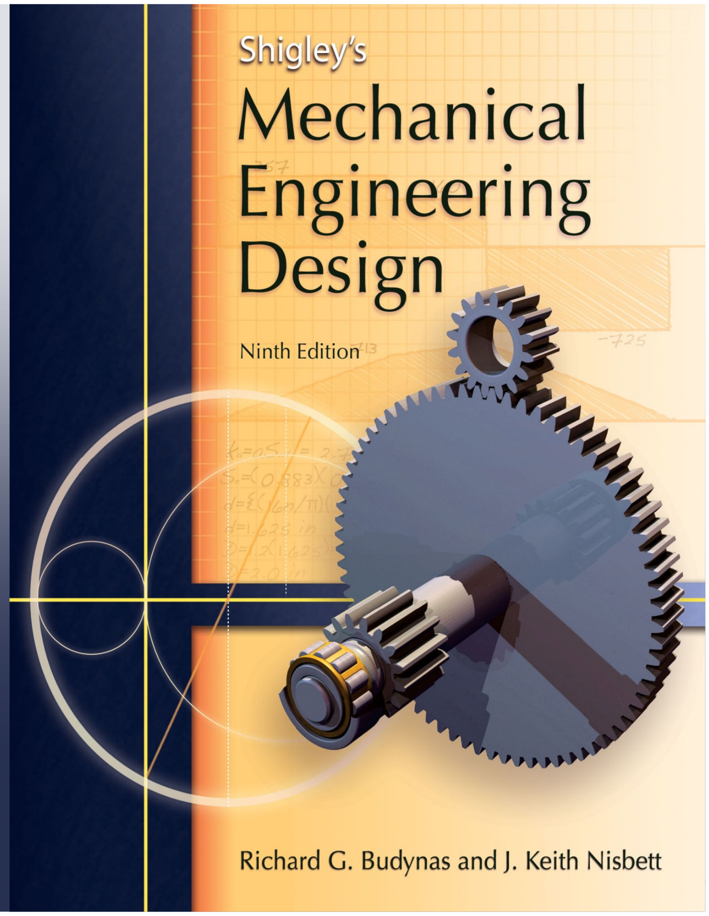
Lecture Slides

Chapter 1

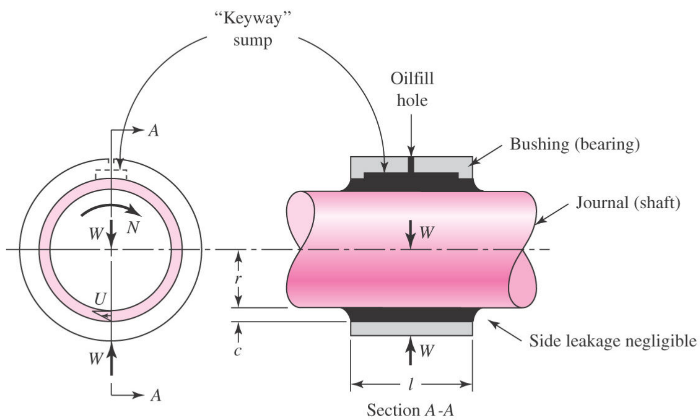
Introduction to Mechanical Engineering Design



Chapter Outline

Mechanical Engineering Design

- Mechanical engineering design involves all the disciplines of mechanical engineering.
- Example
  - Journal bearing (*kaymalı yatak*): fluid flow, heat transfer, friction, energy transport, material selection, thermomechanical treatments, statistical descriptions, etc.

