MIET2510

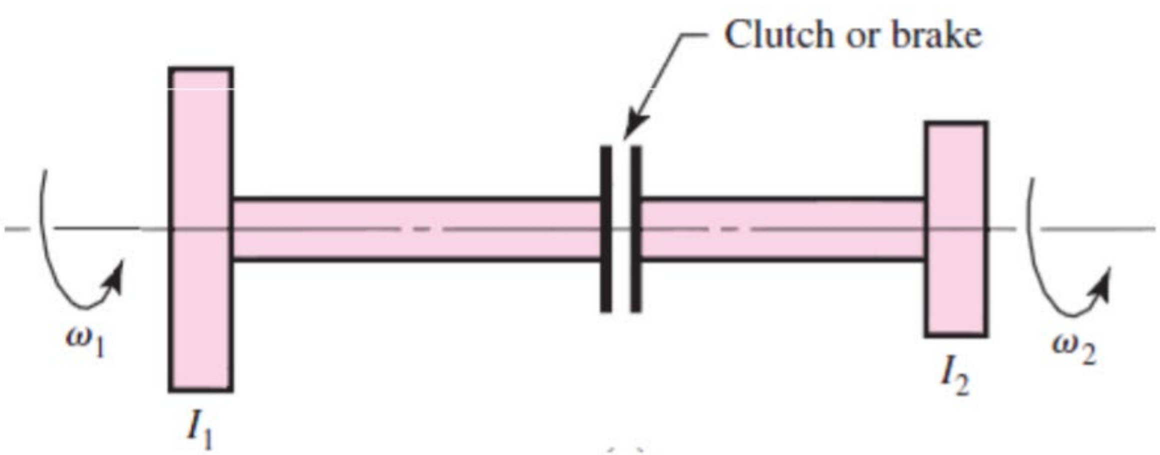
Mechanical Design

Week 10 – Clutches and Brakes

School of Science and Technology, RMIT Vietnam

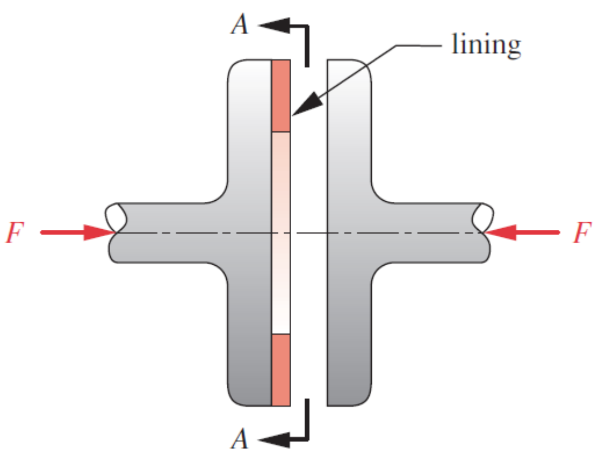
Introduction

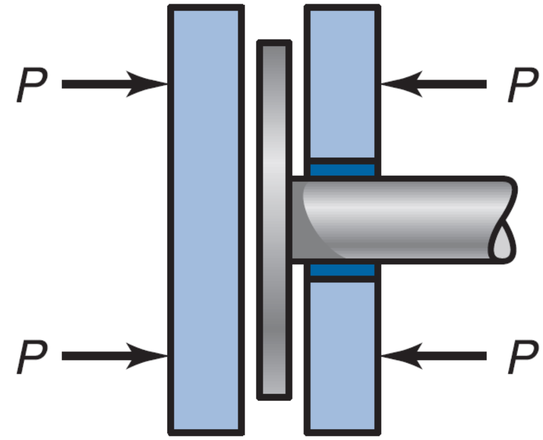
Clutches and brakes are used extensively in all kinds of machinery. Vehicles all need brakes to slow down or stop their motion, as do many stationary machines. Clutches are needed to interrupt the flow of power from a prime mover (engine, etc.) to the load.



Introduction

A clutch and a brake are essentially the same device, the principal difference being that both sides of a clutch (input and output) are capable of rotation, but the output side of a brake is fixed to some nonrotating "ground plane," which itself may have some other motion, as in the case of an automobile chassis.

