Design of Machines and Mechanical Systems (PC-BTM711)

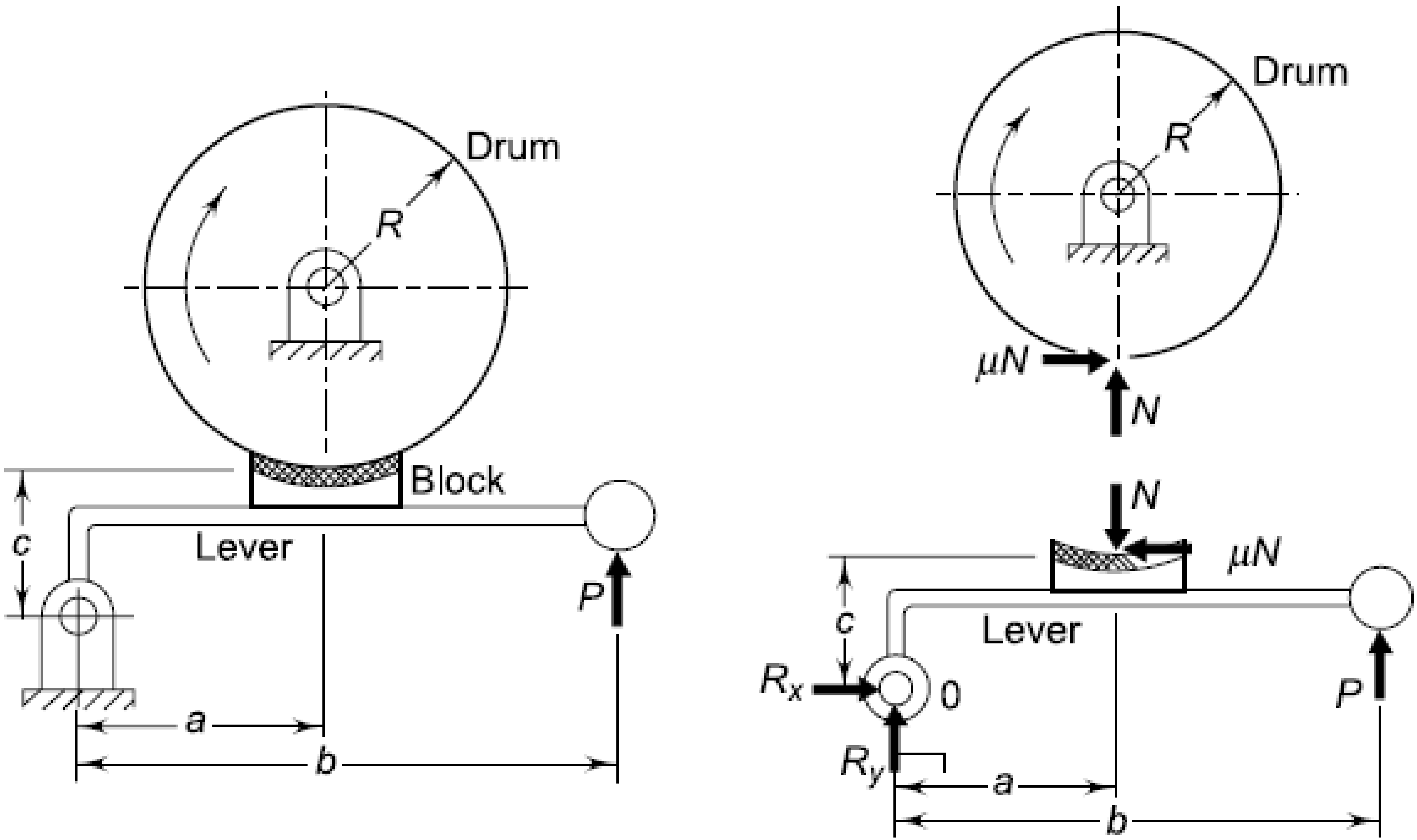
Session 16

Module 4: Design of Brakes – Further Topics

Session Outcomes

- Design block brake with long shoe
- Design of pivoted block brake
- Design of disk brake
- Discuss thermal considerations

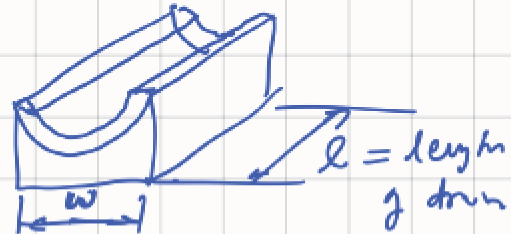
Block brake with short shoe



Ref: Bhandari V.B., Design of Machine Elements (2017)

