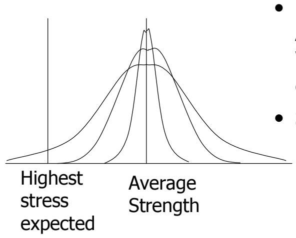
Solution:

$$z = \frac{80 - 70}{\sqrt{4^2 + 3^2}} = 2$$

$$\phi(2) = 0.975$$

Hence, reliability = 0.975

Safety Factor : Does not ensure reliability



- Usually defined as Average Strength / Worst stress expected
- Same safety factor, but different reliability

Safety Margin

- (Average Strength - Worst Stress) / (Standard deviation of load and strength)

$$\text{Safety Margin} = \frac{S - L}{\sqrt{\sigma_S^2 + \sigma_L^2}}$$

$$\text{Reliability} = \phi(SM)$$

Other reliability indices

- Mean Time to Failure (MTTF)
  - Mean Time to Failure of a nonrepairable product or mean time to first failure of a repairable product
- Mean Life
  - Mean value of life ("life" may be related to major overhaul, wear-out time, etc.)

Other indices...

- Mean Time to First Failure (MTFF)
  - Mean Time to First Failure of a repairable product
- Mean Time Between Maintenance (MTBM)
  - Mean Time Between a specified type of maintenance action

Other indices...

- b_{10} life
  - Life during which 10% of the population would have failed
- b_{50} life
  - Median life, or life during which 50% of the population would have failed
- Repairs/100
  - Number of repairs per 100 operating hours

Reliability Testing