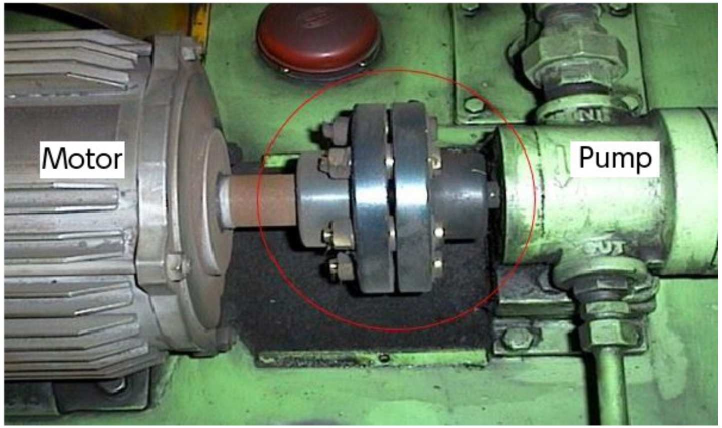
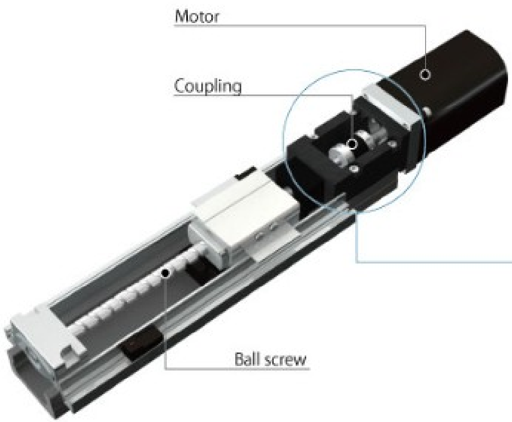
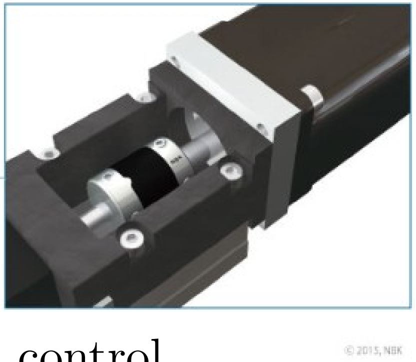
Shaft Couplings

- To connect the driver shafts to the driven shafts
- To adjust for the misalignments of the shafts
- To reduce transmission of shock loads from one shaft to the other
- To provide protection against overloads



Power transmission (strength, high torque)





Accuracy, zero backlash – high torsional stiffness

Motion control

https://www.nbk1560.com/en/resources/coupling/article/powertransmission-about/

Typed of Shaft Couplings

Rigid Couplings

Connects two shafts that are perfectly aligned

Sleeve/Muff coupling

Clamp or compression coupling

Flange coupling

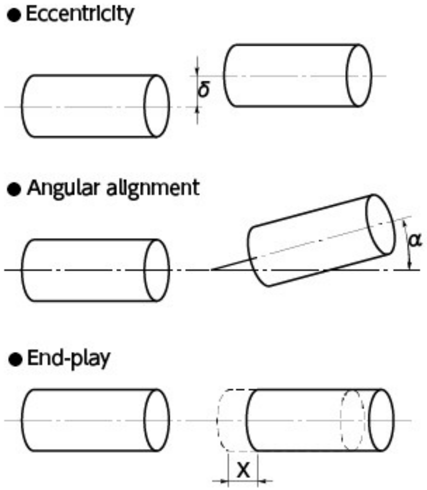
Flexible Couplings

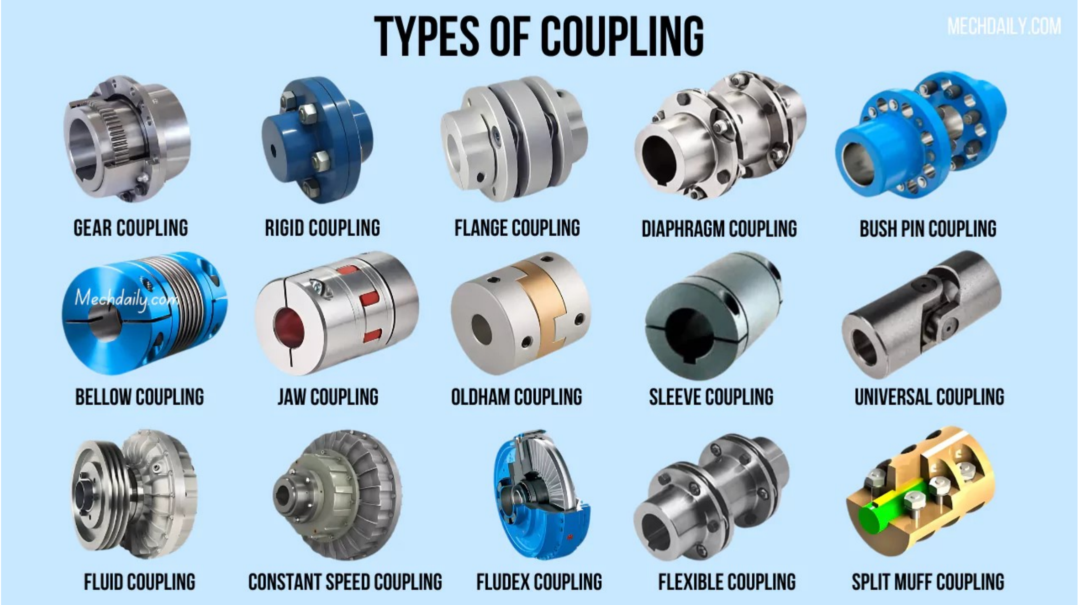
Connects two shafts that have lateral and/or Angular **misalignment**