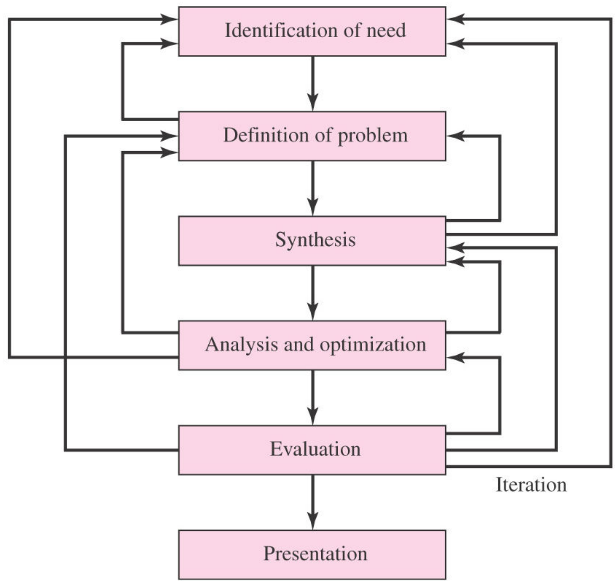


Design

- To formulate a plan for the satisfaction of a specified need
- Process requires innovation, iteration, and decision-making
- Communication-intensive
- Products should be
  - Functional
  - Safe
  - Reliable
  - Competitive
  - Usable
  - Manufacturable
  - Marketable

The Design Process

- Iterative in nature
- Requires initial estimation, followed by continued refinement



Design Considerations

- Some characteristics that influence the design

1	Functionality	14	Noise
2	Strength/stress	15	Styling
3	Distortion/deflection/stiffness	16	Shape
4	Wear	17	Size
5	Corrosion	18	Control
6	Safety	19	Thermal properties
7	Reliability	20	Surface
8	Manufacturability	21	Lubrication
9	Utility	22	Marketability
10	Cost	23	Maintenance
11	Friction	24	Volume
12	Weight	25	Liability
13	Life	26	Remanufacturing/resource recovery

Computational Tools

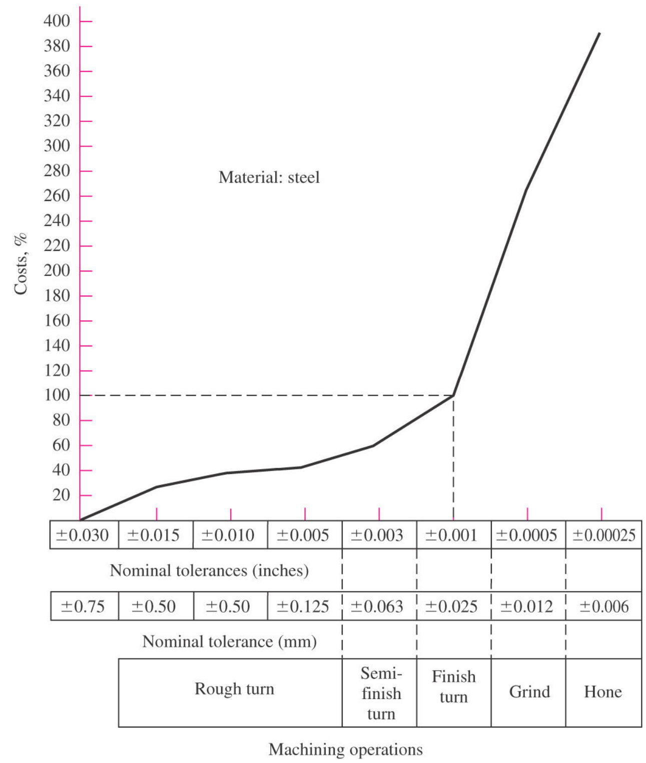
- Computer-Aided Engineering (CAE)
  - Any use of the computer and software to aid in the engineering process
  - Includes
    - Computer-Aided Design (CAD)
      - Drafting, 3-D solid modeling, etc.
    - Computer-Aided Manufacturing (CAM)
      - CNC toolpath, rapid prototyping, etc.
    - Engineering analysis and simulation
      - Finite element, fluid flow, dynamic analysis, motion, etc.
    - Math solvers
      - Spreadsheet, procedural programming language, equation solver, etc.

Economics

- Cost is almost always an important factor in engineering design.
- Use of standard sizes is a first principle of cost reduction.
- Table A-17 lists some typical preferred sizes.
- Certain common components may be less expensive in stocked sizes.

