MAE 325
Fall 1999
HW 13 Solutions

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PROBLEM 14-2

Statement: **A 3/4-6 Acme thraed screw is used to lift a 2-kN load. The mean collar diameter is 40 mm. Find the torque to lift and to lower the load using a ball-bearing thrust washer. What are the efficiencies? Is it sel-locking?**

Units: $kN := 10^3 \cdot N$

Given:

Screw diameter	$d := 0.750 \cdot in$	Applied load	$P := 2 \cdot kN$
Collar diameter	$d_c := 40 \cdot mm$	Radial thread angle	$\alpha := 14.5 \cdot deg$
Threads per inch	$N_t := 6 \cdot in^{-1}$		

Assumptions: 1. The thread coefficient of friction is $\mu := 0.15$.
2. The collar coefficient of friction is $\mu_c := 0.02$.

Solution: See and Mathcad file P1402.

1. Get the thread pitch diameter from Table 14-3. $d_p := 0.667 \cdot in$

2. Determine the thread pitch and lead.

$p := \frac{1}{N_t}$ $\quad p = 0.167 \, in$

$L := p$ $\quad L = 0.167 \, in$

3. Use equations 14.5 to determine the lifting (up) and lowering (down) torques.

$$T_u := \frac{P \cdot d_p}{2} \cdot \frac{(\mu \cdot \pi \cdot d_p + L \cdot \cos(\alpha))}{(\pi \cdot d_p \cdot \cos(\alpha) - \mu \cdot L)} + \mu_c \cdot P \cdot \frac{d_c}{2} \qquad T_u = 42.68 \, in \cdot lbf$$

$$T_d := \frac{P \cdot d_p}{2} \cdot \frac{(\mu \cdot \pi \cdot d_p - L \cdot \cos(\alpha))}{(\pi \cdot d_p \cdot \cos(\alpha) + \mu \cdot L)} + \mu_c \cdot P \cdot \frac{d_c}{2} \qquad T_d = 18.25 \, in \cdot lbf$$

4. Use equation 14.7*c* to determine the lifting (up) and lowering (down) efficiencies.

$$e_u := \frac{P \cdot L}{2 \cdot \pi \cdot T_u} \qquad e_u = 27.9 \, \%$$

$$e_d := \frac{P \cdot L}{2 \cdot \pi \cdot T_d} \qquad e_d = 65.4 \, \%$$

5. Use equation 14.6*a* to determine if the screw is self-locking.

$$self\_locking := \begin{array}{|l} return \text{ "yes" } if \ \mu \ge \frac{L}{\pi \cdot d_p} \cdot \cos(\alpha) \\ \text{"no"} \ otherwise \end{array}$$

$self\_locking = \text{"yes"}$

8.142 The 10-lb bar AE is suspended by a cable that passes over a 5-in.-radius drum. Vertical motion of end E of the bar is prevented by the two stops shown. Knowing that $\mu_s = 0.30$ between the cable and the drum, determine (*a*) the largest counterclockwise couple $\mathbf{M}_0$ that can be applied to the drum if slipping is not to occur, (*b*) the corresponding force exerted on end E of the bar.

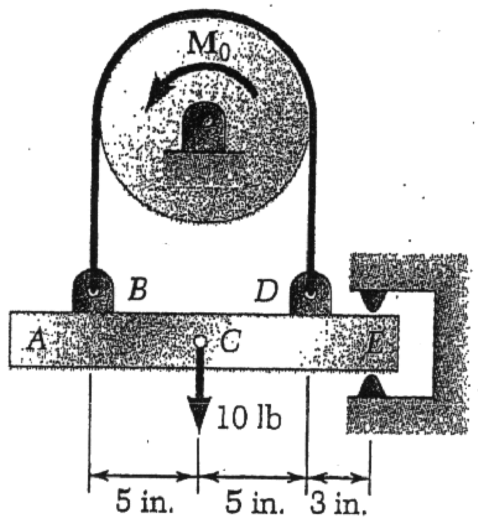
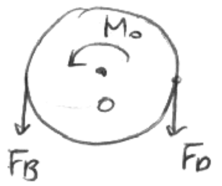