Bush type pin coupling

Universal coupling

Oldham coupling

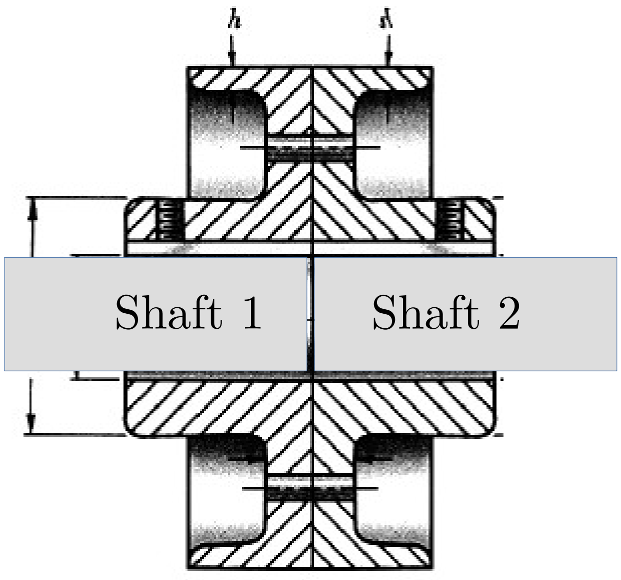


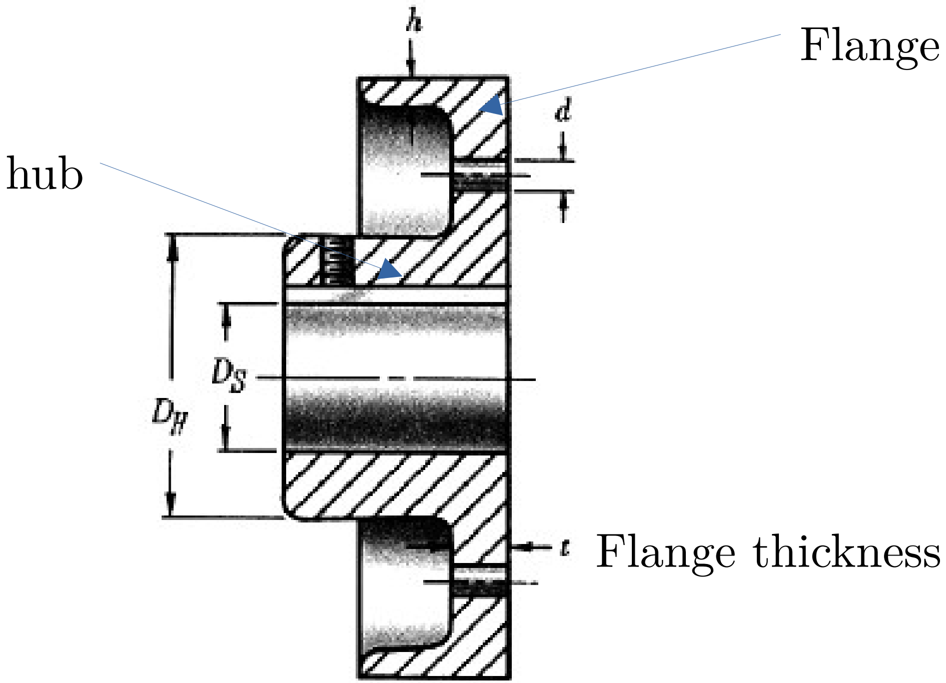


https://www.mechdaily.com/what-is-coupling-and-types-of-coupling/

https://www.nbk1560.com/en/resources/coupling/article/powertransmission-about/

Design of Rigid Coupling - Nomenclature

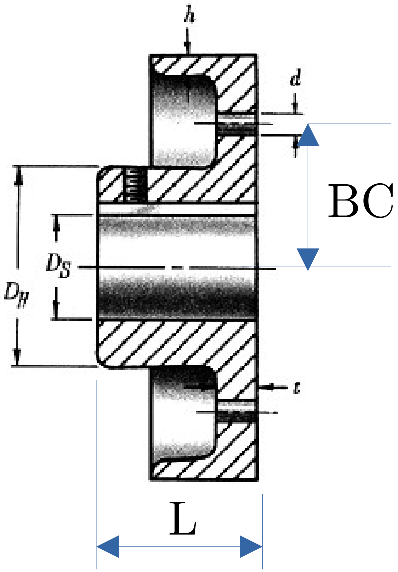




Design of Rigid Coupling

Consider the solid coupling shown in the figure. Assume that there 6 bolts connecting the two flanges and that the load transfer takes place through the bolts. The shaft carries a steady load of 40 kW at 150 rpm. For all the parts, the yield stress In tension is 400 MPa and the yield stress in shear is 200 MPa. Identify the critical locations and find the factor of safety at each of the locations based on the yield stress. Assume DS = 56 mm, DH = 108 mm, t = 7 mm, d = 8 mm. The key dimensions are as follows: W = 16 mm, T = 10 mm, L = 90mm, BC = 152 mm

2



Critical Locations

Key – failure: shear stress, crushing stress

Bolts – failure: shear stress, crushing stress

Flange – failure: shear

Hub – failure: shear

Design of Rigid Coupling

$P := 40\ \mathrm{kW} \quad N := 6 \quad BC := 76\ \mathrm{mm} \quad Wi := 16\ \mathrm{mm} \quad Ds := 56\ \mathrm{mm} \quad d := 8\ \mathrm{mm}$

$w := 150\ \mathrm{rpm} = 15.708\ \frac{\mathrm{rad}}{\mathrm{s}} \quad Th := 10\ \mathrm{mm} \quad Le := 90\ \mathrm{mm} \quad t := 7\ \mathrm{mm} \quad Dh := 108\ \mathrm{mm}$

$yst := 400\ \mathrm{MPa} \quad yss := 200\ \mathrm{MPa}$

$$\boxed{T := \frac{P}{w} = 2546.4791\ \mathrm{N\ m}}$$

Key calculations

$$F := \frac{T}{\left(\frac{Ds}{2}\right)} = 90945.6818\ \mathrm{N}$$

$$Kss := \frac{F}{Wi \cdot Le} = 63.1567\ \mathrm{MPa} \quad \boxed{FOS1 := \frac{yss}{Kss} = 3.1667}$$

$$Kbs := \frac{F}{(Th \cdot 0.5 \cdot Le)} = 202.1015\ \mathrm{MPa} \quad \boxed{FOS2 := \frac{yst}{Kbs} = 1.9792}$$

Bolt Calculations

Force carried by each bolt

$$Fb := \frac{T}{(6 \cdot BC)} = 5584.384\ \mathrm{N}$$

Shear stress in a bolt

$$Bss := \frac{Fb}{\frac{\pi}{4} \cdot d^2} = 111.0978\ \mathrm{MPa} \quad \boxed{FOS3 := \frac{yss}{Bss} = 1.8002}$$