Braking torque

$$M_t = \mu N \cdot R$$



p = permissible pressure between brake & drum

$$\boxed{N = p \times w \times l}$$

Taking moment of all forces @ pivot

$$Pb - Na + (\mu N).c = 0$$

$$\boxed{P = \left(\frac{a - \mu c}{b}\right) N}$$

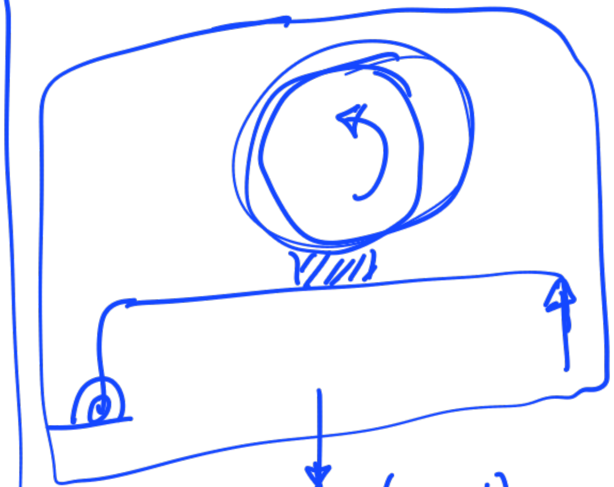
① partially self energizing design

$a - \mu c > 0$, $p = +ve$

② $a - \mu c = 0 \Rightarrow P = 0$

Self-locking brake → lack of control → undesirable

③ $a - \mu c < 0$



$$Pb - Na - (\mu N).c = 0$$

$$\Rightarrow \boxed{P = \left(\frac{a + \mu c}{b}\right) N}$$

Self-locking ?

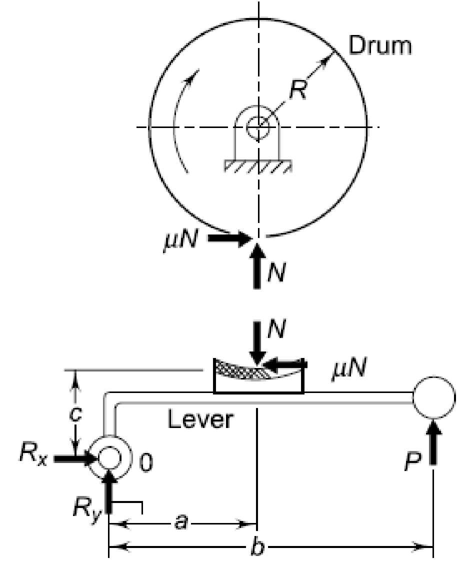
QUIZ

Self-Locking Block Brake

smaller

$$Pb - Na + (\mu N).c = 0$$

$$Pb = +(\quad)$$



For a block brake to be **non-self-locking**, the moment of frictional force about pivot should be

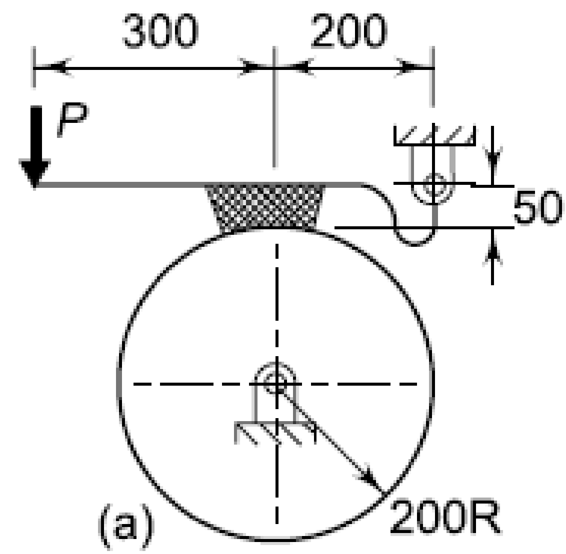
1) Higher than moment of the normal reaction force on drum about pivot

2) Lower than moment of the normal reaction force on drum about pivot ✓

Example-1: Block brake with small shoe

A single block brake with torque capacity of 250 Nm is shown in figure. The brake drum rotates at 100 rpm and coefficient of friction is 0.35. Calculate:

- The actuating force and hinge pin reactions for clockwise rotation of drum.
- The actuating force and hinge pin reactions for anti-clockwise rotation of drum.
- The rate of heat generation during braking action
- The dimensions of block if permissible intensity of pressure is 1 N/mm^2. The length of block is twice its width.
- State if the brake is self-locking



