MACHINE ELEMENTS AND STRESSES

DAY 1: MACHINE DESIGN

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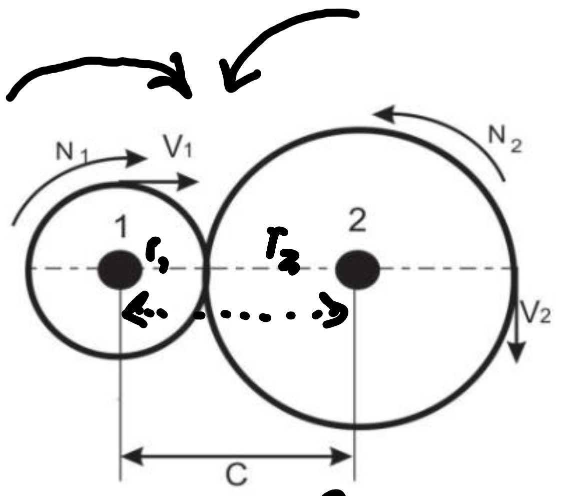
m rad/s

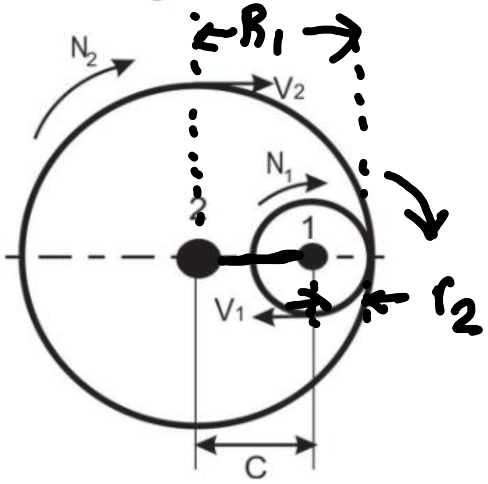
$V = RN$

I. MACHINE ELEMENTS

1. Cylinders Rolling in opposite direction:
   A. Tangential Speed $V_1 = V_2 = \cancel{\pi} D_1 N_1 = \cancel{\pi} D_2 N_2$
   B. Relation of Diameter and Speed $D_1 N_1 = D_2 N_2$
   C. Speed Ratio = $\dfrac{Speed\ of\ Driver}{Speed\ of\ the\ Driven} = \dfrac{N_1}{N_2} = \dfrac{D_2}{D_1}$
   D. Center Distance = $R_1 + R_2 = \frac{D_1 + D_2}{2}$



2. Cylinders Rolling in the same direction:
   A. Tangential Speed $V_1 = V_2 = \pi D_1 N_1 = \pi D_2 N_2$
   B. Relation of Diameter and Speed $D_1 N_1 = D_2 N_2$
   C. Speed Ratio = $\dfrac{Speed\ of\ Driver}{Speed\ of\ the\ Driven}$
   D. Center Distance = $R_1 - R_2 = \frac{D_1 - D_2}{2}$



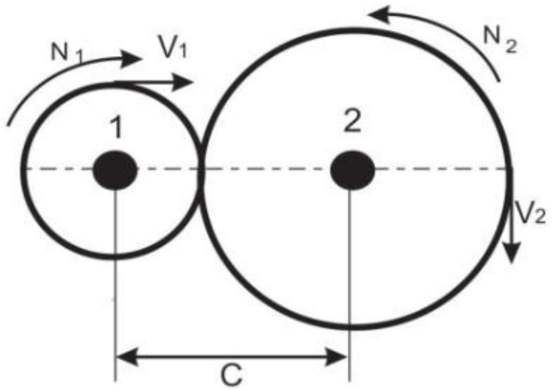
I. MACHINE ELEMENTS

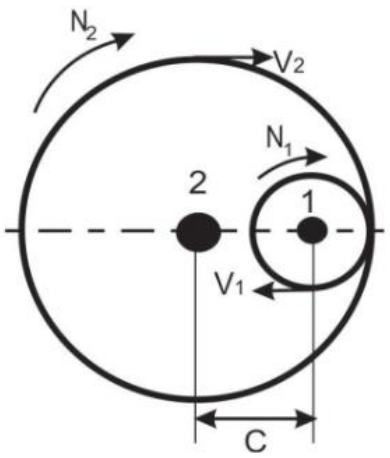
Important Notes:

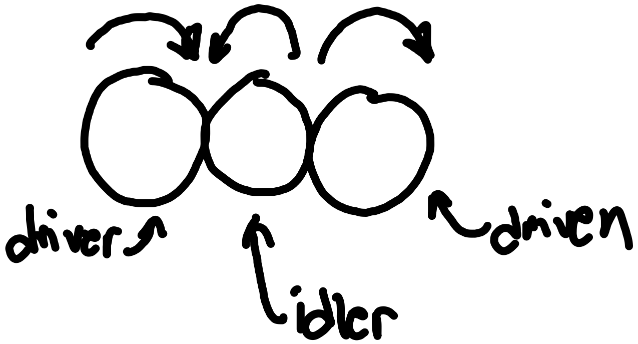
-Odd number of gears and idlers → Same Direction

-Even number of gears and idlers → Opposite Direction

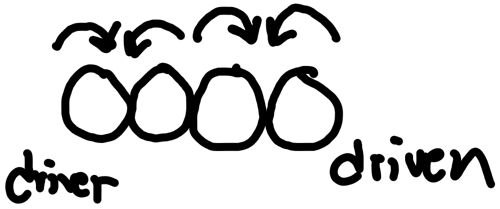
-Number of idlers has no bearing in the speed of the driven cylinder, assuming no friction loss.







2 cylinder + 1 idler = 3 total



2 cylinder + 2 idlers = 4 total

SAMPLE PROBLEMS

MACHINE ELEMENTS

1. Two parallel shafts connected by pure rolling turn in the same direction and having a speed ratio of 2.75. What is the distance of the two shaft if the smaller cylinder is 22 cm in diameter?

   A. 16.60 cm B. 30.25 cm C. 25.25 cm D. 19.25 cm

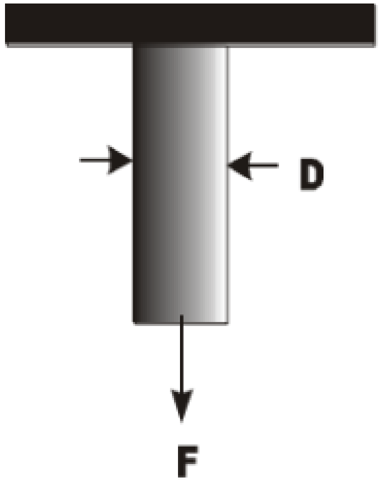
2. Three cylinder A:B:C has a speed ratio of 3:2:4 are externally in contact to each other. If center distance between cylinder A and C is 13in, fin the diameter of cylinder B.

   A. 15.34in B. 18.95in C. 12.34in D. 9.37in

   30 in

II. STRESSES

1. Stress (S) = a total resistance that a material offers to an applied load, $lb/in^2, kg/cm^2, KN/m^2$
2. Ultimate Stress (S_u) = is the stress that would cause failure
3. Yield Stress = (S_y) = is maximum stress without causing deformation
4. Allowable Stress (S_{allow}) = Ultimate stress/Factor of Safety
5. Design Stress (S_d) = stress used in determining the size of a member.

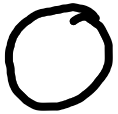


$$S_d = \frac{S_u}{F.S.} \qquad \text{or} \qquad S_d = \frac{S_y}{F.S.}$$

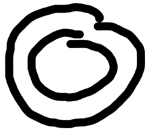
where: F.S. = Factor of Safety

6. Tensile Stress (S_t) = $S_t = \frac{F_t}{A}$

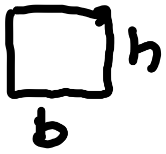
For solid circular cross section: $A = \frac{\pi}{4}D^2$