Bearing stress in the bolt

$$Bbs := \frac{Fb}{t \cdot d} = 99.7211\ \mathrm{MPa} \quad \boxed{FOS4 := \frac{yst}{Bbs} = 4.0112}$$

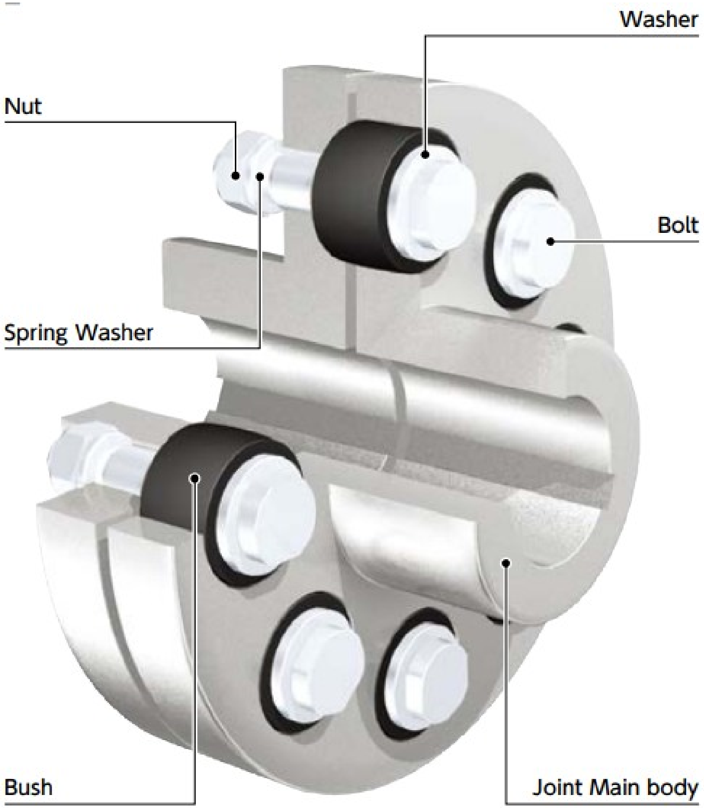
Flange thickness Calculations

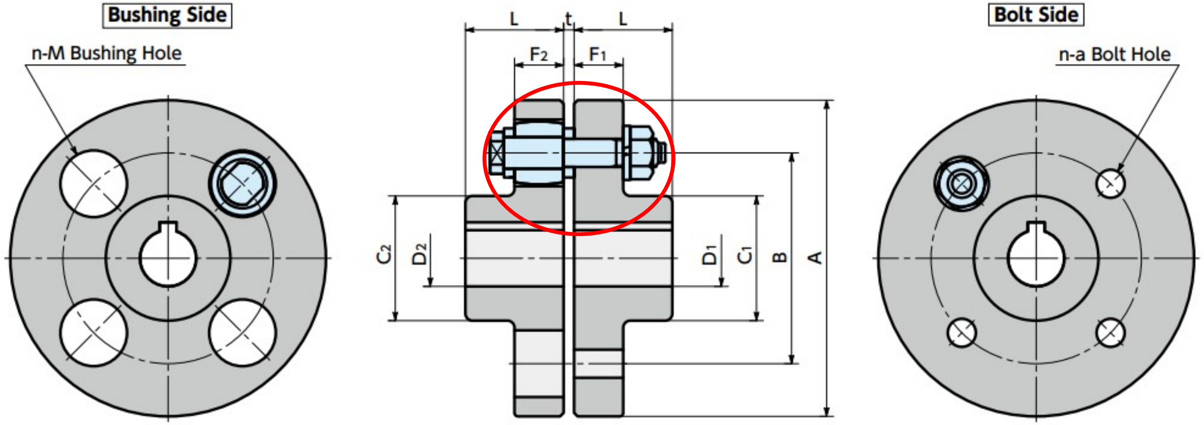
$$Hss := \frac{T}{\pi \cdot 0.5 \cdot Dh^2 \cdot t} = 19.8552\ \mathrm{MPa} \quad \boxed{FOS5 := \frac{yss}{Hss} = 10.0729}$$

Additional calculations:

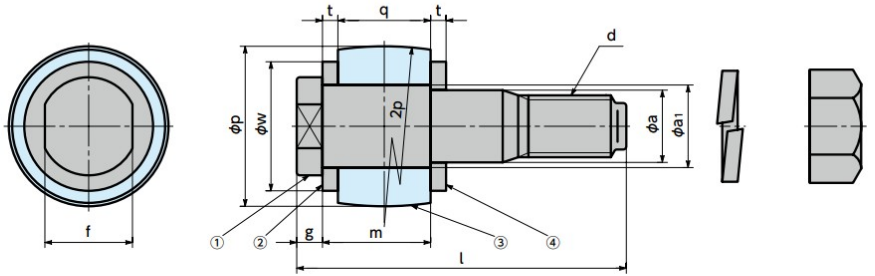
$$(\tau_{max})_{hub} = \frac{TJ(D_H/2)}{G}, \quad J = \frac{\pi}{16}(D_H^4 - D_S^4)$$

Design of Flexible Coupling (Bush-Pin Flexible Coupling)