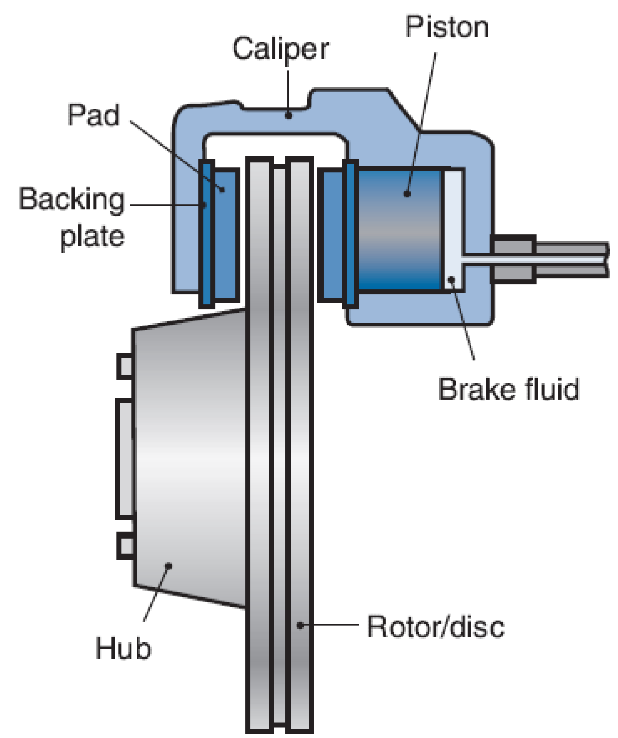




Types of Clutches and Brakes

Many different styles of clutches/brakes are made, but the most common style uses frictional contact between two or more surfaces to couple the input and output sides together. Clutches and Brakes are examples of machines that use friction in a useful way.

The friction surfaces can be moved into and out of engagement by any of several means including direct mechanical, electromagnetic, pneumatic, hydraulic, or combinations of these.



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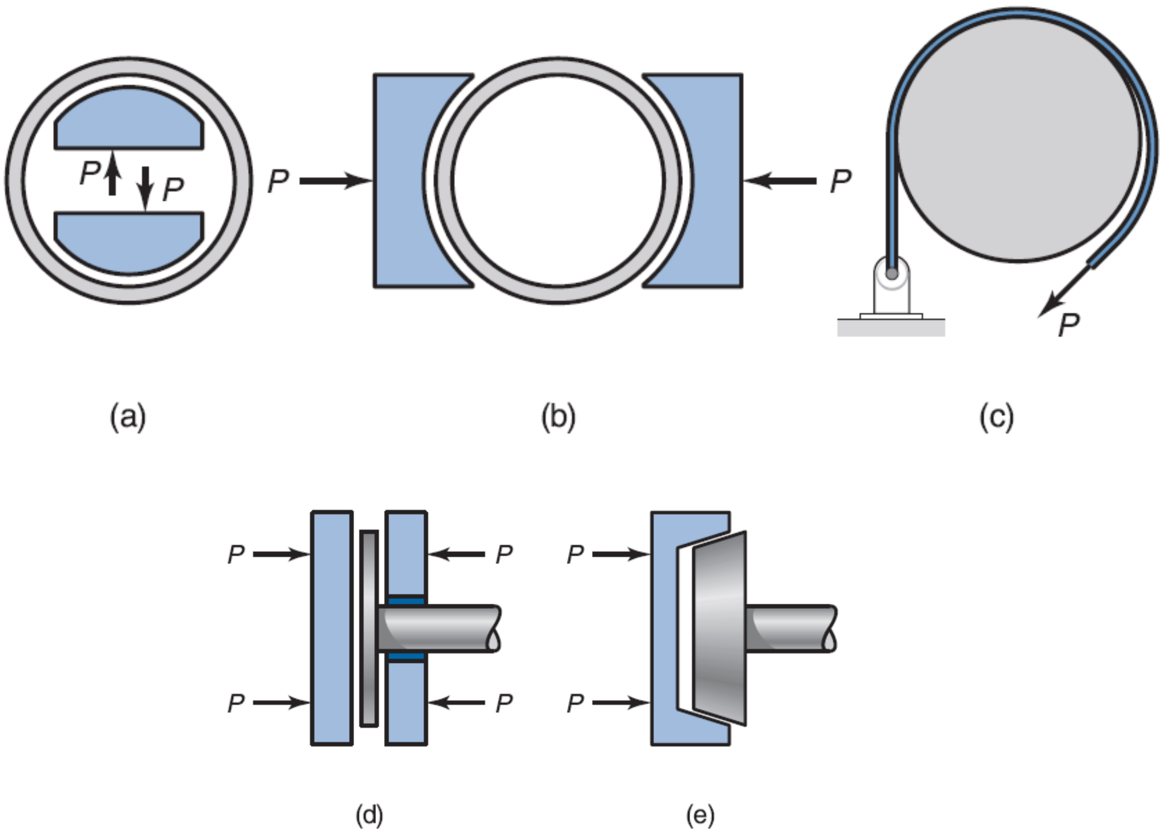
Types of Clutches and Brakes

There are five different types of clutch and brake: a) Internal, expanding rim type, b) external contracting rim type, c) band brake, d) thrust disk, e) cone disk.



