Meeting 37 – 4/29/22

In-Class Agenda

1. What is a Power Screw?
2. Forces on a screw
3. Torques
4. Efficiency

Upcoming Assignments

31	4/11	P3 Help	P3 Due
32	4/13	Springs	P4 Assigned
	4/15	**NO CLASS**	
33	4/18	Static Spring Example	
34	4/20	Dynamic Spring Example	
35	4/22	Gears	A7 - Dynamic Spring
36	4/25	Gear Loads	
37	4/27	Power Screw	
38	4/29	Power Screw Example	
39	5/2	Fasteners	A8 - Power Screws and Gears
40	5/4	Fasteners Example	
41	5/6	P4 Help	
42	5/9	P4 Help	
			P4 Due

Riddle

A hunter encountered a bear in a wasteland. There was nobody else there. Both were frightened and ran away. The hunter ran to the north, and the bear to the west. Suddenly the fellow stopped, aimed his gun to the south and shot the bear. What color was the bear?

ME466 Elements of Machine Design

Lecture 37
Introduction to Power Screws

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What type of simple machine is a thread?

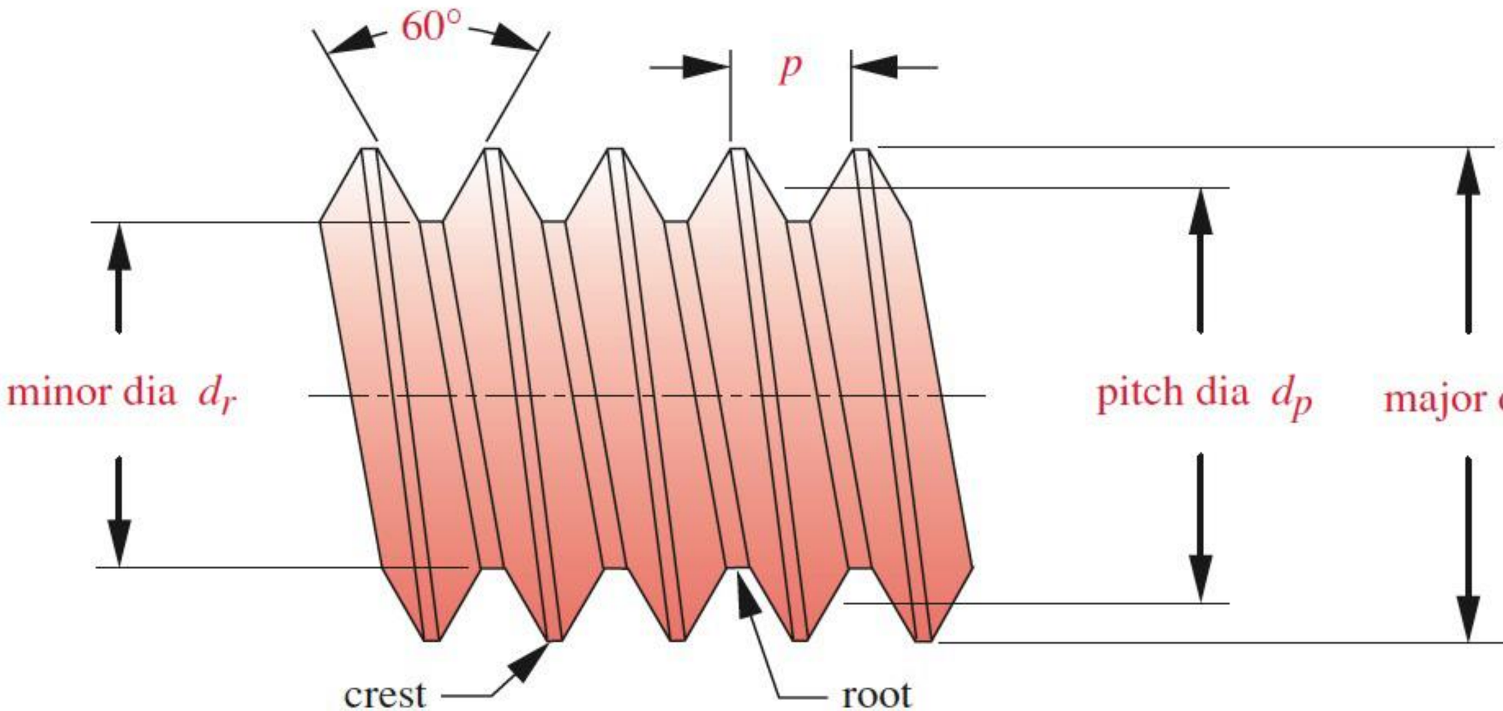


FIGURE 15-2

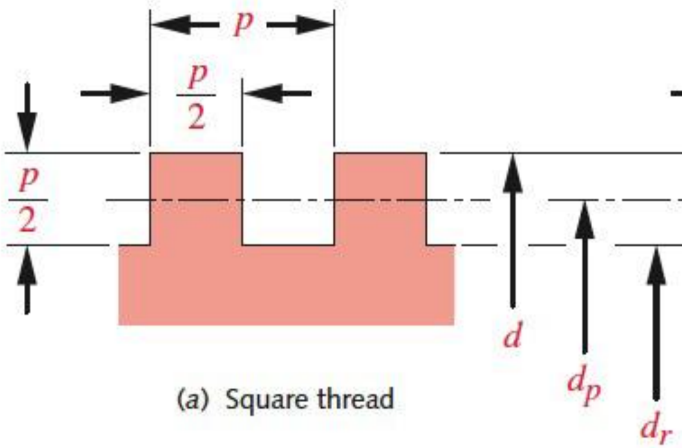
Unified National and ISO Standard Thread Form

Threads used to drive serve two functions:

- Power transmission
  - Rotational to linear, or linear to rotational
  - Examples: Car jack
- Accurate locating
  - Servomotor-driven linear actuators
  - Examples: All CNC machines, robots, manufacturing equipment

To transmit power, 60º angle is too inefficient.