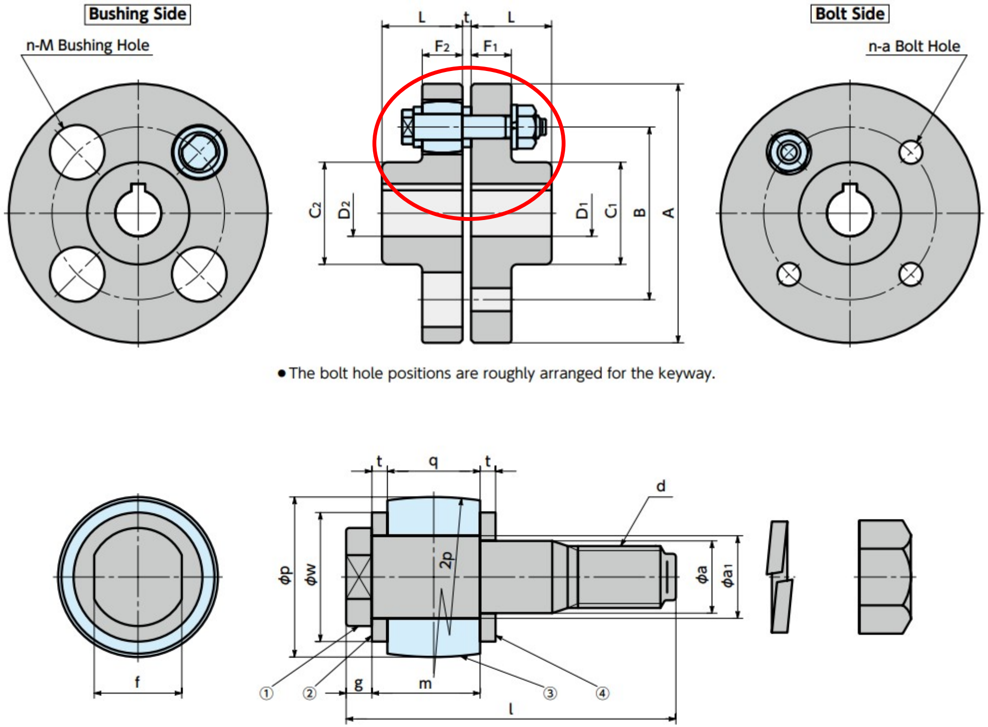


• The bolt hole positions are roughly arranged for the keyway.



https://www.nbk1560.com/en/resources/coupling/article/powertransmission-about/

Design of Flexible Coupling (Bush-Pin Flexible Coupling)



• The bolt hole positions are roughly arranged for the keyway.

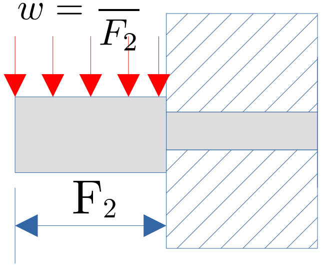
Additional calculations as compared to the rigid coupling:

- Flange thicknesses are not identical $F_1 \neq F_2$ (independent calculations required)
- Bush failure – bearing pressure greater than permissible

$$p_{bush} = \frac{F}{F_2 d_{bush}}$$

- Bolt or Pin failure – check for combined bending and torsion

$$w = \frac{F}{F_2}$$



Cantilever beam with uniformly distributed load

Combined torsion+bending

https://www.nbk1560.com/en/resources/coupling/article/powertransmission-about/

Selection of Coupling

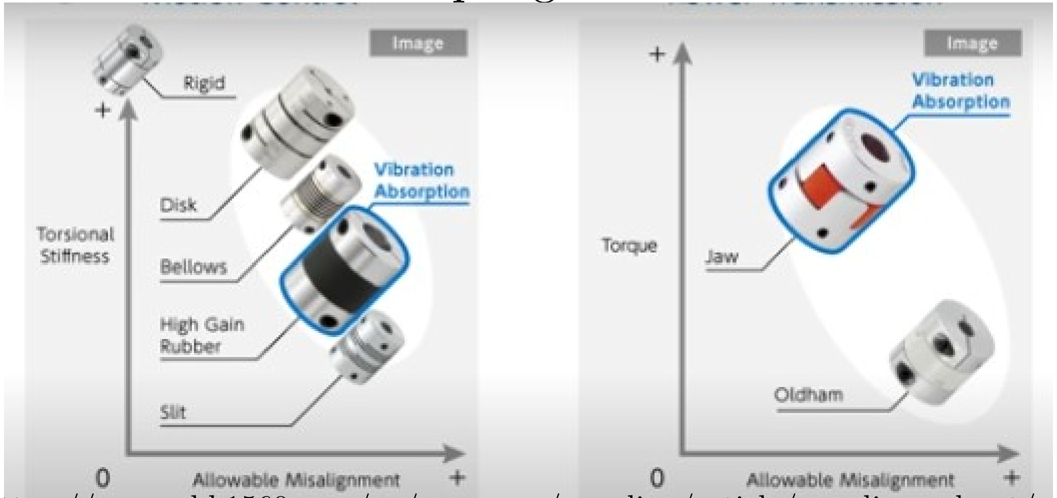
- **Type of coupling** – depends on features such as vibration absorption capacity, torque transmission, torsional stiffness, misalignment, ect

- **Material of the coupling** – depends on the environmental conditions

- **Size of the coupling** – torque transmission requirements, diameter of the shafts to be connected

