Module 12

Design of Brakes

Lesson
2
Design of Band and Disc Brakes

Instructional Objectives:

After reading this lesson the students should learn:

- Different types of band brakes
- Design of band brakes
- Design of disc brakes
- Properties of friction materials

1. Band brakes:

The operating principle of this type of brake is the following. A flexible band of leather or rope or steel with friction lining is wound round a drum. Frictional torque is generated when tension is applied to the band. It is known (see any text book on engineering mechanics) that the tensions in the two ends of the band are unequal because of friction and bear the following relationship:

$$\frac{T_1}{T_2} = e^{\mu\beta},$$

where T_1 = tension in the taut side,

T_2 = tension in the slack side,

μ = coefficient of kinetic friction and

β = angle of wrap.

If the band is wound around a drum of radius R, then the braking torque is

$$T_{br} = \left(T_1 - T_2\right) R = T_1\left(1 - e^{-\mu\beta}\right) R$$

Depending upon the connection of the band to the lever arm, the member responsible for application of the tensions, the band brakes are of two types,

(a) Simple band brake:

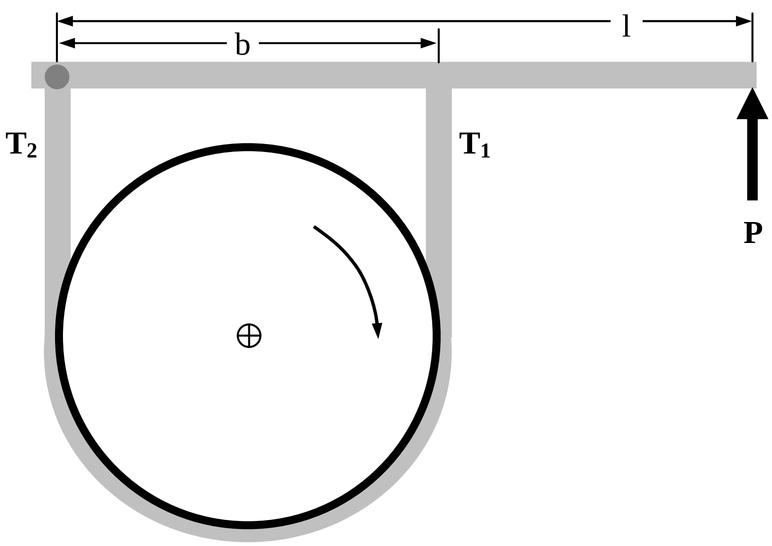
In simple band brake one end of the band is attached to the fulcrum of the lever arm (see figures 12.2.1(a) and 1(b)). The required force to be applied to the lever is

$P = T_1 \dfrac{b}{l}$ for clockwise rotation of the brake drum and

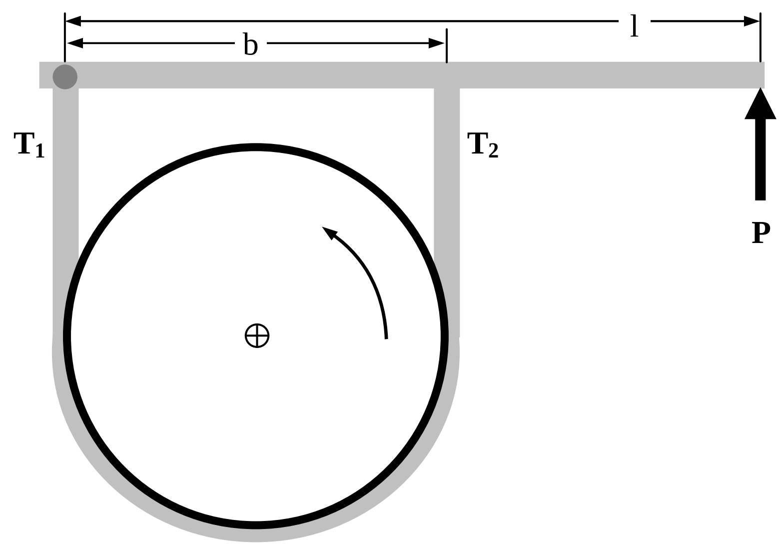
$P = T_2 \frac{b}{l}$ for anticlockwise rotation of the brake drum,

where l = length of the lever arm and

b = perpendicular distance from the fulcrum to the point of attachment of other end of the band.



1(a): Band brake with CW rotating drum



1(b): Band brake with CCW rotating drum

Figure 12.2.1: Band brakes

(b) Differential band brake:

In this type of band brake, two ends of the band are attached to two points on the lever arm other than fulcrum (see figures 12.2.2(a) and 12.2.2(b)). Drawing the free body diagram of the lever arm and taking moment about the fulcrum it is found that

$P = T_2 \frac{a}{l} - T_1 \frac{b}{l}$, for clockwise rotation of the brake drum and

$P = T_1 \frac{a}{l} - T_2 \frac{b}{l}$, for anticlockwise rotation of the brake drum.