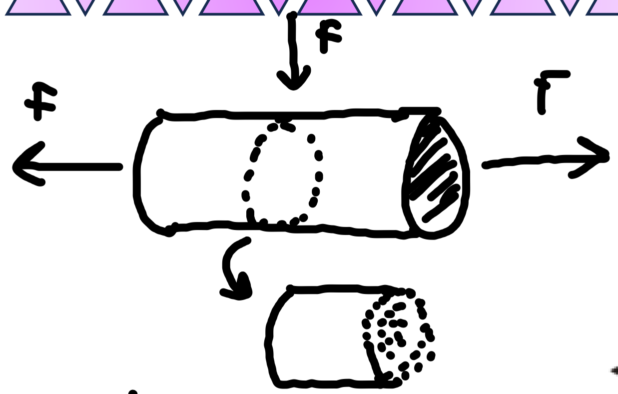
For hollow circular cross section: $A = \frac{\pi}{4}(D^2 - d^2)$



For rectangular cross section: $A = base\ x\ height = b\ x\ h$

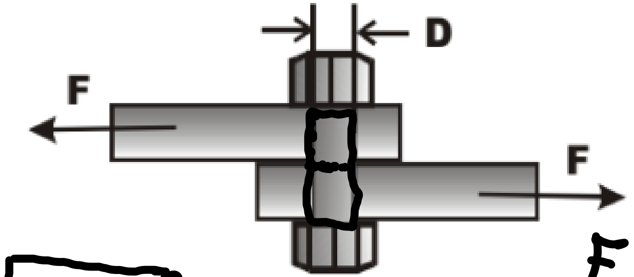


II. STRESSES



7. Compressive Stress (S_c) = $S_c = \frac{F_c}{A}$

8. Shearing Stress (S_s)

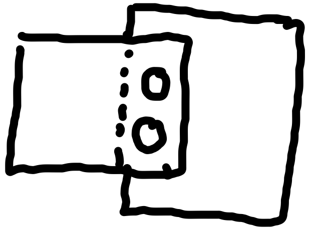


two

A. For single bolt of rivet needed to join to plates together.

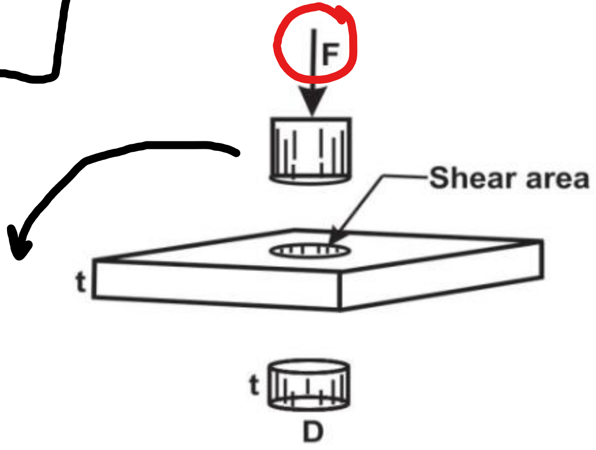
$S_s = \frac{F}{A}$ where: single rivet: A = $\frac{\pi}{4}D^2$

double rivet: A = 2($\frac{\pi}{4}D^2$)



$$S_s = \frac{F}{2A} ; \frac{F}{3A}$$

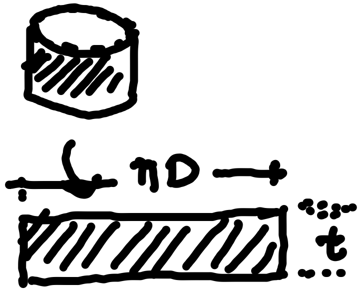
B. Shearing due to punching of hole.



