Machine Design

Machine & Machin Element

Machine - perform useful work when some form of energy is applied

Machine element - smallest component of machine

Machine Design

Combination of scientific principle
technical, information
imagination

↓ to perform

maximum economy and efficiancy

Need for Design

→ safe, more efficient & comfortable

↓

safe design

→ friction b/w people & product

↓

design fail

↓

need for design arises

Basic Procedure of Machine Design

Market survey
↓
Define product specification
↓
Selection of Mechanism
↓
Prepare general layout
↓
Design individual component
↓
Prepartion of prototype

Machine Elements

→ Elementary Component of machine

(gears, shaft, clutch) ↳ General purpose machine element
↳ Special " " "

BASIC REQUIREMENTS OF MACHINE ELEMENTS

Strength	Safety
Rigidity	Conformance of Standards
Wear Resistance	Reliability
Minimum Dimensions and Weight	Maintainability
Manufacturability	Minimum Life Cycle Cost

Design of machine elements

- → Specification of function
- → Selection of material
- → Determination of Dimensions
- → Determination of force
- → Failure Criterion
- → Design Modification
- → Working Drawing

Traditional Design Methods

- ① Design by Craft evolution
- Design by drawing

Design Synthesis

Process of selecting
- → Configuration
- → materials
- → Shapes
- → dimension of product

Main objective is optimization

Ergonomics → relationship between man & machine

$\underbrace{\text{Ergo}}_{\text{work}}\underbrace{\text{nomics}}_{\text{natural laws}}$

→ to solve problems b/w man & machine
using → anotomical
→ physiological
→ psycoligical principles

Aesthetic Consideration

→ Customer attracted towards appealing product

→ external appearance dominates sale in market

Hooke's Law, elastic & Plastic behaviour

elastic behaviour - material return backs to its original size after removal of force

Plastic behaviour - deformation remains after removal force

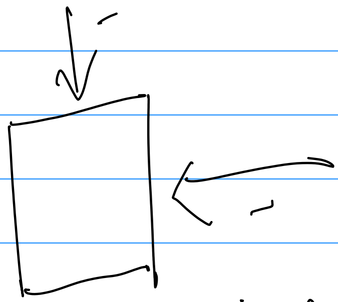
Hooke's law

$$F = K \Delta x$$

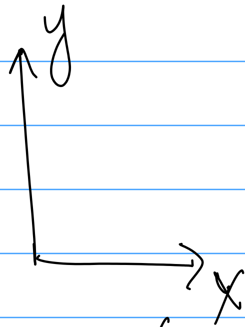
F → Force
K → Spring Constant
Δx → streched length - orignal length