- Square thread:
  - Greatest strength and efficiency
  - Hard to manufacture



(a) Square thread

FIGURE 15-3

Square, Acme, and Buttress Threads

Example of a power screw

- Notice:
  - Thrust bearing
  - Effect of gravity

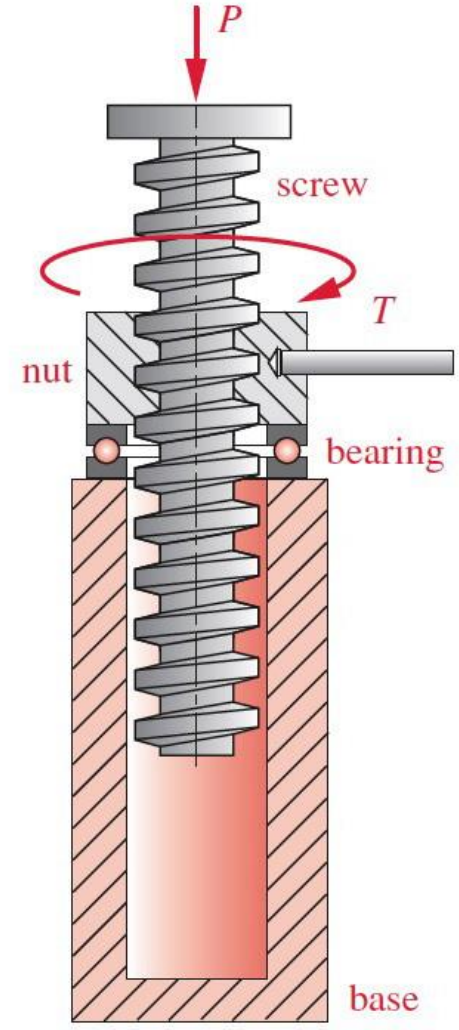


FIGURE 15-4

An Acme-Thread Power-Screw Jack

Square nut Force Analysis

- $d_p = pitch\ diameter$

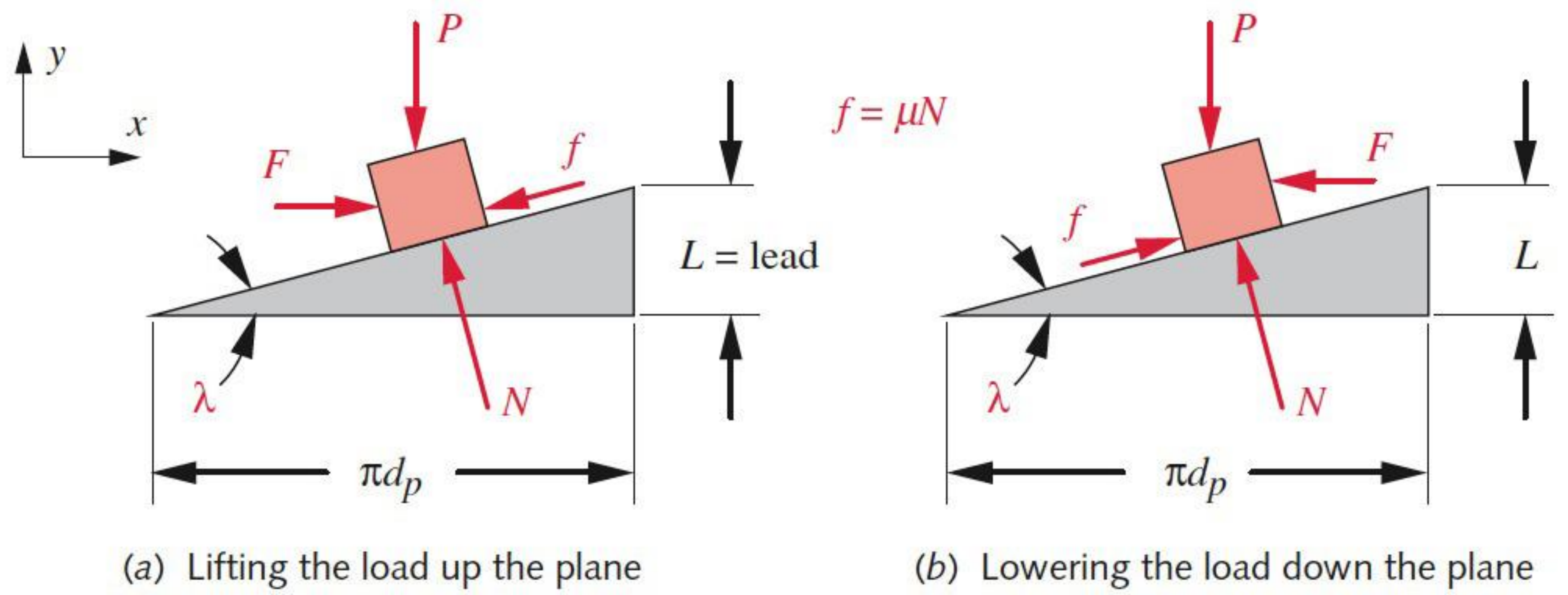
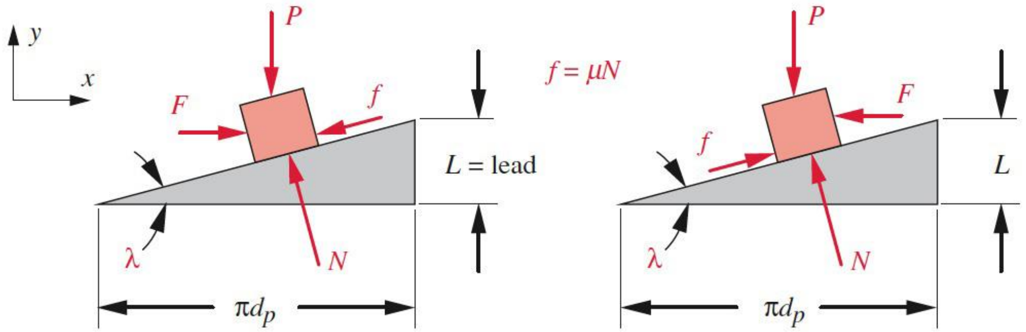