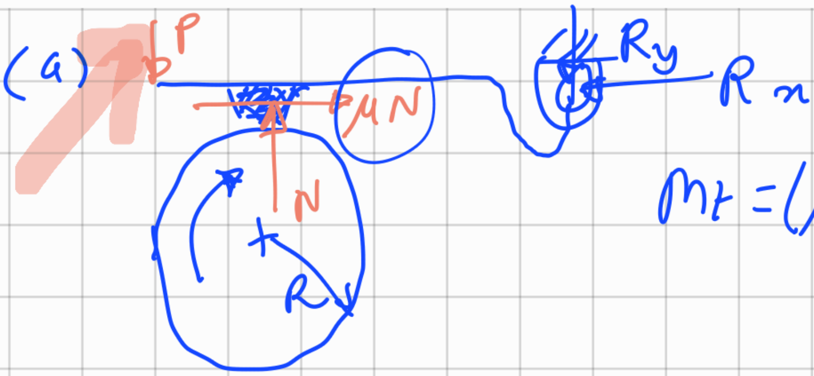
Ref: Bhandari V.B., Design of Machine Elements (2017)

$\boxed{M_t = 250 \text{ N-m}}$

$n = 100$ rpm

$\mu = 0.35$

(a)



$M_t = (\mu N) \cdot R$

$$N = \frac{M_t}{\mu R} = \frac{250 \times 10^3}{0.35 \times 200} = \boxed{3571.4 N}$$

Taking moment about pivot.

$$-P \times 500 - \mu N \times 50 + N \times 200 = 0$$

$$P = \frac{-0.35 \times 3571.4 \times 50 + 3571.4 \times 200}{500}$$

$$P = \boxed{1303.56 \text{ N}}$$

$$R_x = \mu N = \boxed{1250 \text{ N}}$$

$$R_y = N - P = \boxed{2321.4 \text{ N}}$$

(ii) Anticlockwise rotation of drum

$$-P \times 500 + \mu N \times 50 + N \times 200 = 0$$

$$\Rightarrow P = \boxed{1553.6 \text{ N}}$$

$$R_x = \mu N = \boxed{1250 \text{ N}}$$

$$R_y = N - P = \boxed{2017.8 \text{ N}}$$

(iii) Rate of heat generation during braking

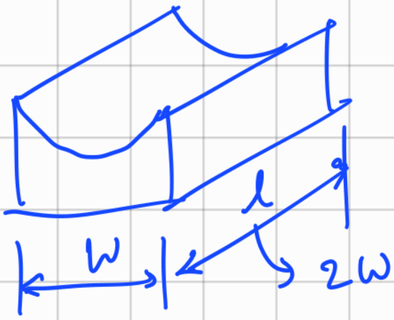
Average $\to \dot{Q} = \underbrace{M_t \cdot \omega}$ $\to \omega_{avg}$