- **Fastening method** – how to connect the coupling to the shaft

Motion control



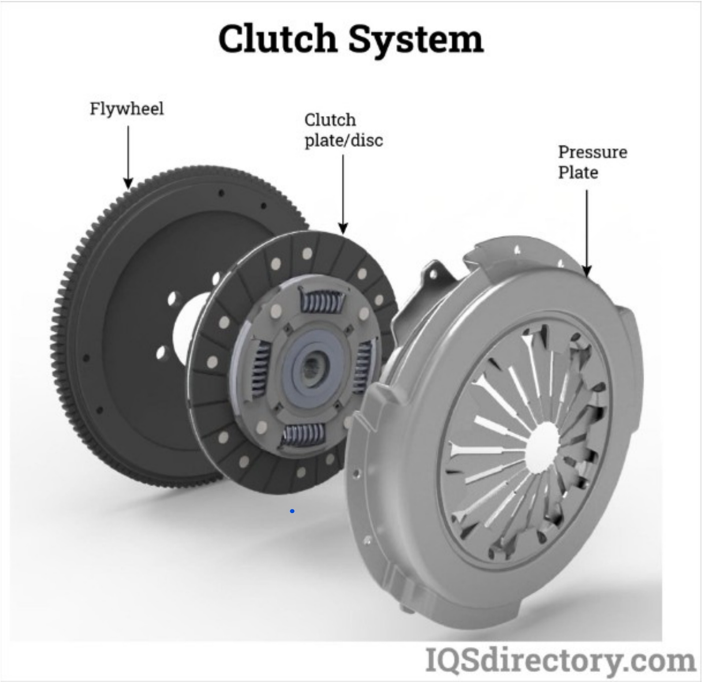
Power transmission

https://www.nbk1560.com/en/resources/coupling/article/couplicon-about/

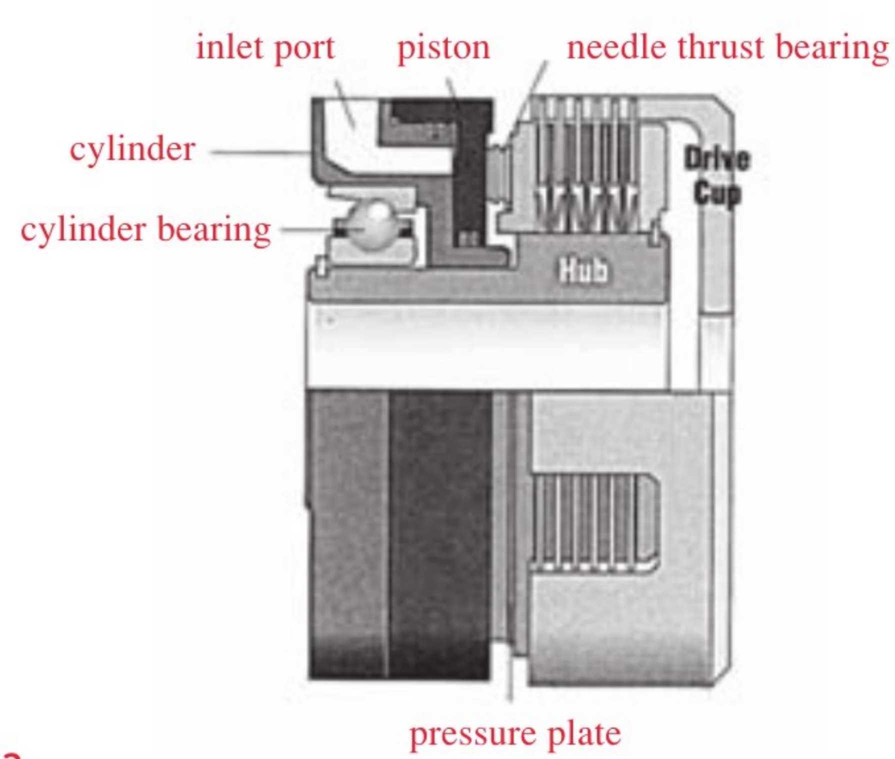
Friction Disk Clutches

Couplings provide a permanent connection while clutches provide a temporary connection between the shafts

https://www.youtube.com/watch?v=devo3kdSPQY



https://frictionmaterials.com/clutch-disc/



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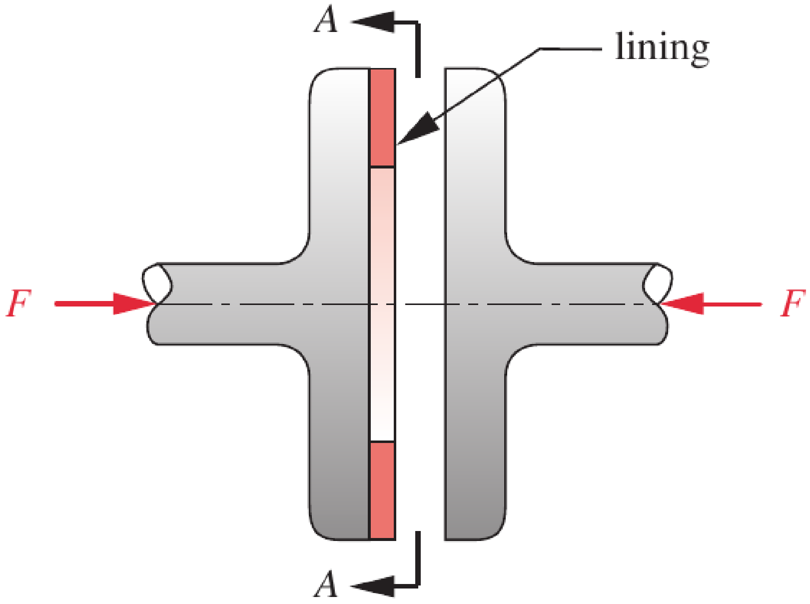
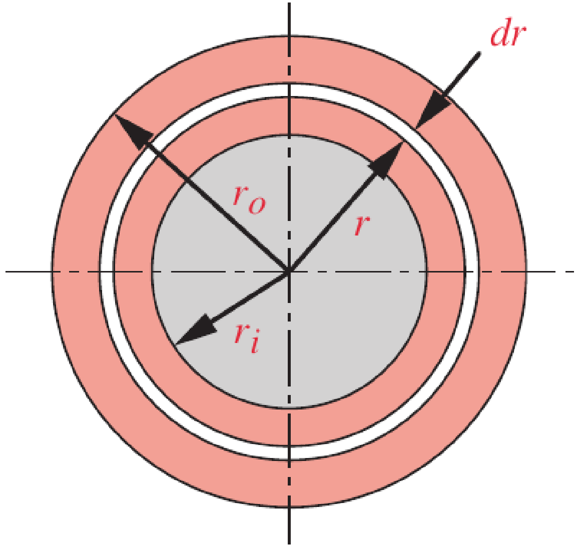
Friction Disk Clutches





Section A-A

Disk clutch consists of two disks, one lined with a high-friction material, pressed together axially with a normal force to generate the friction force needed to transmit torque.

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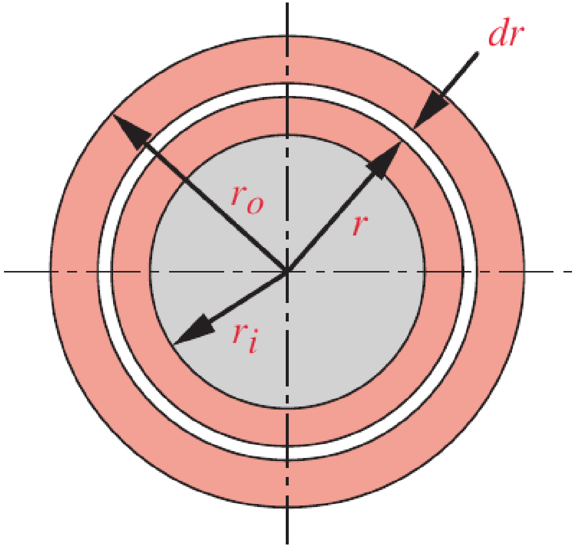
Design of Friction Disk Clutches

Uniform Pressure $\boldsymbol{p_o}$. It is assumed that a constant pressure p_o acts between the disk



The normal force acting of a ring of thickness dr at a distance at r is

$$dN = 2\pi p_o r dr$$

Friction force acting of a ring of thickness dr at a distance at r is

$$dF_r = \mu_f dN = 2\pi p_o \mu_f r dr \qquad \mu_f \text{ is the coefficient of friction}$$