$S = \frac{F}{A}$ where: A = πDt (for punching a hole) t = plate thickness

A = 4St (for square hole) S = length of side of square

C. Pressure needed to punch a hole,

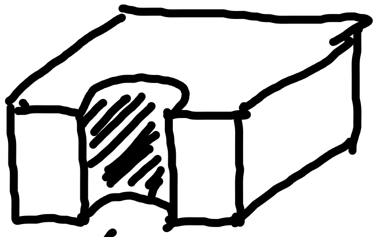


F = d x t x 80 (tons)

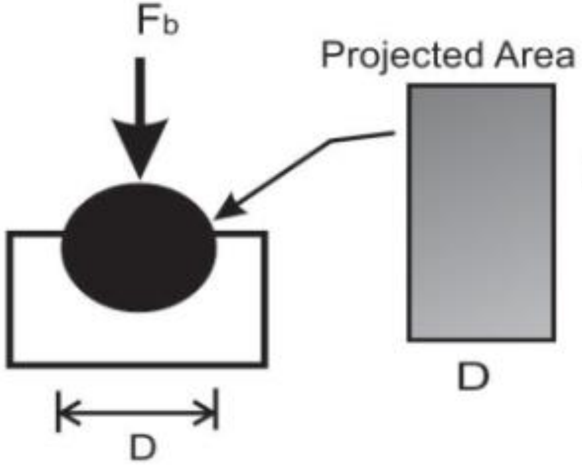
where: d = diameter (in) t = thickness (in)

II. STRESSES

9. Bearing Stress (S_b) = $S_b = \frac{F_b}{A}$ where: A = DL



A = DL



10. Factor of Safety (FS)

A. Based on yield strength FS = S_y/Sall

B. Based on ultimate strength FS = S_u/Sall

$S_d = \frac{S_U}{FS} = \frac{S_y}{FS}$

11. Torsional Shear Stress (S_s) $S_s = \frac{Tc}{J} = \frac{16T}{\pi D^3}$

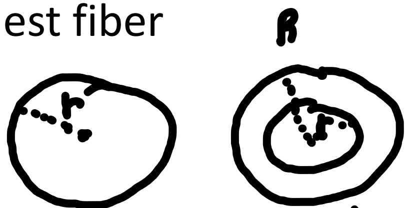
where: J = polar moment of inertia = $\pi D^4/32$ (for solid shaft)

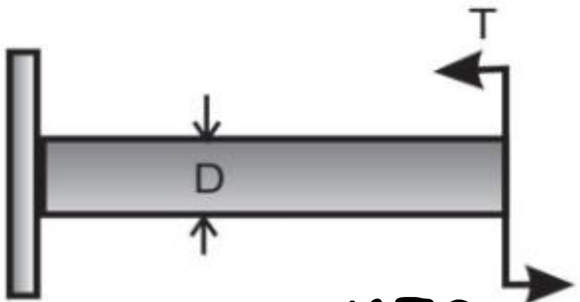
T = Torque

c = distance from neutral axis to the farthest fiber

c = r (for circular cross section) = D/2

D = diameter

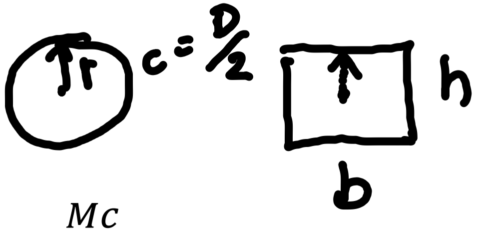




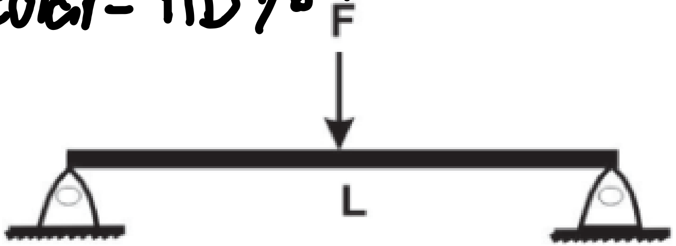
hollow

$$S_s = \frac{Tc}{J} \to \frac{T\frac{\cancel{D}}{2}}{\frac{\pi D^{\cancel{4}3}}{32}} = \frac{16T}{\pi D^3} \; ; \; \frac{Tc}{J} = \frac{T\,D/2}{\frac{\pi(D^4-d^4)}{32}} = \frac{16TD}{\pi(D^4-d^4)}$$