$= 250 \times \left[(100+0)/2 \times \frac{2\pi}{60} \right]$

$= \boxed{1308.75\ W}$

(iv) Dimensions of block

$\boxed{p_{max} = 1 \frac{N}{mm^2}}$



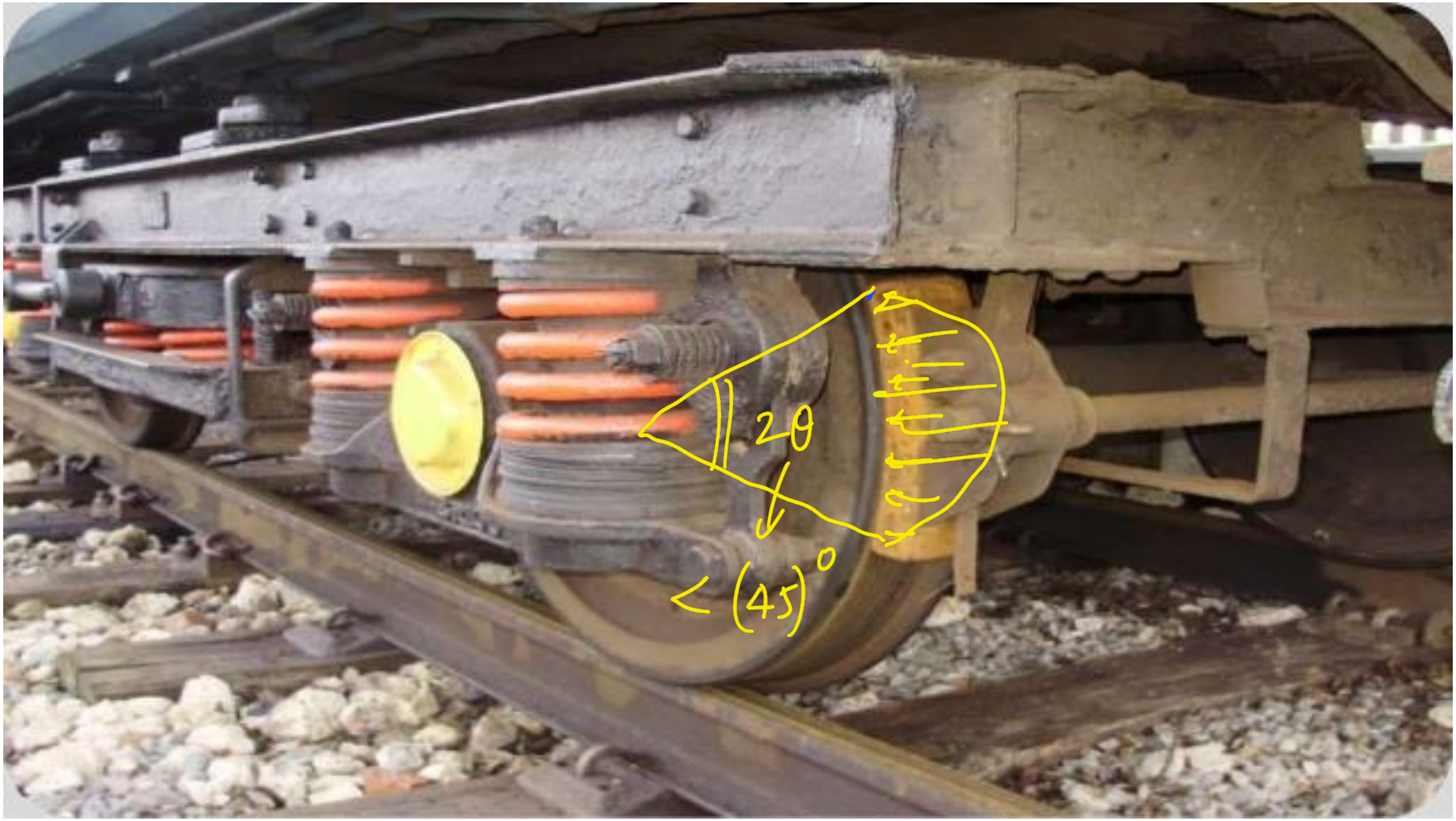
$p_{max} = \frac{N}{w \times (2w)}$ $\to l$

$1 = \frac{3571.4}{2w^2}$

$\Rightarrow w = 42.3\ mm \approx \boxed{45\ mm}$

$l = 2w = \boxed{90\ mm}$

Design of Block Brake with Long Shoe



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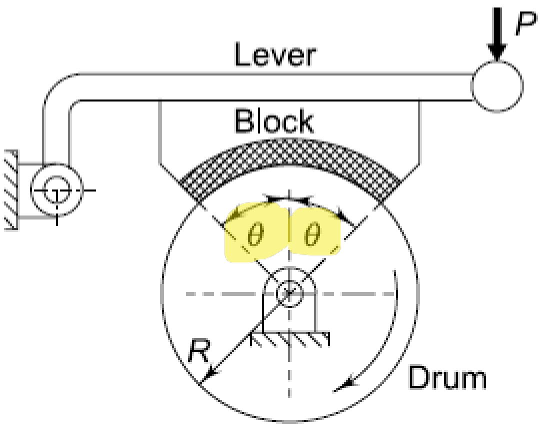
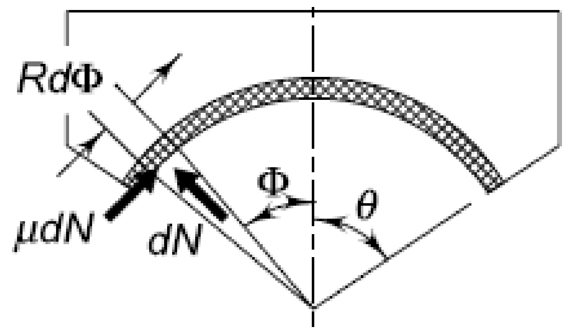
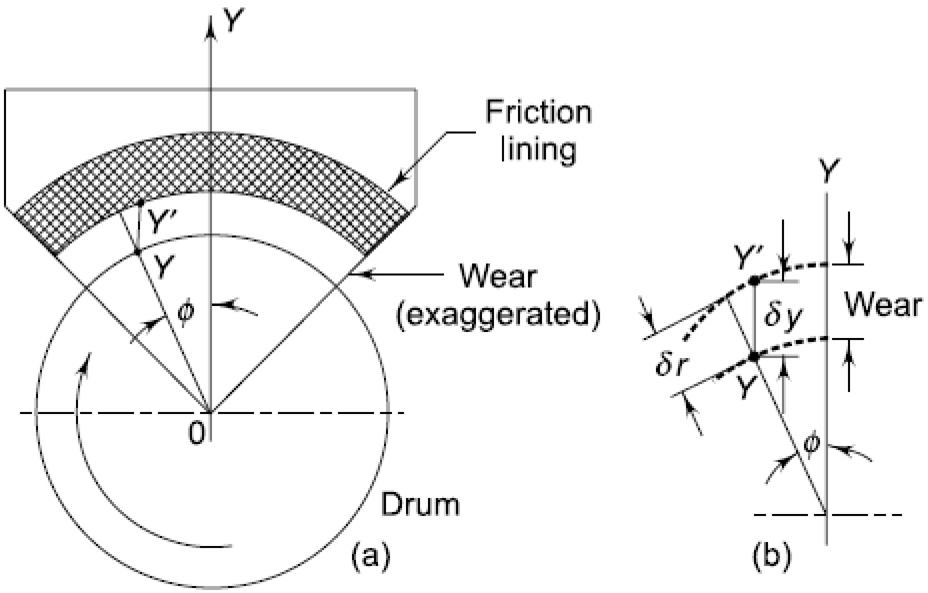
Design of Block Brake with Long Shoe