Torque transmitted through a ring of thickness dr at a distance at r is

$$dT = r dF_r = 2\pi p_o \mu_f r^2 dr$$

Total torque transmitted though a disk with inner radius $r_i$and outer radius r_0

$$T = \int_{r_i}^{r_o} dT = \frac{2}{3}\pi p_o \mu_f (r_o^3 - r_i^3)$$

Axial force acting on the disk

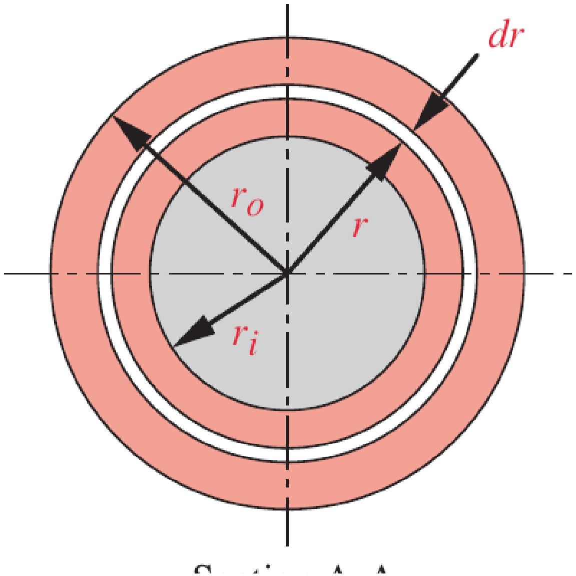
$$N = \int_{R_i}^{R_o} dN = \pi p_o (r_0^2 - r_i^2)$$

The torque expressed in terms of of the axial force is given by

$$T = \frac{2}{3}\mu_f \frac{(r_o^2 + r_o r_i + r_i^2)}{r_i + r_o} N$$

Design of Friction Disk Clutches

Constant wear rate *W*. It is assumed that the wear rate is constant over the contacting surfaces. The wear rate W at a point is direction proportional to the pressure and the velocity at that point $W = kpV = kpr\omega$ If the disk is rotating at a constant angular velocity, then $pr = C$, a constant The pressure can be expressed in terms of the maximum pressure as: $p = p_{max}\frac{r_i}{r}$



The normal force acting of a ring of thickness dr at a distance at r is

$$dN = 2\pi p r dr = 2\pi C dr = 2\pi p_{max} r_i dr$$

Friction force acting of a ring of thickness dr at a distance at r is

$$dF_r = \mu_f dN = 2\pi \mu_f p_{max} r_i dr$$

Torque transmitted through a ring of thickness dr at a distance at r is

$$dT = r dF_r = 2\pi \mu_f p_{max} r_i r dr$$

Total torque transmitted though a disk with inner radius $r_i$and outer radius r_0

$$T = \int_{r_i}^{r_o} dT = \pi p_{max} \mu_f r_i (r_o^2 - r_i^2)$$

Axial force acting on the disk

$$N = \int_{R_i}^{R_o} dN = 2\pi p_{max} r_i (r_0 - r_i)$$

The torque expressed in terms of of the axial force is given by

$$T = \frac{1}{2}\mu_f (r_o + r_i) N$$

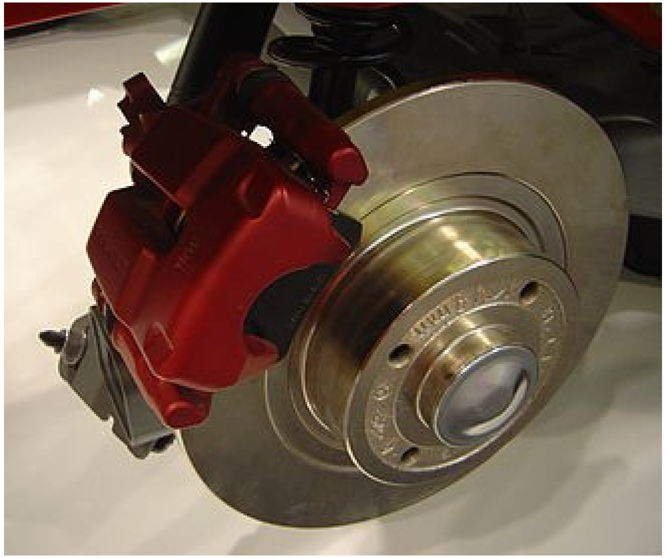
Design of Friction Disk Clutches

- The uniform-wear assumption gives a lower torque capacity for the clutch than does the uniform-pressure assumption.

- Clutches are usually designed based on uniform wear.

- A clutch may be close to a uniform-pressure condition when new, but will tend toward a uniform-wear condition with use. As a result, they will have a greater capacity when new but will end up close to the predicted design capacity after they are worn in.

Disk Brakes



https://en.wikipedia.org/wiki/Disc_brake

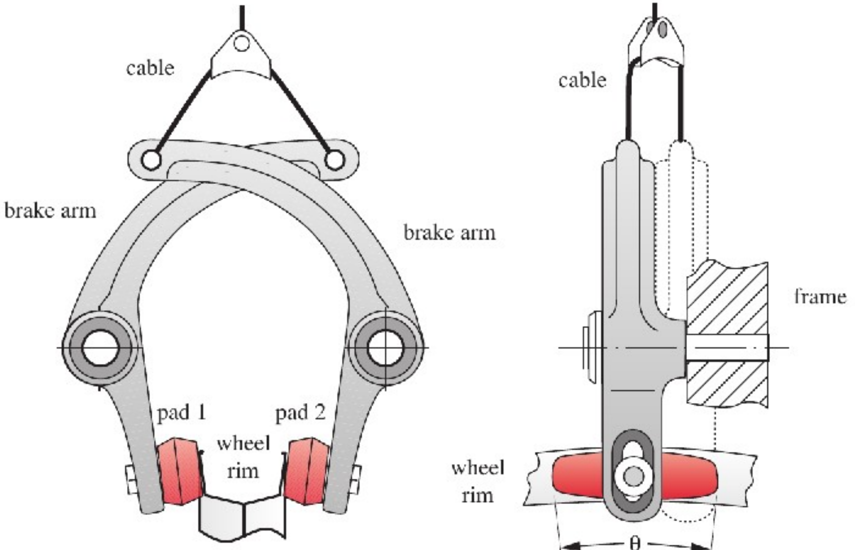


FIGURE 17-8

- The disk clutch equations also apply to disk brakes.
- Disk brakes are rarely made with linings covering the entire circumference of the face, because they would then overheat. Need to use the appropriate value of θ for the included angle of the brake pads in equation.
- In addition, there will be at least **two** braking surfaces