Tolerances

- Close tolerances generally increase cost
  - Require additional processing steps
  - Require additional inspection
  - Require machines with lower production rates

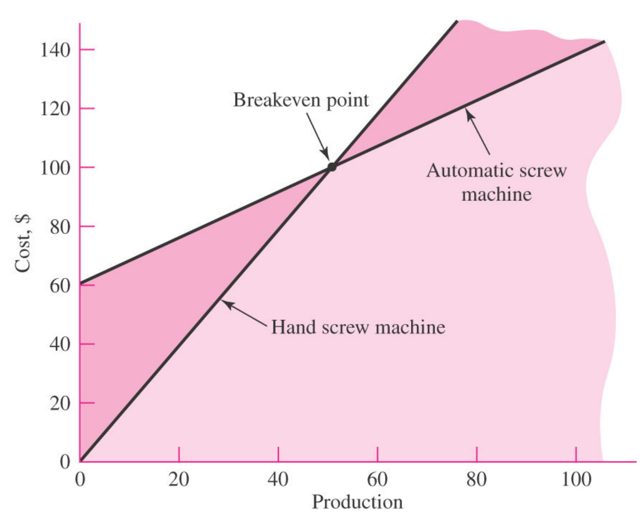


Breakeven Points

- A cost comparison between two possible production methods
- Often there is a breakeven point on quantity of production

EXAMPLE (vida üretimi örneği)

- Automatic screw machine
  - 25 parts/hr
  - 3 hr setup
  - \$20/hr labor cost
- Hand screw machine
  - 10 parts/hr
  - Minimal setup
  - \$20/hr labor cost
- Breakeven at 50 units



Breakeven Points

SOLUTION TO EXAMPLE (vida üretimi örneği)

Stress and Strength

- Strength
  - An inherent property of a material or of a mechanical element
  - Depends on treatment and processing
  - May or may not be uniform throughout the part
  - Examples: Ultimate strength, yield strength

- Stress
  - A state property at a specific point within a body
  - Primarily a function of load and geometry
  - Sometimes also a function of temperature and processing

Uncertainty

- Common sources of uncertainty in stress or strength
  - Composition of material and the effect of variation on properties.
  - Variations in properties from place to place within a bar of stock.
  - Effect of processing locally, or nearby, on properties.
  - Effect of nearby assemblies such as weldments and shrink fits on stress conditions.
  - Effect of thermomechanical treatment on properties.
  - Intensity and distribution of loading.
  - Validity of mathematical models used to represent reality.
  - Intensity of stress concentrations.
  - Influence of time on strength and geometry.
  - Effect of corrosion.
  - Effect of wear.
  - Uncertainty as to the length of any list of uncertainties.

Uncertainty

- Stochastic method
  - Based on statistical nature of the design parameters
  - Focus on the probability of survival of the design's function (reliability)
  - Often limited by availability of statistical data

Uncertainty

- **Deterministic method**
  - Establishes a *design factor, n_d*
  - Based on absolute uncertainties of a *loading parameter* and a *strength parameter*

$$n_d = \frac{Strength\ parameter}{Loading\ parameter}$$

  - For instance, if the parameter is load;

$$n_d = \frac{Allowable\ Load}{Maximum\ Applied\ Load}$$

Example 1-1

- Consider that the allowable load on a structure is known with an uncertainty of ±15%, and the maximum applied load is known within ±20%. If the nominal value of the allowable load is 9 kN, determine

  (a) the design factor, (b) the nominal value of the maximum applied load

Solution

Example 1-2

A rod with a cross-sectional area of A and loaded in tension with an axial force of $P =$ 10 kN undergoes a stress of $\sigma = P/A$. Using a material strength of 200 MPa and a *design factor* of 3.0, determine the minimum diameter of a solid circular rod. Using Table A–17, select a preferred fractional diameter and determine the rod's *factor of safety*.