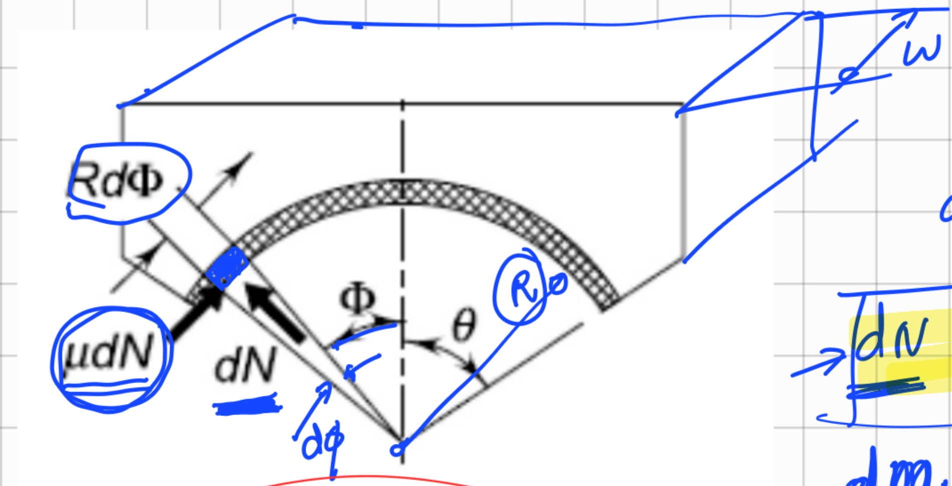
$M_t = \mu N R$



Equivalent coefficient Of friction

$$\boxed{\mu' = \mu\left[\frac{4\sin\theta}{2\theta + \sin 2\theta}\right]}$$

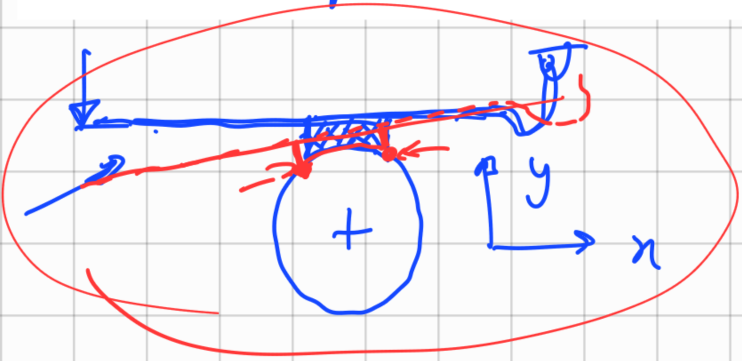
Ref: Bhandari V.B., Design of Machine Elements (2017)