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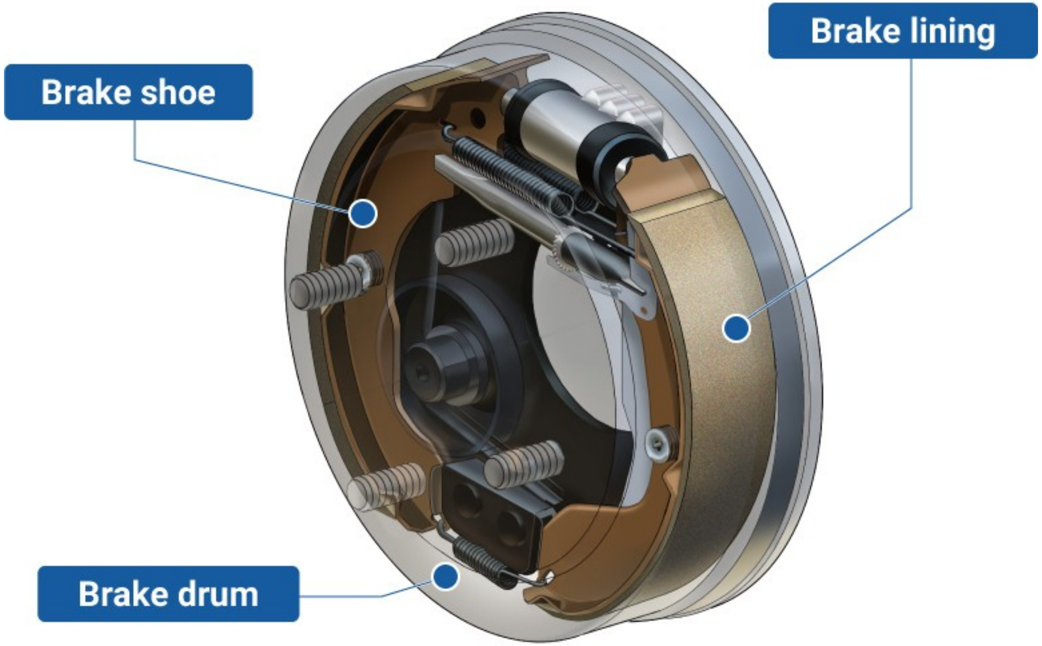
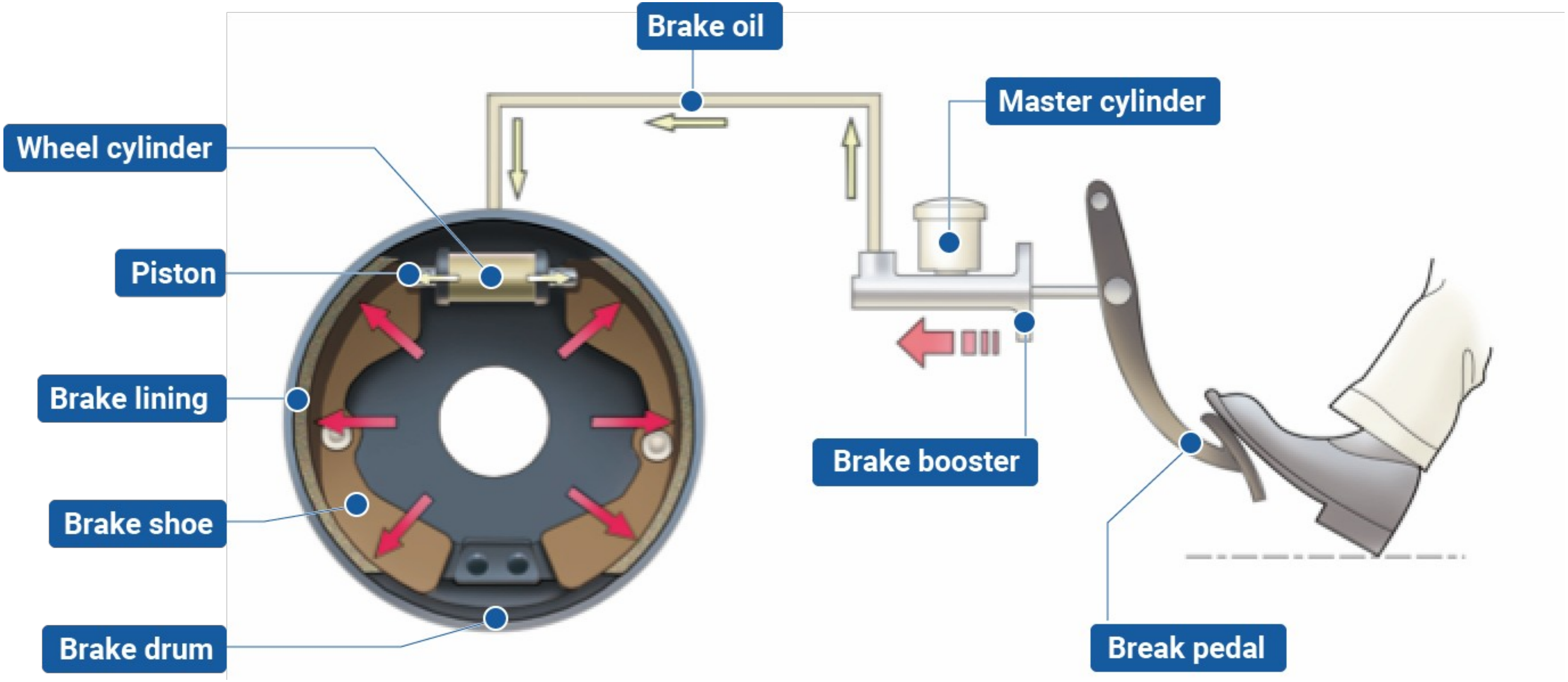
Design of Drum Brakes



- Drum brakes apply the friction force to the circumference of a cylinder, either externally, internally, or both.
- The part to which the friction material is riveted or bonded with adhesive is called the brake shoe
- The part against which the brake shoe rubs is called the brake drum.
  The shoe is forced against the drum to create the friction torque.