FIGURE 15-6

Force Analysis at the Screw-Nut Interface



(a) Lifting the load up the plane (b) Lowering the load down the plane

Square threads:

$$\tan\lambda = \frac{L}{\pi d_p}$$

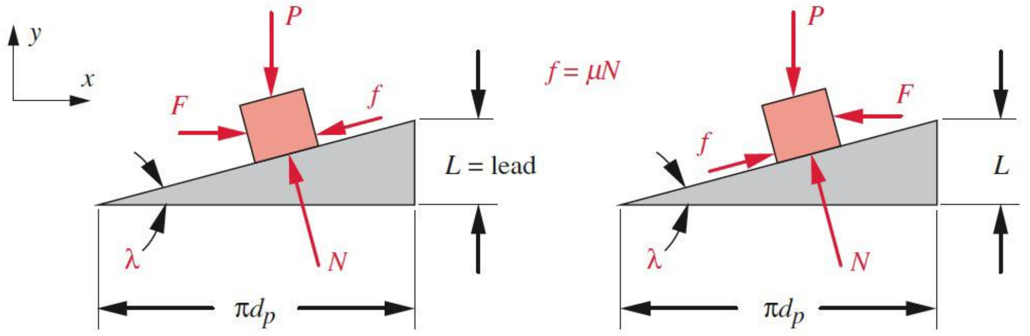
$$F = N(\mu\cos\lambda + \sin\lambda)$$

$$N = \frac{P}{\cos\lambda - \mu\sin\lambda}$$

$$F = P\frac{(\mu\cos\lambda + \sin\lambda)}{\cos\lambda - \mu\sin\lambda}$$

- Torque:

$$T_{s_u} = F\frac{d_p}{2} = P\frac{d_p}{2}\frac{(\mu\cos\lambda + \sin\lambda)}{\cos\lambda - \mu\sin\lambda} = P\frac{d_p}{2}\frac{(\mu\pi d_p + L)}{\pi d_p - \mu L}$$



(a) Lifting the load up the plane (b) Lowering the load down the plane

Square threads:

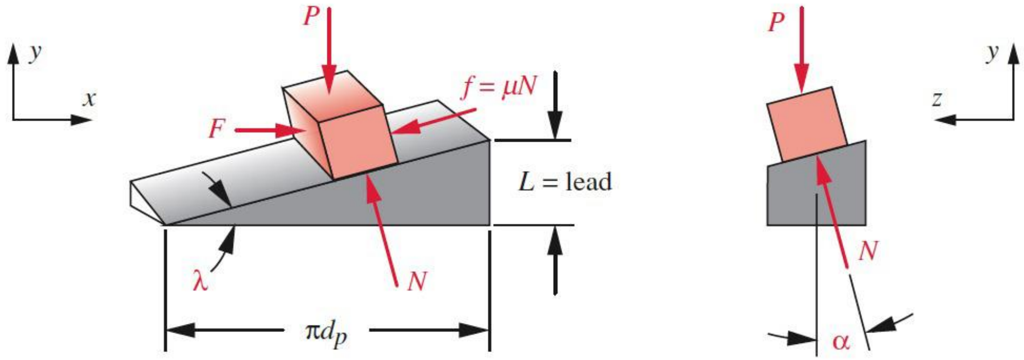
Torque at the the thrust collar (because of friction)

$$T_C = \mu_c P \frac{d_c}{2}$$

Total torque to lift against the load (up) and with the load (down)

$$T_u = T_{s_u} + T_C = P \frac{d_p}{2} \frac{(\mu \pi d_p + L)}{\pi d_p - \mu L} + \mu_c P \frac{d_c}{2}$$

$$T_d = T_{s_d} + T_C = P \frac{d_p}{2} \frac{(\mu \pi d_p - L)}{\pi d_p + \mu L} + \mu_c P \frac{d_c}{2}$$



Acme threads:

Torque at the the thrust collar (because of friction)

$$T_C = \mu_c P \frac{d_c}{2}$$

New terms because of α. (Acme: $\alpha = 14.5^o$)

$$T_u = T_{s_u} + T_C = P\frac{d_p}{2}\frac{\left(\mu\pi d_p + L\,\mathbf{cos}\,\boldsymbol{\alpha}\right)}{\pi d_p\,\mathbf{cos}\,\boldsymbol{\alpha} - \mu L} + \mu_c P\frac{d_c}{2}$$

$$T_d = T_{s_u} + T_C = P\frac{d_p}{2}\frac{\left(\mu\pi d_p - L\,\mathbf{cos}\,\boldsymbol{\alpha}\right)}{\pi d_p\,\mathbf{cos}\,\boldsymbol{\alpha} + \mu L} + \mu_c P\frac{d_c}{2}$$

CAN THESE TERMS BE NEGATIVE?