$$dN = p \cdot dA$$

$$dN = p \cdot (R \cdot d\phi \cdot w)$$

$$\boxed{dN = (R\,d\phi \cdot w)\,p \quad \text{---(1)}}$$

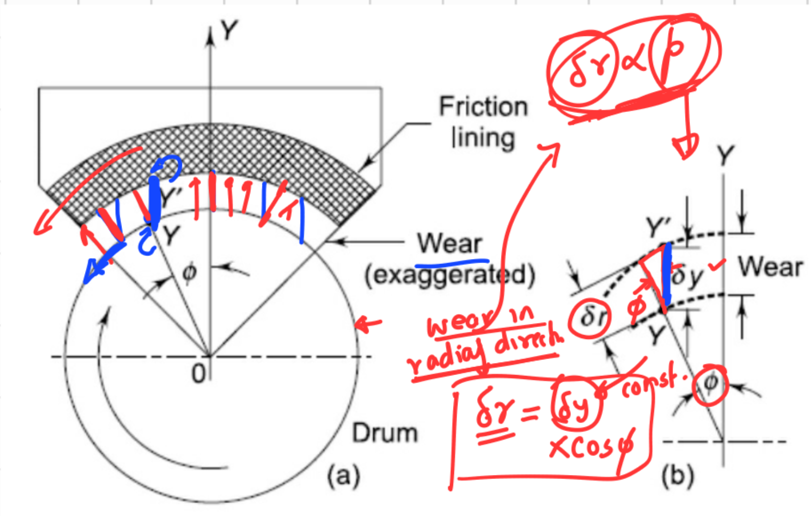


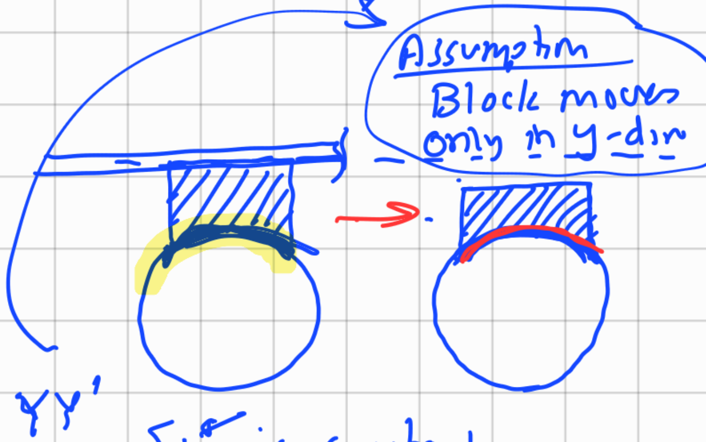
$$dm_t = (\mu\, dN) \cdot R$$

$$= \mu\,(R\,d\phi\,w)\,p \cdot R$$

$$dm_t = \mu R^2 d\phi \cdot w \cdot p \leftarrow f(\phi)$$

$$m_t = \mu R^2 w \cdot \int p \cdot d\phi \quad \text{---(2)}$$





YY' ← δy is constant

also we have

$$\delta r = \delta y \cdot \cos\phi$$

$$\Rightarrow \frac{\delta r}{\cos\phi} = \text{constant} \quad \text{--(3)}$$

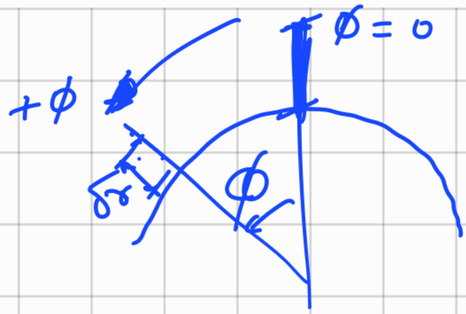
The observation about wear phenomenon tells.

$\delta r \propto p \longrightarrow \delta r \propto$ heat genern

From (3)

$$\frac{p}{\cos\phi} = \text{constant}.$$

$$p = \underline{\underline{k}} \cdot \cos\phi$$



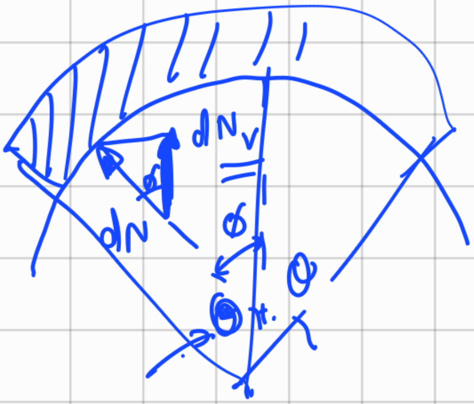
at $\phi = 0$, δr is max

$$\Rightarrow p = p_{max}$$

$$\Rightarrow p_{max} = k \cdot \cos(0^\circ)$$

$$\Rightarrow k = p_{max}$$

$$\boxed{\underline{\underline{p}} = p_{max} \cdot \cos\phi} \quad \text{--- (4)}$$



From (1) & (4)

$$\underline{\underline{dN_v}} = \underbrace{(R\, d\phi\, w)(p_{max} \cos\phi)}_{dN} \cdot \cos\phi$$

$$N_v = \int_{-\theta}^{\theta} dN_v = \boxed{} \int_{-\theta}^{\theta} \underline{\cos^2\phi\, d\phi}$$

$$\boxed{\underline{N_v} = \frac{1}{2} R\, w\, p_{max} (2\theta + \sin 2\theta)} \quad \text{--- (5)}$$