Table A-17: Preferred Sizes

Millimeters
0.05, 0.06, 0.08, 0.10, 0.12, 0.16, 0.20, 0.25, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.0, 1.1, 1.2, 1.4, 1.5, 1.6, 1.8, 2.0, 2.2, 2.5, 2.8, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0, 9.0, 10, 11, 12, 14, 16, 18, 20, 22, 25, 28, 30, 32, 35, 40, 45, 50, 60, 80, 100, 120, 140, 160, 180, 200, 250, 300

Example 1-2 Solution

Reliability

- *Reliability*, *R* – The statistical measure of the probability that a mechanical element will not fail in use

- *Probability of Failure*, p_f – the number of instances of failures per total number of possible instances

$$R = 1 - p_f \qquad (1\text{–}4)$$

- Example: If 1000 parts are manufactured, with 6 of the parts failing, the reliability is

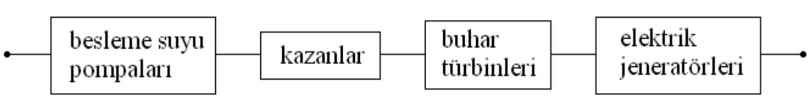
$$R = 1 - \frac{6}{1000} = 0.994 \qquad \text{or } 99.4\ \%$$

System Reliability - 1

- *Series System* – a system that is accepted to have failed if **any component** within the system fails
- The overall reliability of a series system is the product of the reliabilities of the individual components.

$$R = \prod_{i=1}^{n} R_i \qquad (1\text{-}5)$$

- Örnek: 4 ana parçadan oluşan bir ısıl sistem



$R_1 = 0.99$ $\quad R_2 = 0.96$ $\quad R_3 = 0.98$ $\quad R_4 = 0.97$

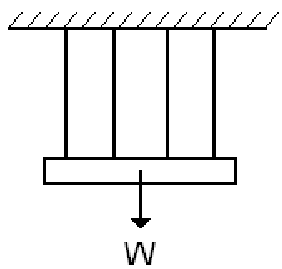
Sistem güvenilirliği: $R = 0.99 \times 0.96 \times 0.98 \times 0.97 = \mathbf{0.90}$

System Reliability - 2

- *Parallel System* – a system that is accepted to have failed if **all components** within the system fails
- The overall reliability of a parallel system is computed from

$$R = 1 - \prod_{i=1}^{n} (1 - R_i)$$

- Örnek: 4 çubuktan oluşan bir taşıma sistemi



$R_1 = R_2 = R_3 = R_4 = 0.90$

Sistem güvenilirliği:

R = 1 - (1-0.90)^4 = **0.9999**

Dimensions and Tolerances

- *Nominal size* – The size we use in speaking of an element.
  - Is not required to match the actual dimension
- *Limits* – The stated maximum and minimum dimensions
- *Tolerance* – The difference between the two limits
- *Bilateral tolerance* – The variation in both directions from the basic dimension, e.g. 1.005 ± 0.002 in.
- *Unilateral tolerance* – The basic dimension is taken as one of the limits, and variation is permitted in only one direction, e.g.

$$1.005 \begin{smallmatrix} +0.004 \\ -0.000 \end{smallmatrix} \text{ in}$$

Example 1-3

A shouldered screw contains three hollow right circular cylindrical parts on the screw before a nut is tightened against the shoulder. To sustain the function, the gap w must equal or exceed 0.003cm. The parts in the assembly depicted in Fig. 1–4 have dimensions and tolerances as follows:

$$a = 1.750 \pm 0.003 \text{ cm} \qquad b = 0.750 \pm 0.001 \text{ cm}$$
$$c = 0.120 \pm 0.005 \text{ cm} \qquad d = 0.875 \pm 0.001 \text{ cm}$$

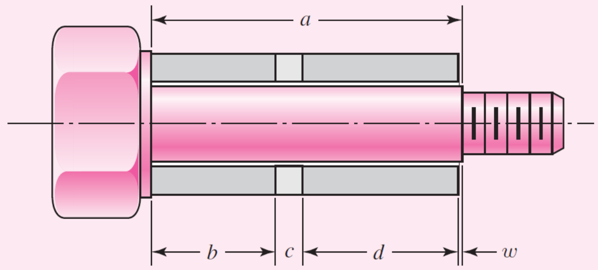


Figure 1-4

All parts except the part with the dimension d are supplied by vendors. The part containing the dimension d is made in-house.

(a) Estimate the mean and tolerance on the gap w.

(b) What basic value of d will assure that $w \geq$ 0.003cm?

Example 1-3 Solution