Brakes and Clutches

ME 313: Mechanical Design
Week 12

Topics

- Types of brakes and clutches
- Actuation force required
- Torque capacity
- Operating time

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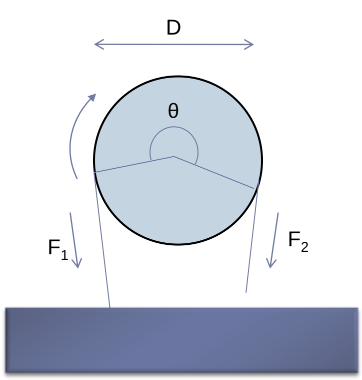
Types of Clutches and Brakes

- Band Brake
- Frictional Contact
- Disk Brake
- Cone Brake

Band Brake: Overview



- Much like belt and pulley, band brake use friction to apply negative torque

Band Brake

- Similar in principles to band and pulley power transmission

$$F_1 = F_2 e^{\mu\theta}$$

- Torque capacity

$$T = (F_1 - F_2)\frac{D}{2}$$

Frictional Contact Axial Clutches and Brakes: Overview

- Axial force translate directly to normal force and friction
- Friction allows transfer of torque

Frictional Contact Axial Clutches and Brakes Calculation

- Assuming uniform pressure

$$F = \frac{\pi p_a}{4}(D^2 - d^2)$$

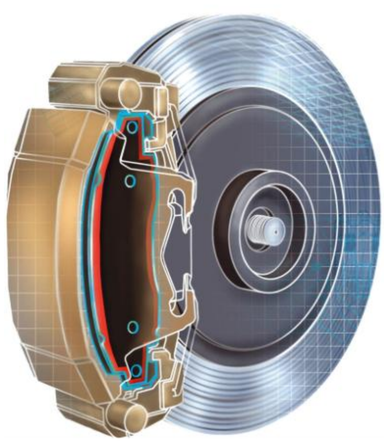
- Torque capacity

$$T = 2\pi\mu p_a \int_{d/2}^{D/2} r^2 dr$$

$$= \frac{\pi\mu p_a}{12}(D^3 - d^3)$$

$$= \frac{\mu F}{3}\frac{D^3 - d^3}{D^2 - d^2}$$

Disk Brakes: Overview



- Similar in principle to frictional contact axial clutches or brakes

Disk Brake

- Assuming uniform pressure

$$F = (\theta_2 - \theta_1) p_a \int_{r_i}^{r_o} r dr$$

$$= \frac{1}{2}(\theta_2 - \theta_1) p_a (r_o^2 - r_i^2)$$

- Torque capacity

$$T = \mu(\theta_2 - \theta_1) p_a \int_{r_i}^{r_o} r^2 dr$$

$$= \frac{1}{3}\mu(\theta_2 - \theta_1) p_a (r_o^3 - r_i^3)$$

$$= \frac{2}{3}\mu F \left(\frac{r_o^3 - r_i^3}{r_o^2 - r_i^2} \right)$$

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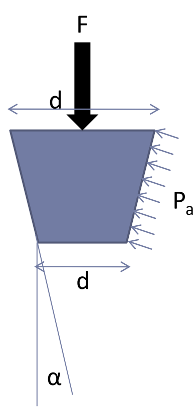
Cone Clutches and Brakes: Overview



- Due to cone shape, axial force is supported by normal force on the cone surface
- Friction between cone and drum can carry torque

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Cone Clutches and Brake: Force and Torque Calculation

- Assuming uniform pressure

$$F = p_a dA \sin\alpha = \int_{d/2}^{D/2} p_a \left(\frac{2\pi r dr}{\sin\alpha}\right)(\sin\alpha)$$

$$= \frac{\pi p_a}{4}(D^2 - d^2)$$

- Torque capacity

$$T = \mu r p_a dA = \int_{d/2}^{D/2} \mu r p_a \left(\frac{2\pi r dr}{\sin\alpha}\right)$$

$$= \frac{\mu \pi p_a}{12\sin\alpha}(D^3 - d^3)$$

$$= \frac{\mu F}{3\sin\alpha}\left(\frac{D^3 - d^3}{D^2 - d^2}\right)$$

Operating Time

- We have that

$$-T = I\ddot{\theta}$$

- assuming the torque from brake is constant and that a system is rotating at ω

$$\ddot{\theta} = -\frac{T}{I}$$

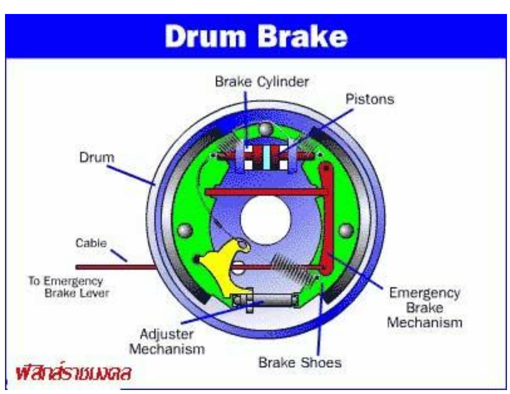
$$-\omega = -\int_0^t \frac{T}{I} dt$$

$$t = \frac{\omega I}{T}$$

Conclusion

Internal Expanding Rim (Drum Brake)

- Used mostly in automotive applications



Moments from Force on Drum

- Pressure distribution

$$p = \frac{p_a \sin\theta}{\sin\theta_a}$$

- Moment from friction

$$M_f = \frac{\mu p_a br}{\sin\theta_a}\int_{\theta_1}^{\theta_2} \sin\theta(r - a\cos\theta)d\theta$$

- Moment from normal force

$$M_N = \frac{p_a abr}{\sin\theta_a}\int_{\theta_1}^{\theta_2} \sin^2\theta d\theta$$

Required Actuation Force and Torque Capacity

- Actuation force balances out the moment

$$F = \frac{M_N - M_f}{c}$$

- Torque capacity

$$T = \int \mu r dN = \frac{\mu p_a br^2}{\sin\theta_a}\int_{\theta_1}^{\theta_2} \sin\theta d\theta$$

$$= \frac{\mu p_a br^2(\cos\theta_1 - \cos\theta_2)}{\sin\theta_a}$$