From (2), (4)

$$\boxed{M_t = \mu R^2 \cdot w\, p_{max} (2 \sin\theta)} \text{ --- (6)}$$

$$\frac{M_t}{N_v} = \boxed{}$$

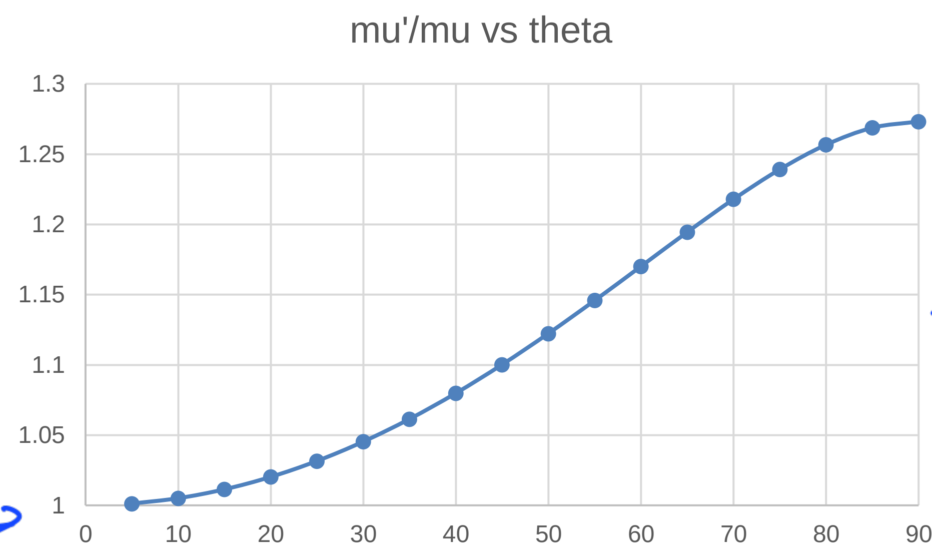
From (5) & (6)

$$\boxed{M_t = \left[\mu \frac{4 \sin\theta}{(2\theta + \sin 2\theta)}\right] \cdot N_v \cdot R}$$

$$M_t = \mu_{eqv.} \cdot N \cdot R$$

Design of Block Brake with Long Shoe

μ_{eqv}



$\mu_{eqv} > \mu$

$\longrightarrow \theta$

Equivalent coefficient Of friction

$$\mu' = \mu \left[\frac{4 \sin \theta}{2\theta + \sin 2\theta} \right]$$

Ref: Bhandari V.B., Design of Machine Elements (2017)

Block Brake with Long Shoe

QUIZ

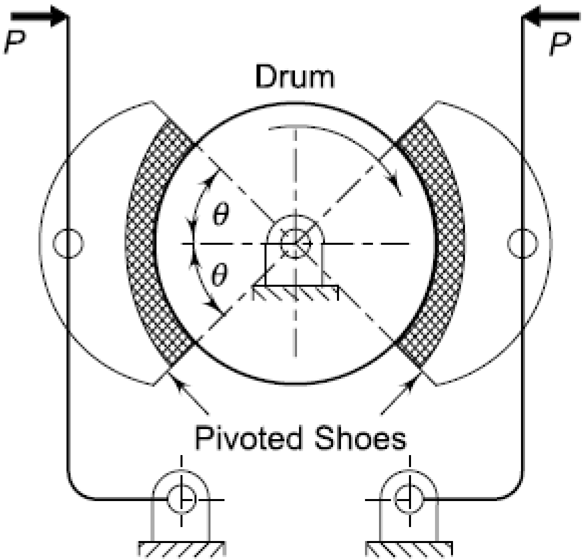
Which of the statement is FALSE regarding block brake with long shoe?