σ_x σ_y → Normal stress

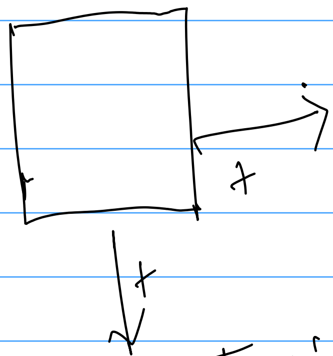
τ_{xy} → Shear stress



Compression

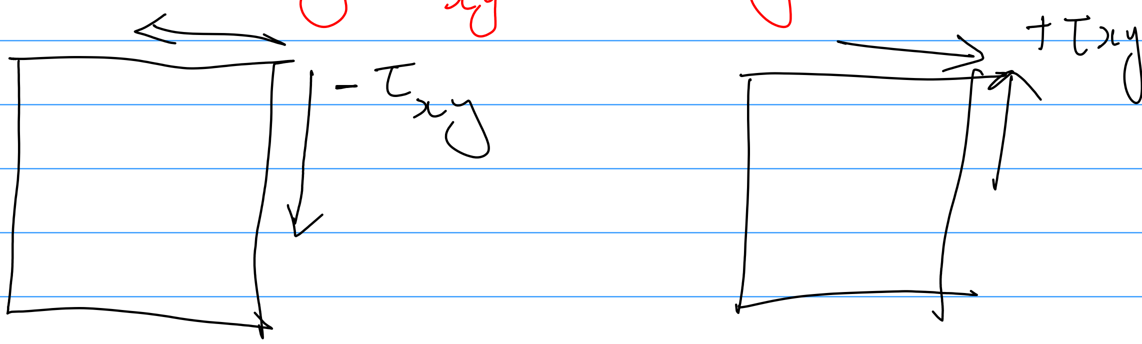


Reference Co-ordinate

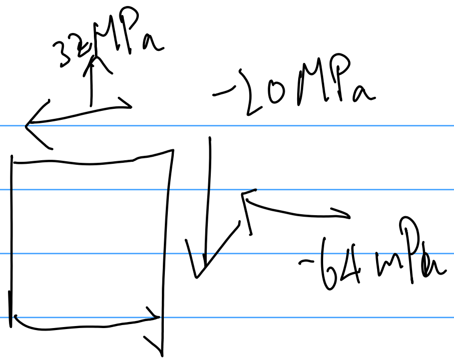


Tension

Determining τ_{xy} & its sign



Shear force



Three different methods

→ Mohr's Circle
→ Matrix & Determinants
→ Formulae

Mohr's Circle

⇒ Give graphical solution

1) Determine the principal stress σ_1 & σ_2

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2}$$

2) Determine the max shear stress τ_{max1} & τ_{max2}

$$\tau_{max1,2} = \pm \frac{(\sigma_1 - \sigma_2)}{2}$$

3) Determine Principal direction φ_1 & φ_2

$$\tan(2\varphi_1) = \frac{2\tau_{xy}}{\sigma_x - \sigma_y} \qquad \varphi_2 = \varphi + 90^\circ$$

Failure of Ductile & brittle materials

Failure of ductile material → initiation of yielding

Failure of brittle material → fracture

Theories of failure for ductile material

→ Maximum shear stress theory (Tresca Yield criterion)

Most cause of yielding → slipping
↓
occurs along the contact planes of randomly ordered crystal

Slipping is due to shear stress $\tau_{max}^{abs} = \frac{\sigma_{max} - \sigma_{min}}{2}$

Maximum Distortion Energy theory (Von Mises Yield criterion)

For 3-d ⇒ $\sigma_0 = \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}$

For 2-d ⇒ $\sigma_0 = \sqrt{\sigma_1^2 - \sigma_1 \sigma_2 + \sigma_2^2}$

$\left.\begin{array}{l} |\sigma_1| = \sigma_y \\ |\sigma_2| = \sigma_y \end{array}\right\}$ σ_1 & σ_2 have same sign

$|\sigma_1 - \sigma_2| = \sigma_y$
↓
for opposite sign

$\Rightarrow$ Yield stress Occurs when $\sigma_0 = \sigma_y$

Allowable stress, σ_{allow} by Safety factor, SF

While desiging

$$\sigma_{allow} \leq \sigma_0$$

where $\sigma_0 \leq \frac{\sigma_y}{SF}$

Theory of failure for brittle materials

Failure of a brittle material in tension

Failure of a brittle material in torsion

For plane stress

$$|\sigma_1| = \sigma_{ultimate}$$

$$|\sigma_2| = \sigma_{ultimate}$$

stress due to

axial load $= \frac{F}{A}$

torsional load $= \frac{Tc}{J}$

Polar moment of inertia

Design Against fluctuating loads

fluctuating loads:

- forces which are not static & vary with time
- 80% of component fail due to this

Three popular Criterions

- Gerber line
- Soderberg line
- Goodman line

Stress Concentration

- localisation (accumulation) of high stress due to irregularities
- to find stress concentration, stress concentration factor is used

$$K_t = \sigma_{max} / \sigma_0$$

Causes of stress Concentration

- Variation in property of material
- load application
- Abrupt change in section
- Discontinuities
- Machining scratches

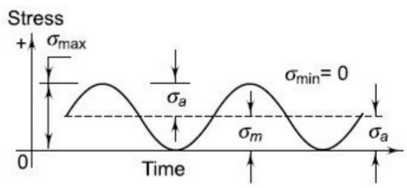
Stress Concentration factors

→ Ductile material under static load
→ Ductile material under fluctuating load
→ Brittle material

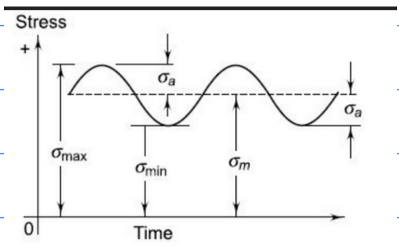
→ To reduce stress concentration
→ avoid abrupt change in stress flow line
→ smoother change gives lower stress concentration

Variables stress → magnitude / direction / both changing

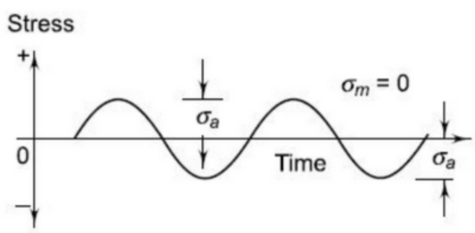
→ Fluctuating stress
→ Repeated stress
→ Reversed stress



(b) Repeated stresses



(a) Fluctuating stresses



(c) Reversed stresses

$$\sigma_{mean} = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$\sigma_{alternating} = \frac{\sigma_{max} + \sigma_{min}}{2}$$