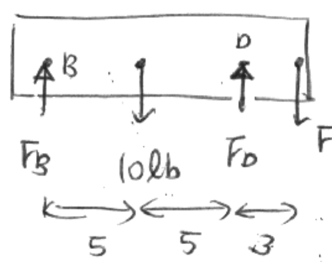
Fig. P8.142

FBD

①



②



① → $\dfrac{F_D}{F_B} = e^{\mu_s \beta} = 2.57$

$\mu_s = 0.30 \quad \beta = \pi$

$\therefore F_D = 2.57\, F_B$

② → $\Sigma M_{/E} = -3F_D + 8 \cdot 10 - 13F_B = 0$

$2.57 F_B$

$\therefore F_B = 3.86 \text{ lb}$

$F_D = 9.92 \text{ lb}$

② → $\Sigma F = F_B + F_D - 10 - F_E = 0$

$F_E = F_B + F_D - 10 = 3.78$

$\therefore \boxed{F_E = 3.78 \text{ lb} \downarrow}$

① → $\Sigma M_{/o} = M_o + 5F_B - 5F_D = 0$

$M_o = 5(F_D - F_B) = 30.26$

$\therefore \boxed{M_o = 30.26 \text{ lb} \cdot \text{in}}$ ↺

8.144 The strap wrench shown is used to grip the pipe firmly without marring the external surface of the pipe. Knowing that $a = 200$ mm, $r = 30$ mm, and $\theta = 65°$, determine the smallest coefficient of static friction between the pipe and the strap for which the wrench will be self-locking.

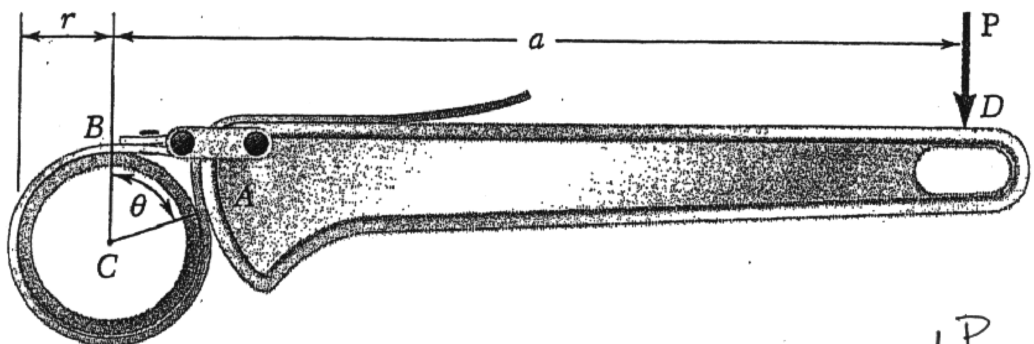
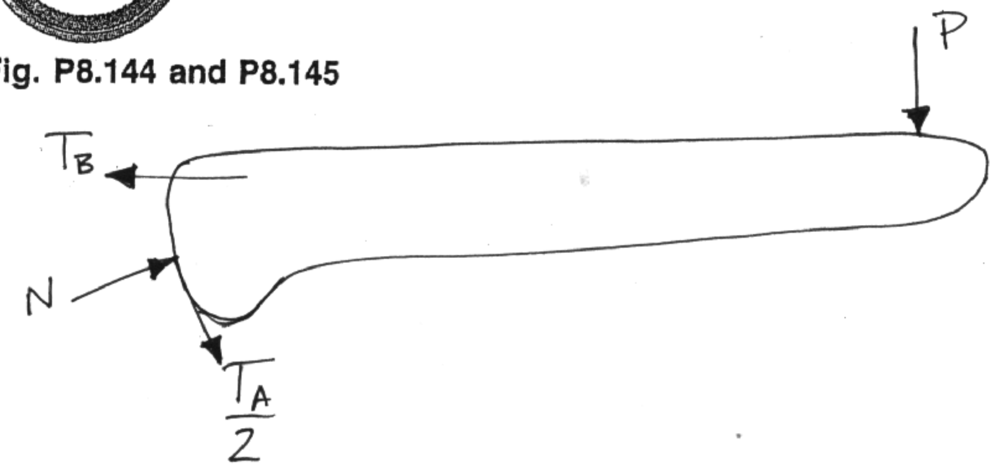
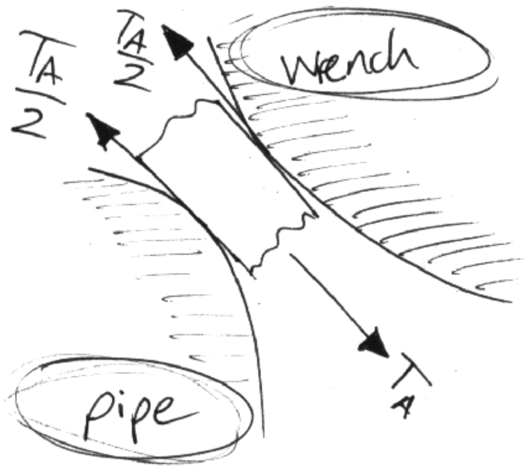