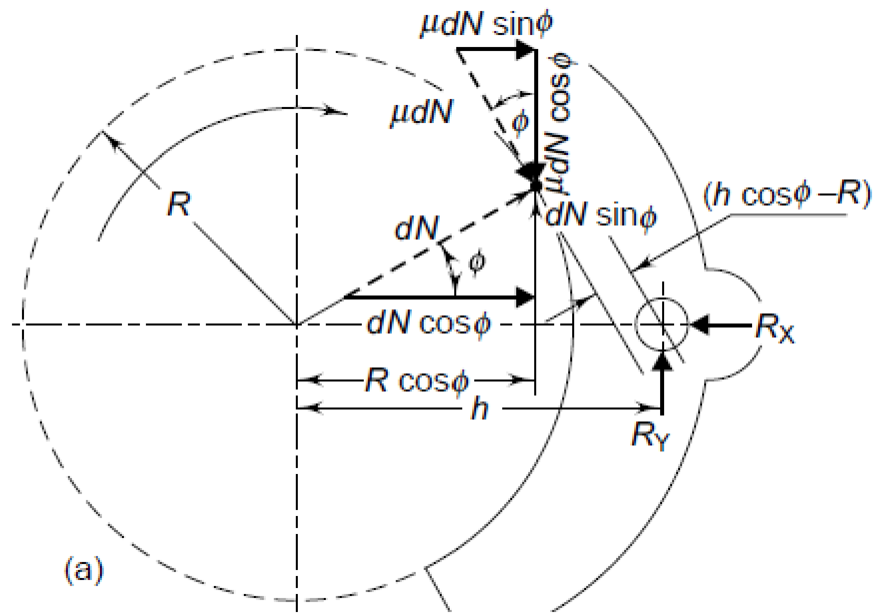
1) Contact pressure varies across circumference of drum True
2) Amount of radial wear is proportional to contact pressure True $\delta r \propto p$
3) Equivalent coefficient of friction is smaller than actual coefficient of friction X
4) ~~None of the above statements are FALSE~~ X

Pivoted Block Brake with Shoe

https://www.frictionbraking.com/technical/uic-k-type-brake-block-tread-braking/

Pivoted Block Brake with Long Shoe





DDB T12.3

$h = \dfrac{4R\sin\theta}{2\theta + \sin 2\theta}$	(12.10)	h = distance of pivot from axis of brake drum (mm) R = radius of brake drum (mm) θ = semi-block angle of each shoe (rad)
$M_t = 2\mu R^2 w\, p_{\max} \sin\theta$	(12.11)	M_t = braking torque capacity of each shoe (N-mm) μ = coefficient of friction between friction lining and drum w = width of friction lining (mm) p_{max} = maximum intensity of pressure between friction lining and brake drum (MPa or N/mm^2)
$R_x = \dfrac{1}{2} R w p_{\max}(2\theta + \sin 2\theta)$	(12.12)	R_x = reaction at each pivot in X direction (N)
$R_y = \dfrac{1}{2} \mu R w p_{\max}(2\theta + \sin 2\theta)$	(12.13)	R_y = reaction at each pivot in Y direction (N)

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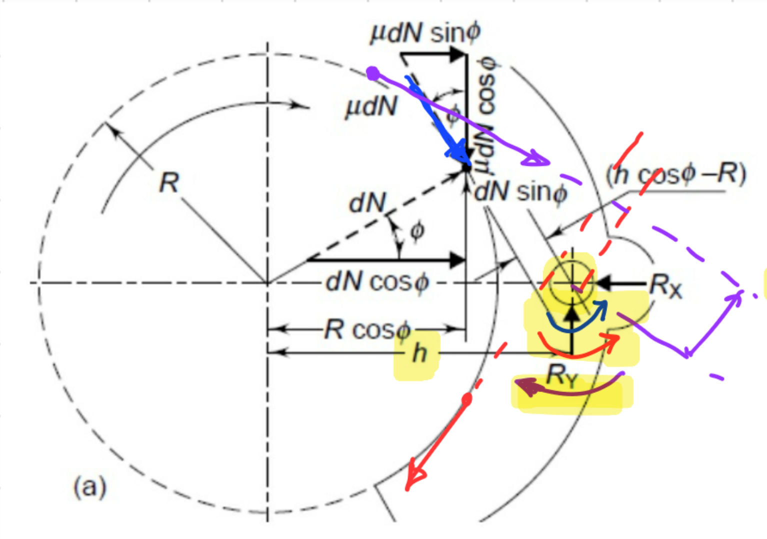

$\Sigma M_{@\,pivot} = 0$

moment of all frictional forces about pivot $= 0$

$$\boxed{M_f = \int_{-\theta}^{\theta} (\mu\, dN)(h\cos\phi - R) = 0}$$

We have $dN = R\, d\phi . w . p = R . d\phi . w . p_{max} \cos\phi$

$$M_f = 0 \Rightarrow 2\int_{-\theta}^{\theta} \cos\phi\,(h\cos\phi - R) . d\phi = 0$$

$$\boxed{h = \frac{4R\sin\theta}{2\theta + \sin 2\theta}}$$

$$dM_t = 2\mu R^2 w . p_{max} \sin\theta$$

NV $\rightarrow$

$$R_x = \frac{1}{2} R w p_{max} (2\theta + \sin 2\theta)$$

$$R_y = \frac{1}{2} . \mu R w p_{max} (2\theta + \sin 2\theta)$$