Self-Locking vs Back-Drivable

- Sometimes we want self-locking (jack)

$$T_d = T_{s_d} + T_C = P\frac{d_p}{2}\frac{\left(\boldsymbol{\mu\pi d_p - L\cos\alpha}\right)}{\pi d_p\cos\alpha + \mu L} + \mu_c P\frac{d_c}{2}$$

$$\mu \geq \frac{L}{\pi d_p}\cos\alpha = \tan\lambda\cos\alpha$$

- Sometimes we want back-drivable (robotics)

Friction values

- For oil-lubricated thread-nut combination:
  - $\mu = 0.15 \pm 0.05$
  - $\mu_c \approx \mu$
- For roller-element thrust bearings:
- $\mu_c = 0.01\ to\ 0.02$

- You can also use roller-elements in the threads.

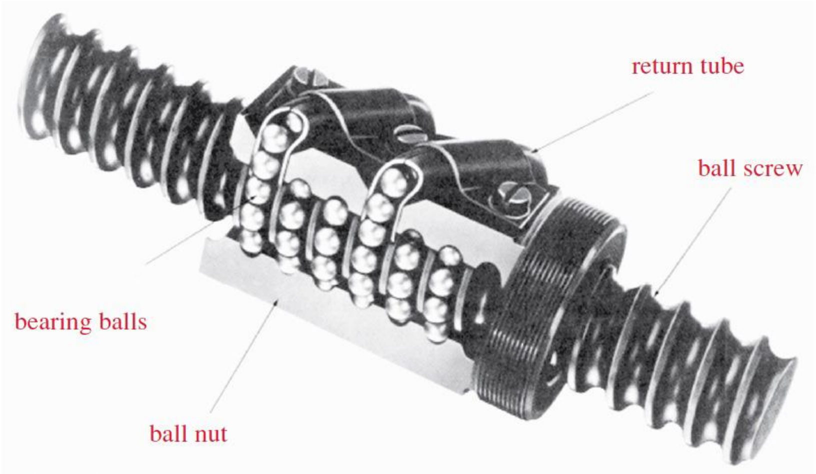


FIGURE 15-9

A Ball Screw and Ball Nut *Courtesy of Thompson-Saginaw Ball Screw Co., Saginaw, Mich.*

Screw Efficiency

The general equation for efficiency is:

$$e = \frac{W_{out}}{W_{in}} = \frac{PL}{2\pi T}$$

For Square Threads, not including the collar friction:

$$e = \frac{1 - \mu \tan\lambda}{1 + \mu \cot\lambda}$$

Table 15-4
Lead Angle and Efficiency for Standard Acme Threads with Coefficient of Friction $\mu = 0.15$

Size	Lead Angle (deg)	Efficiency %
1/4 - 16	5.2	36
5/16 - 14	4.7	34
3/8 - 12	4.5	34
7/16 - 12	3.8	30
1/2 - 10	4.0	31
5/8 - 8	4.0	31
3/4 - 6	4.5	34
7/8 - 6	3.8	30
1 - 5	4.0	31
1 1/8 - 5	3.6	28
1 1/4 - 5	3.2	26
1 3/8 - 4	3.6	29
1 1/2 - 4	3.3	27
1 3/4 - 4	2.8	24
2 - 4	2.4	21
2 1/4 - 3	2.9	25
2 1/2 - 3	2.6	23
2 3/4 - 3	2.4	21
3 - 2	3.3	27
3 1/2 - 2	2.8	24
4 - 2	2.4	21
4 1/2 - 2	2.1	19
5 - 2	1.9	18