Hence, P is negative if

$$e^{\mu\beta} = \frac{T_1}{T_2} > \frac{a}{b} \text{ for clockwise rotation of the brake drum}$$

and $$e^{\mu\beta} = \frac{T_1}{T_2} < \frac{a}{b}$$ for counterclockwise rotation of the brake drum. In these cases the force is to be applied on the lever arm in opposite direction to maintain equilibrium. The brakes are then self locking.

The important design variables of a band brake are the thickness and width of the band. Since the band is likely to fail in tension, the following relationship is to be satisfied for safe operation.

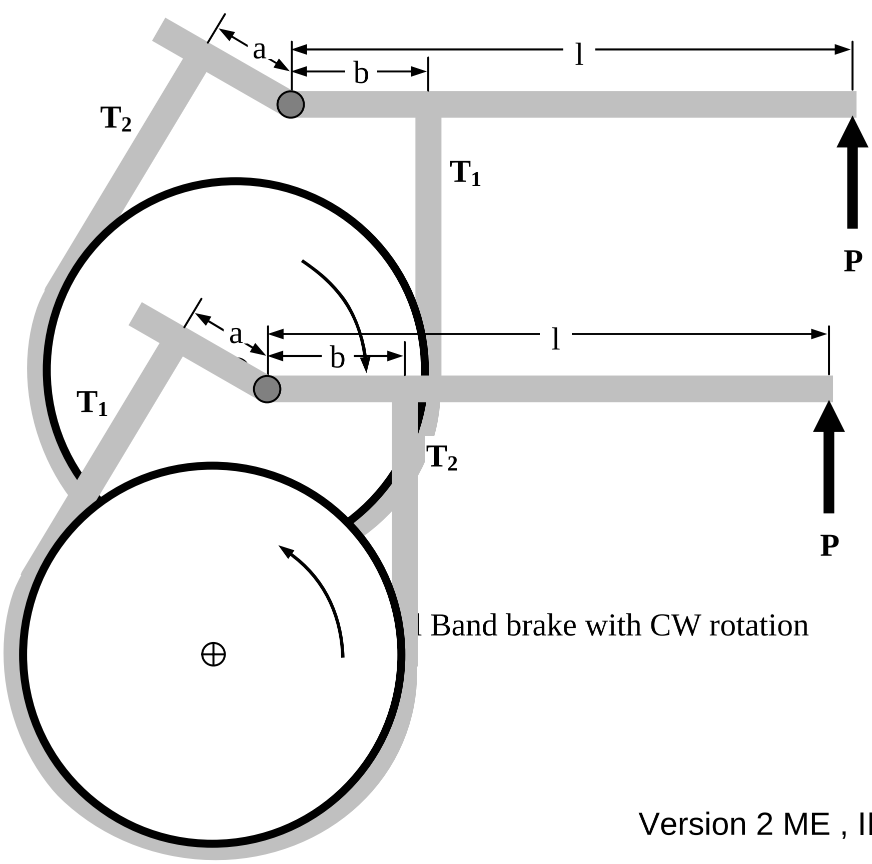
$$T_1 = wts_T$$

where w = width of the band,

t = thickness of the band and

s_T = allowable tensile stress of the band material. The steel bands of the following dimensions are normally used

w	25-40 mm	40-60 mm	80 mm	100 mm	140-200 mm
t	3 mm	3-4 mm	4-6 mm	4-7 mm	6-10 mm



l Band brake with CW rotation

Fig 12.2.2(b): Differential Band brake with CCW rotation

2. Band and block brakes:

Sometimes instead of applying continuous friction lining along the band, blocks of wood or other frictional materials are inserted between the band and the drum. In this case the tensions within the band at both sides of a block bear the relation

$$\frac{T_1}{T_1'} = \frac{1+\mu\tan\theta}{1-\mu\tan\theta},$$

where T_1 = tension at the taut side of any block

T_1' = tension at the slack side of the same block

2θ = angle subtended by each block at center.

If n number of blocks are used then the ratio between the tensions at taut side to slack side becomes

$$\frac{T_1}{T_2} = \left(\frac{1+\mu\tan\theta}{1-\mu\tan\theta}\right)^n.$$

The braking torque is $T_{br} = (T_1 - T_2)R$

3. Disc brake:

In this type of brake two friction pads are pressed axially against a rotating disc to dissipate kinetic energy. The working principle is very similar to friction clutch. When the pads are new the pressure distribution at pad-disc interface is uniform, i.e.

$$p = \text{constant}.$$

If *F* is the total axial force applied then $p = \frac{F}{A}$, where *A* is the area of the pad.

The frictional torque is given by

$$T_{braking} = \frac{\mu F}{A} \oint_A r\, dA$$

where μ = coefficient of kinetic friction and *r* is the radial distance of an infinitesimal element of pad. After some time the pad gradually wears away. The wear becomes uniforms after sufficiently long time, when

$$pr = \text{constant} = c \text{ (say)}$$

where $F = \oint p\, dA = c \oint \frac{dA}{r}$. The braking torque is

$$T_{braking}' = \mu \oint pr\, dA = \mu A c = \frac{\mu A F}{\oint \frac{dA}{r}}$$

It is clear that the total braking torque depends on the geometry of the pad. If the annular pad is used then

$$T_{br} = \frac{2}{3} \mu F \left(\frac{R_1^3 - R_2^3}{R_1^2 - R_2^2} \right)$$

$$T_{br}' = \mu F \left(\frac{R_1 + R_2}{2} \right)$$

where R_1 and R_2 are the inner and outer radius of the pad.