Fig. P8.144 and P8.145

FBD:



element of belt at A:



assume tension in belt goes to zero past point of contact at A... half of T_A transmitted to pipe and half to wrench

$$\Sigma \underset{\sim}{M}_{/A} = -(a - r\sin\theta)P\underset{\sim}{k} + r(1-\cos\theta)T_B\underset{\sim}{k} \Rightarrow \text{relates } P \text{ and } T_B$$

$$= \underset{\sim}{0}$$

$$T_B = P\,\frac{\frac{a}{r} - \sin\theta}{1 - \cos\theta}$$

for incipient slip:

$$\frac{T_B}{T_A} = e^{\mu_s \beta} \qquad \beta = 2\pi - \theta \qquad \ldots T_B \text{ is high-side tension}$$

$$\frac{T_A}{2} = \mu_s N$$

now to get rid of P in favor of N

$$\sum \underset{\sim}{F} = T_B \underset{\sim}{i} - P \underset{\sim}{j} + N(\sin\theta \underset{\sim}{i} + \cos\theta \underset{\sim}{j}) + \frac{T_A}{2}(\cos\theta \underset{\sim}{i} - \sin\theta \underset{\sim}{j}) = \underset{\sim}{0}$$

$$\left(\sum \underset{\sim}{F}\right)\cdot \underset{\sim}{j} = -P + N\cos\theta - \frac{T_A}{2}\sin\theta = -P + N(\cos\theta - \mu_s \sin\theta) = 0$$

$$\therefore \quad P = N(\cos\theta - \mu_s \sin\theta)$$

substitute into T_B expression:

$$T_B = N\left(\frac{\frac{a}{r} - \sin\theta}{1-\cos\theta}\right)(\cos\theta - \mu_s \sin\theta)$$

$$\therefore \quad \frac{T_B}{T_A} = \frac{1}{2\mu_s}\left(\frac{\frac{a}{r} - \sin\theta}{1-\cos\theta}\right)(\cos\theta - \mu_s \sin\theta)$$