Endurance limit

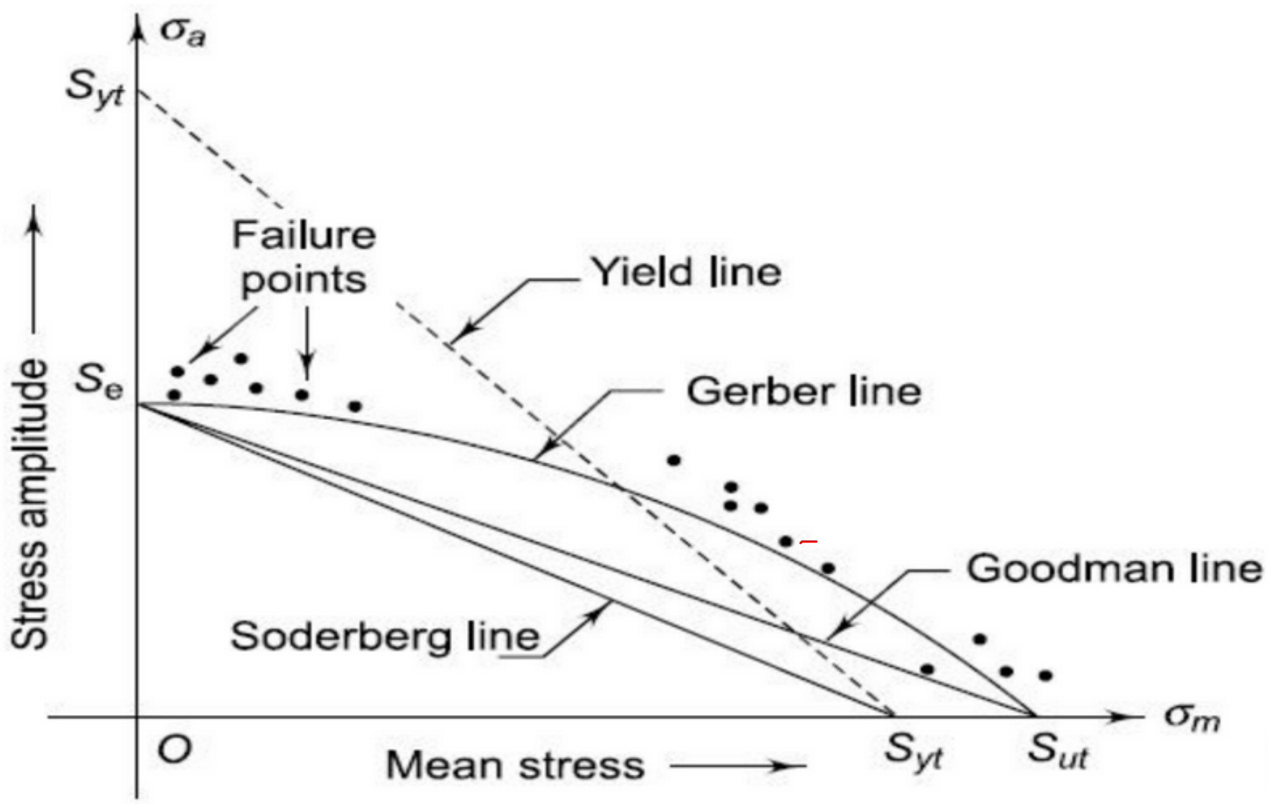
→ maximum amplitude of frequency a specimen can stand for ∞ cycles

→ In general $\infty = 10^6$ times

Notch sensitivity

→ Sensitivity of material developing notch during fluctuating load

Soderberg and Goodman Equation



Pf - 2

Spring - elastic body - function → distort on load
→ recover on removal

Applications

- to absorb shock and vibration — Car spring
- to apply force in brakes — Clutch
- Storage of potential energy — watches & toys

Types of springs

Helical springs

Conical & Volute spring

Torsion spring

Laminate / leaf springs

Disc or bellevile springs

Special purpose springs

Helical springs

→ Wired coils in form of helix
→ Cross section may be circular, square or rectangular

Closed & open Coil helical springs

Closely Coiled
- wires are so close to each other
- Subjected to torsion (twisting force)
- major force - shear stress due to twisting

Open Coil
- gap between two adjacent turns
- application is limited

Advantages
- Easy to manufacture
- Avaible in wide range
- reliable
- Constant spring rate
- performance can be predicted

Conical & Volute Spring
- application where varying spring rate
  spring rate ↑ with load ↑
- Constant pitch & angle
- decreasing coil → ↑ in spring rate
- reduces → Vibration problem with varying mass
- Shear stress due to twisting

Torsion Springs

→ helical or spiral type

helical → load winds up spring

spiral → used where load tends to increase

Major force Tensile & Compressive

Disc Springs

→ consists of number of conical discs around central tube

→ used when high spring rate is required

Special Purpose Springs

→ liquid springs, rubber springs, ring springs

Materials for helical spring

Properties → high fatigue strength

→ high ductility

Services

Severe service - rapid loads

Average intermittent operation

light service - static load, infrequently varied