4. Friction materials and their properties.

The most important member in a mechanical brake is the friction material. A good friction material is required to possess the following properties:

- High and reproducible coefficient of friction.
- Imperviousness to environmental conditions.
- Ability to withstand high temperature (thermal stability)
- High wear resistance.
- Flexibility and conformability to any surface.

Some common friction materials are woven cotton lining, woven asbestos lining, molded asbestos lining, molded asbestos pad, Sintered metal pads etc.

Review questions and answers:

Q.1. A double shoe brake has diameter of brake drum 300mm and contact angle of each shoe 90 degrees, as shown in figure below. If the coefficient of friction for the brake lining and the drum is 0.4, find the spring force necessary to transmit a torque of 30 Nm. Also determine the width of the brake shoe if the braking pressure on the lining material is not to exceed 0.28 MPa.

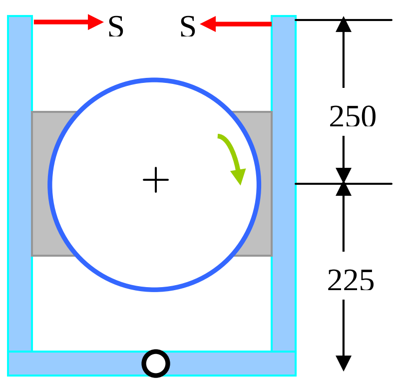


Figure 12.2.3

Ans. The friction force required to produce the given torque is

$$F_1+F_2=\frac{30}{0.150}=200(N)$$

The normal forces on the shoes are $N_1=\frac{F_1}{\mu'},\ \mathrm{N}_2=\frac{F_2}{\mu'},$ where $\mu'=\frac{4\mu\sin\theta_0}{2\theta_0+\sin 2\theta_0}(\theta_0=\frac{\pi}{4})=0.44.$ Writing the moment equilibrium equations about the pivot points of individual shoes (draw correct FBDs and verify)

$$-Sl+N_1x+F_1a=0\ \Rightarrow\ \mathrm{F}_1=\frac{Sl}{a+\frac{x}{\mu'}}=0.718\ S,\text{ and}$$

$$Sl-N_2x+F_2a=0\ \Rightarrow\ \mathrm{F}_2=\frac{Sl}{\frac{x}{\mu'}-a}=1.1314\ S$$

This yields S = 98.4(N).

Width of the friction lining :

According to the pressure distribution assumed for a shoe brake, the maximum bearing pressure occurs at the centerline of the shoe. The width of the brake lining must be selected from the higher values of the normal forces, in this case N_2. Noting that

$$N_2=Rbp_{\max}\int_{-\pi/4}^{\pi/4}\cos^2\theta\,d\theta,$$

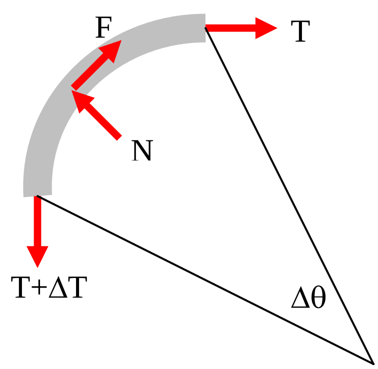
Where R = 0.150, $p_{\max}=0.28\ X\ 10^6,\ \mathrm{N}_2=1.314\times 98.4/0.44,$ the value of b is calculated to be 5.4 mm or 6 mm (approx.).

Q2. A differential band brake has brake drum of diameter 500mm and the maximum torque on the drum is 1000 N-m. The brake embraces 2/3rd of the circumference. If the band brake is lined with asbestos fabric having a coefficient of friction 0.3, then design the steel band. The permissible stress is 70 MPa in tesnion. The bearing pressure for the brake lining should not exceed 0.2 MPa.

Ans. The design of belt is to be carried out when the braking torque is maximum i.e. T_{br} = 1000 N-m. According to the principle of band brake

$$T_{br} = T_1(1-e^{-\mu\beta})\,R = T_1\left(1-e^{-0.3\times\frac{4\pi}{3}}\right)\times 0.25$$

Which yield $T_1 = 5587N$, $T_2 = e^{-\mu\beta}\,T_1 = 1587N$. In order to find the pressure on the band, consider an infinitesimal element. The force balance along the radial direction yields



$$N = T\,\Delta\,\theta$$

Since $N = p\,b\,R\,\Delta\,\theta$ so $p = \dfrac{T}{bR}$.

The maximum pressure is $p_{\max} = \dfrac{T_1}{bR}$.

Hence $b = \dfrac{5587}{0.25\times 0.2\times 10^6}$ = 0.112 m (approx.)

The thickness *t* of the band is calculated from the relation

$$S_t\,bt = T_1$$

Which yields $t = \dfrac{5587}{70\times 10^6\times 0.1117} =$ 0.0007145 m or 1 mm (approx.).