Clutches and Brakes

- Working principles and some examples

How Clutches Work

How Brakes Work

Clutch and Brake Design

Except for high-volume, specialized applications such as vehicle design, **a machine designer seldom designs a clutch or brake from scratch**. For the typical machine-design application, one usually selects a commercially available clutch or brake assembly from the many manufacturers' offerings.

The design problem then becomes one of properly defining the torque, speed, and power requirements and the character of the load. The inertia of the rotating elements to be accelerated by a clutch or decelerated by a brake can have a significant effect on the required size of that device and must be carefully calculated.

Clutch and Brake Design

The clutch/brake manufacturers' catalogs contain extensive engineering data that rate each device on its torque and power capacity and also suggest empirical derating factors for situations with shock loads, high duty cycles, etc. Once the loading is well defined, a suitable device can be specified using the manufacturers' rating data modified by their suggested service factors.

The designer's task then becomes that of proper load definition for the application, followed by proper use of the manufacturers' rating data.

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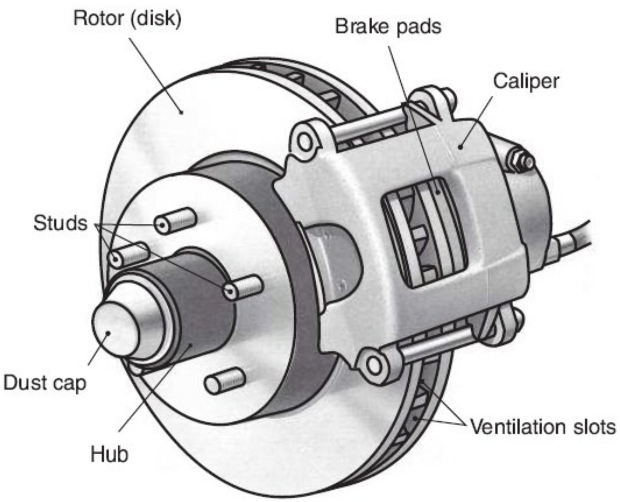
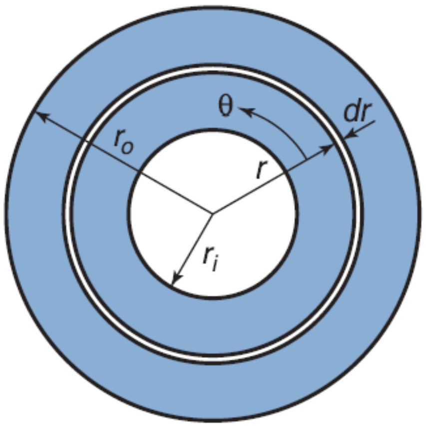
Clutch and Brake Design

Clutches and brakes are essentially energy-transfer or energy-dissipation devices and as such generate a great deal of heat in operation. They must be designed to absorb and transfer this heat without damage to themselves or their surroundings.

The thermal design of clutches and brakes goes beyond the scope of our discussion but **we need to be aware of the heat transfer aspect of clutch/brake design and take it into account based on manufacturer's guidelines.**



Disk Clutches and Brakes

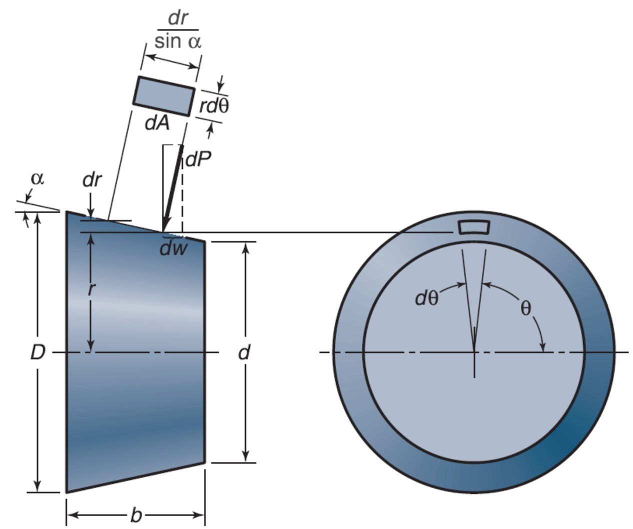


Torque and Normal Actuating Force are computed as:

Uniform Pressure Model: $P_p = \pi p_o \left(r_o^2 - r_i^2\right)$ $\quad T_p = \frac{2\pi\mu p_o}{3}\left(r_o^3 - r_i^3\right) = \frac{2\mu P_p \left(r_o^3 - r_i^3\right)}{3\left(r_o^2 - r_i^2\right)}$

Uniform Wear Model: $P_w = 2\pi p_{\max} r_i \left(r_o - r_i\right)$ $\quad T_w = \pi\mu r_i p_{\max} \left(r_o^2 - r_i^2\right)$

Cone Clutches and Brakes

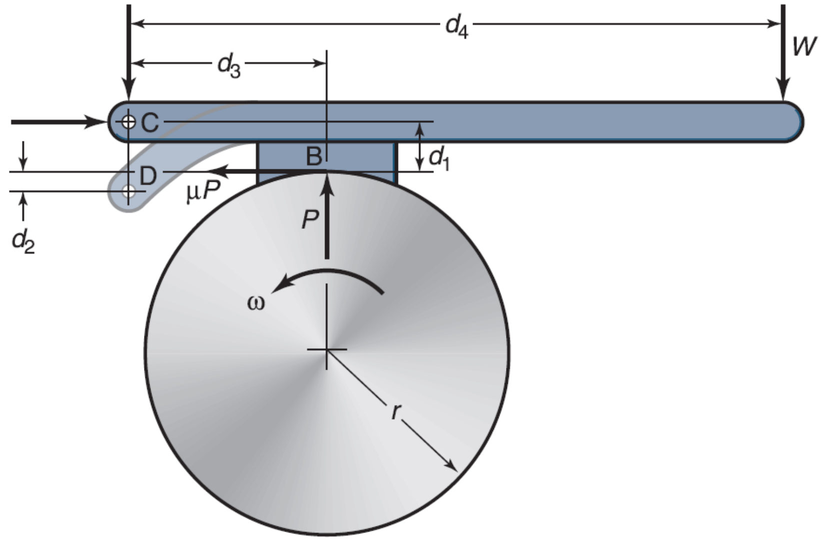


Torque and Normal Actuating Force are computed as:

Uniform Pressure Model: $W = \frac{\pi p_o}{4}\left(D^2 - d^2\right)$ $\quad T = \frac{\mu W \left(D^3 - d^3\right)}{3 \sin\alpha \left(D^2 - d^2\right)}$

Uniform Wear Model: $W = 2\pi c \int_{d/2}^{D/2} dr = \pi c\,(D - d)$ $\quad T = \frac{\mu W}{4 \sin\alpha}(D + d)$

Short-Shoe Clutches and Brakes

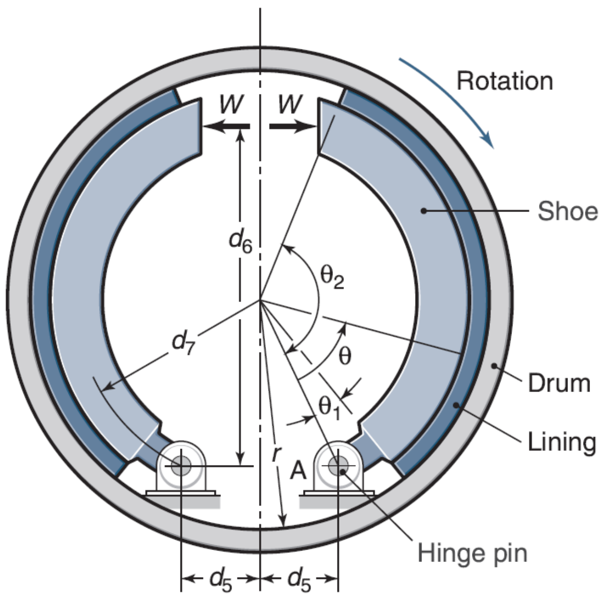


Normal Force: $P = \dfrac{d_4 W}{d_3 - \mu d_1}$

Torque (Energizing): $T = \dfrac{\mu d_4 r W}{d_3 - \mu d_1}$

Torque (Deenergizing): $T = \dfrac{\mu d_4 r W}{d_3 + \mu d_2}$

Long-Shoe (Internal, Expanding) Clutches and Brakes



Pressure Distribution: $$p = p_{\max}\left(\frac{\sin\theta}{\sin\theta_a}\right)$$