II. STRESSES



I :
triangular = $bh^3/36$
rectangular = $bh^3/12$
circular = $\pi D^4/64$



12. Bending Stress (Sf) $S_f = \frac{Mc}{I}$

$S_f = \frac{Mc}{I} = \frac{M \cdot h/2}{bh^3/12}$

for rectangular beam: $S_f = \frac{6M}{bh^2}$

for circular $S_f = \frac{32M}{\pi D^3}$

where: M = moment

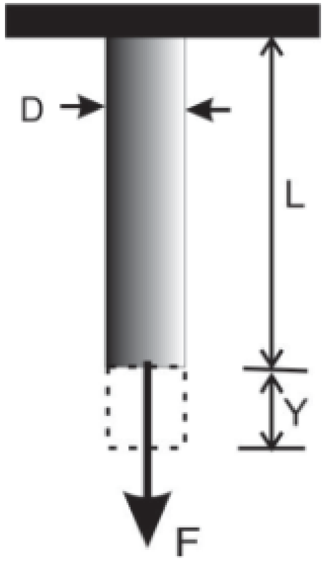
c = distance of farthest fiber from neutral axis

I = moment of inertial about the neutral axis

I = $bh^3/12$ = rectangular

$\frac{\text{Stress}}{\text{Strain}} = \frac{F/A}{Y/L}$; $\frac{FL}{AY} = E$; $\frac{FL}{AE} = Y$

Z = section modulus = $\frac{I}{c} = \frac{M}{S_f}$



13. Strain and Elongation Strain = $\frac{Y}{L}$ Stress = $\frac{F}{A}$ E = $\frac{Stress}{Strain} = \frac{FL}{AY}$ Y = $\frac{FL}{AE}$

where: y = elongation due to applied load L = original length

F = force A = area S = Stress

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SAMPLE PROBLEMS

STRESSES

1. A steel tie rod on bridge must be made to withstand a pull of 600 lbs, find the diameter of the rod assuming a factor of safety of 5 and ultimate stress o 64,000 psi.
   A. 0.705 B. 0.891 C. 0.809 D. 0.773

62

½ inch

2. How many 5/16 inch holes can be punch in one motion in a steel plate made of SAE thick using a force of 55 tons. The ultimate strength for shear is 50 ksi and use 2 factor of safety.
   A. 5.8 B. 3.7 C. 5 D. 6.5

3. The shaft whose torque varies from 2000 to 6000 in lbs has 1 ½ in. in diameter and 60000 psi yield strength. Compute for the shaft mean average stress.
   A. 6036 psi B. 6810 psi C. 5162 psi D. 5550 psi

4. A hollow shaft carries a torque 3.4 KN-m at a shearing stress of 55 Mpa. The outside diameter is 1.25 times that of the inside diameter. Find the inside diameter in mm.
   A. 64.87 B. 46.87 C. 84.67 D. 74.64

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II. STRESSES

$$S = \frac{Ey}{L} \; ; \; y = kL(t_2 - t_1)$$

$$= \frac{E\left[k\cancel{L}(t_2 - t_1)\right]}{\cancel{L}} = kE(t_2 - t_1)$$

14. Thermal Elongation; Stresses

$y = k\,L\,(t_2 - t_1)$ $\qquad$ $S = E\,\frac{y}{L} = k\,E\,(t_2 - t_1)$

where: k = coefficient of thermal expansion, m/m-°C

for steel: k = 6.5 x 10^{-6} in/in-°F = 11.7 x 10^{-6} m/m-°C

E = 30 x 10^6 psi = 207 Gpa

$6.5 \times 10^{-6} \frac{in}{in\text{-}F}$ or $11.7 \times 10^{-6} \frac{mm}{mm\text{-}C}$

G = 12 x 10^6 psi = 83 GPa / 11.5 x 10^6 psi = 80 GPa

Relation between shearing and tensile stress based on theory of failure:

$S_{tmax} = S_{ty}$ $\qquad$ $S_{smax} = S_{ty}/2$

15. Variable Stresses

MYAN → Soderberg

$$\frac{1}{FS} = \frac{S_m}{S_y} + k\frac{S_a}{S_n}$$

MUAN → Goodman's Formula

$$\frac{1}{FS} = \frac{S_m}{S_u} + \frac{S_a}{S_n}$$

Gerber Method

$$\frac{1}{FS} = FS\left(\frac{S_m}{S_u}\right)^2 + \frac{S_a}{S_n}$$

where: FS = Factor of Safety

S_y = yield point

S_n = endurance limit

S_m = mean stress = $\frac{S_{max}+S_{min}}{2}$

S_a = Variable Component Stress = $\frac{S_{max}-S_{min}}{2}$

S_{max} = Maximum Stress

S_{min} = Minimum Stress

II. STRESSES

16. Poisson's Ratio (μ) = is the ratio of lateral unit deformation to axial unit deformation

$$\mu = \frac{E}{2G} - 1$$ where: G = shear modulus of elasticity $\varepsilon = strain = \frac{F}{AE}$; $y = \frac{FL}{AE}$

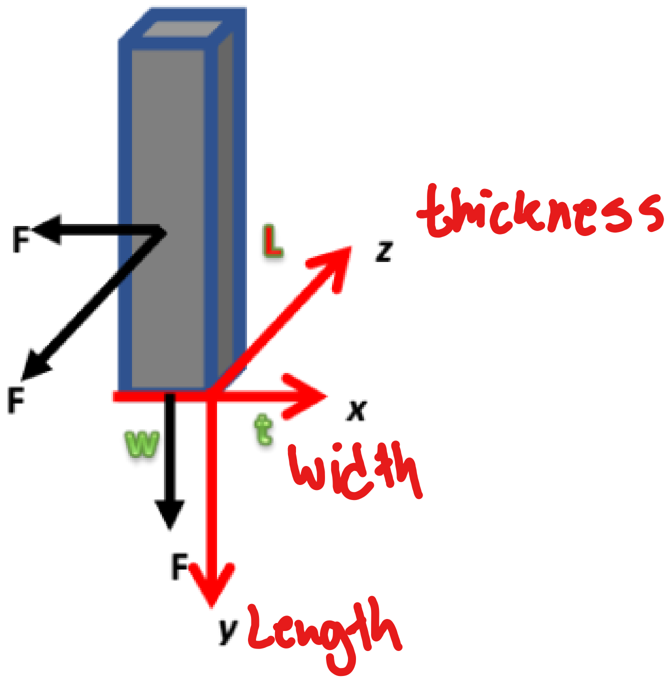
Recall

$$\mu = \frac{\text{Lateral Strain}}{\text{Longitudinal Strain}} = \frac{\varepsilon_y}{\varepsilon_x} = \frac{\varepsilon_z}{\varepsilon_x} \qquad \varepsilon_x = \frac{w_2 - w_1}{w_1} \qquad \varepsilon_y = \frac{L_2 - L_1}{L_1} \qquad \varepsilon_z = \frac{t_2 - t_1}{t_1}$$

$$\frac{y}{L} = \frac{F}{AE}$$

$$\varepsilon = \frac{y}{L}$$

$$\mu = \frac{\varepsilon_y}{\varepsilon_x} = \frac{\frac{\Delta L}{L}}{\frac{\Delta W}{W}}$$



SAMPLE PROBLEMS

STRESS & STRAIN AND POISON RATIO

30000

1. An engine part is being tested with a load of 60000 lb. The allowable tensile stress is 10,000 psi, modulus of elasticity of 40 x 10^6 psi. If the original length of specimen is 42 inches with elongation not exceeding 0.0015 in, what diameter of the specimen is rejected?
   0.015 in
   A. 4.2 in B. 3.0 in C. 2.5 in D. 5.17 in

   20m rail

2. Considered is 20 deg C and a maximum temperature of 30 deg C is designed for, and the modulus of elasticity of steel to be 207,000 MPa, determine the clearance between rails such that adjoining rail will just touch at maximum design temperature.
   A. 2.34 B. 2.32 C. 3.41 D. 1.86

3. A square steel bar 50 mm on a side and 1 m long is subjected to an axial tensile force of 250 KN. Determine the decrease in lateral dimension due to this load. Consider E = 200 Gpa and Poisson's ratio of 0.30.
   A. 0.075 mm B. 0.00015 mm
   C. 0.00075 mm D. 0.0075 mm