https://www.akebono-brake.com/english/product_technology/product/automotive/drum/

Braking System in a Car with Drum Brake

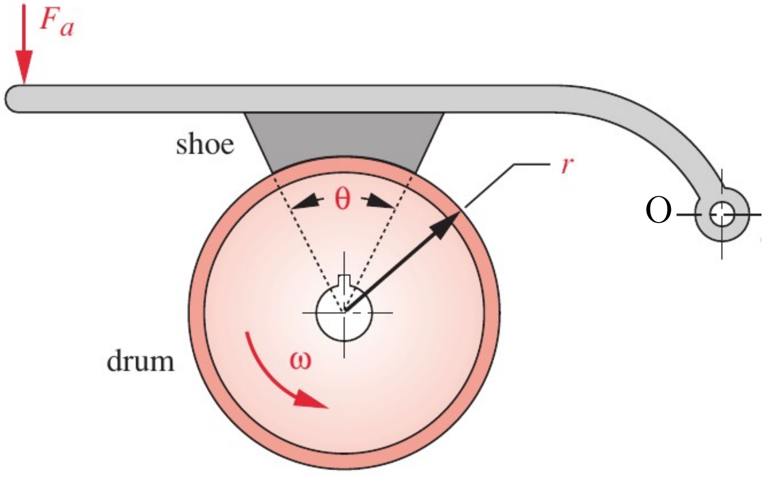


https://www.akebono-brake.com/english/product_technology/product/automotive/drum/

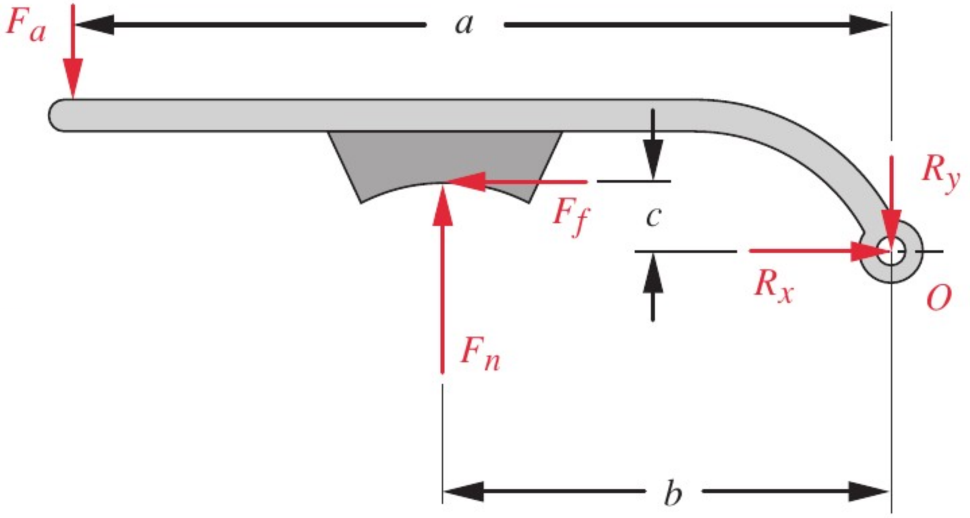
External Drum Brake and Band Brake

https://www.dellnerbubenzer.com/product-types/drum-band-brakes

Short Shoe External Drum Brake



(a) Brake assembly



Free body diagram

Because the angle is small, we assume that the contact area is symmetric as shown and that the pressure is uniform over the contact area

Then $F_n = p_o r\theta w \quad F_f = \mu_f F_n$

Taking moment about point

$$\sum M_o = 0$$

$$aF_a + cF_f - bF_n = 0$$

$$aF_a + c\mu_f F_n - bF_n = 0$$

$$F_a = F_n \frac{b - c\mu_f}{a}$$

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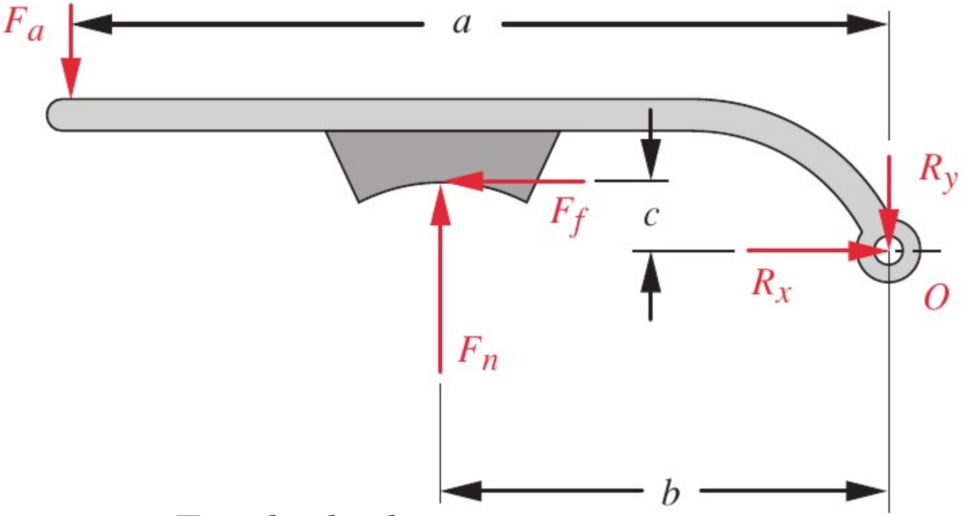
Short Shoe External Drum Brake



Free body diagram

Because the angle is small, we assume that the contact area is symmetric as shown and that the pressure is uniform over the contact area

Then $F_n = p_o r \theta w \quad F_f = \mu_f F_n$

Taking moment about point

$$\sum M_o = 0$$

$$aF_a + cF_f - bF_n = 0$$

$$aF_a + c\mu_f F_n - bF_n = 0$$

$$\boxed{F_a = F_n \frac{b - c\mu_f}{a}}$$

Self energizing brake

- Moment due to the frictional force acts in the same direction as that due to the applied force
- Less applied force is required to stop the rotating part

De-energizing brake

- Moment due to the frictional force acts in the opposite direction as that due to the applied force

Self locking brake

- For a self energizing brake if $b \leq c\mu_f$ then F_a needed to actuate the brake becomes zero or negative
- If the shoe touches the drum, it will grab it and lock. This is most undesirable.

END