Normal Force Moment:

$$\begin{aligned} M_P &= \int d_7 \sin\theta \, dP = \frac{d_7 b r p_{\max}}{\sin\theta_a}\int_{\theta_1}^{\theta_2}\sin^2\theta \, d\theta \\ &= \frac{b r d_7 p_{\max}}{4\sin\theta_1}\left[2\left(\theta_2-\theta_1\right)\frac{\pi}{180^\circ} - \sin 2\theta_2 + \sin 2\theta_1\right] \end{aligned}$$

Friction Force Moment:

$$M_F = -\frac{\mu p_{\max} b r}{\sin\theta_a}\left[r\left(\cos\theta_2 + \cos\theta_1\right) - \frac{d_7}{2}\left(\sin^2\theta_2 - \sin^2\theta_1\right)\right]$$

Self-Energizing shoe: $$-W d_6 - M_F + M_P = 0$$

Deenergizing shoe: $$-W d_6 + M_F + M_P = 0$$

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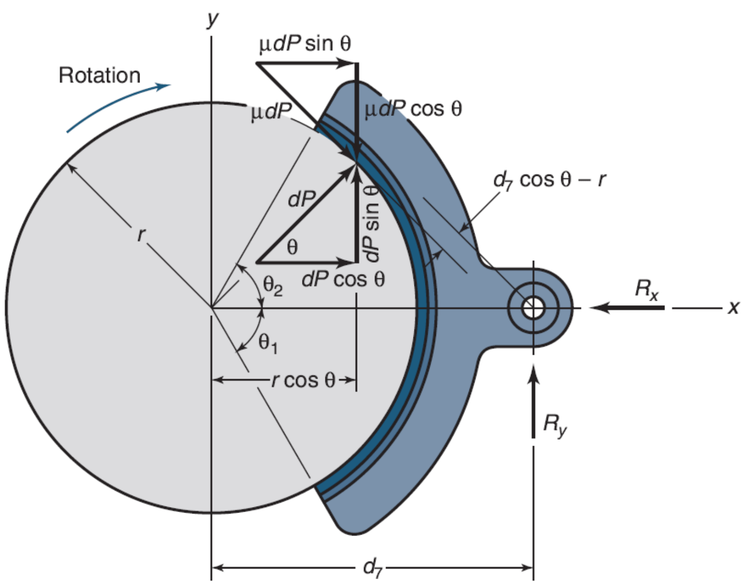
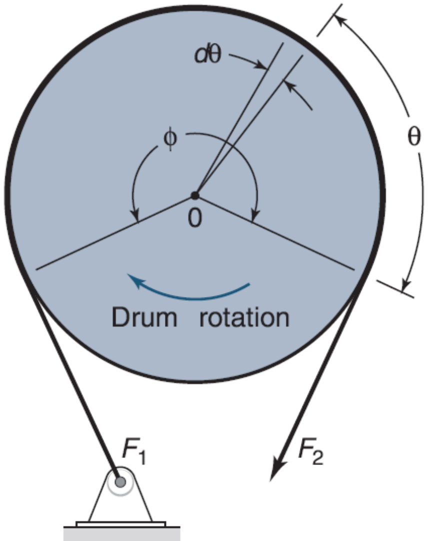
Pivot-Shoe Clutches and Brakes



Pressure Distribution: $p = p_{\max} \cos\theta$

Torques: $T = 2\mu r^2 b p_{\max} \sin\theta_2$

Band Clutches and Brakes



Forces: $$\frac{F_1}{F_2} = e^{\mu\phi\pi/180^\circ}$$

Maximum Pressure: $$p_{\max} = \frac{F_1}{br}$$

Uniform Wear Model: $$T = r(F_1 - F_2)$$

Thank you for your attendance :D

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Reference

- *Mechanical Design of Machine Components (2nd) by Ansel C.Ugural.*
- *Mechanical Engineering Design (10th) by Richard G.Budynas and J. Keith Nisbett.*
- *Theory of Machines and Mechanisms (5th) by John J.Uicker, Gordon R.Pennock, Joseph E. Singley.*

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