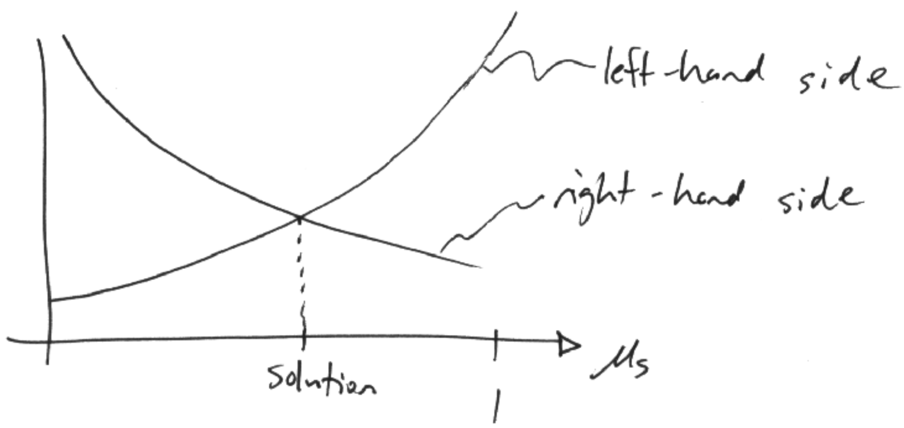
using $T_A = 2\mu_s N$

Thus as μ_s decreases, more normal force is needed for the same T_A and $\frac{T_B}{T_A}$ increases

But as μ_s increases, the ratio $\frac{T_B}{T_A} = e^{\mu_s \beta}$ increases and there is a single solution of

$$e^{\mu_s \beta} = \frac{1}{2\mu_s}\left(\frac{\frac{a}{r} - \sin\theta}{1-\cos\theta}\right)(\cos\theta - \mu \sin\theta)$$

for μ_s



solution by fsolve in matlab is on following page

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fun.m file

```
function [r]=fun(x);
%
% set fixed values
%
theta = 65*pi/180;
beta = 2*pi-theta;
a = 200;
r = 30;
%
% calculate residual (want to be zero)
%
lhs = exp(x*beta);
rhs = ...
1/(2*x) * ((a/r-sin(theta))/(1-cos(theta)))*(cos(theta)-x*sin(theta));
r = lhs - rhs;
```

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matlab i/o

```
>> options = optimset('TolFun',1.0e-12);
>> mu0 = 0.2;
>> [mu,resid] = fsolve('fun',mu0,options)
Optimization terminated successfully:
 Relative function value changing by less than OPTIONS.TolFun

mu =

    0.2556


resid =

   8.8818e-16
```

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PROBLEM 15-7

Statement: **Figure P15-1 shows a single short-shoe drum brake. Find its torque capacity and required actuating force for the dimensions given below. What value of c will make it self-locking?**

Units: $kN := 10^3 \cdot N$ $\quad kPa := 10^3 \cdot Pa$

Given:

Pivot to load	$a := 100\ mm$	Drum radius	$r := 30 \cdot mm$
Pivot to y-axis	$b := 70 \cdot mm$	Drum width	$w := 50 \cdot mm$
Pivot to x-axis	$e := 20 \cdot mm$	Shoe angle	$\theta := 35 \cdot deg$
Maximum pressure	$p_{max} := 1300 \cdot kPa$	Friction coefficient	$\mu := 0.3$

Assumptions: Short-shoe theory is appropriate. The drum rotates CCW.

Solution: See Figure P15-1 and Mathcad file P1507.

1. Determine the normal force on the drum from equation 15.8.

Normal force $\quad F_n := p_{max} \cdot r \cdot \theta \cdot w \quad\quad F_n = 1.191 \cdot kN$

2. Use equation 15.10 to calculate the torque capacity.

Torque capacity $\quad T := \mu \cdot F_n \cdot r \quad\quad T = 10.7 \cdot N \cdot m$

3. Determine the required actuating force from equation 15.11*b* and the brake geometry.

Distance *c* $\quad c := r - e \quad\quad c = 10 \cdot mm$

Actuation force $\quad F_a := F_n \cdot \dfrac{b - \mu \cdot c}{a} \quad\quad F_a = 798 \cdot N$

4. Check to see if the brake is self-locking using the relationship given on page 975 of the text.

$$self\_locking := \left| \begin{array}{l} return\ \text{"yes"}\ \ if\ \ \mu \cdot c \geq b \\ \text{"no"}\ \ otherwise \end{array} \right.$$

$self\_locking = \text{"no"}$

5. Calculate the value of *c* that would make the brake self-locking use the above relationship.

Value of c to self-lock $\quad c_{lock} := \dfrac{b}{\mu} \quad\quad c_{lock} = 233.3 \cdot mm$