Meeting 35 – 4/25/22

In-Class Agenda

1. Spur Gears
2. Nomenclature
3. Other Gears
4. Gear Trains

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

What is as light as a feather, but even the world's strongest man couldn't hold it for more than a few minutes?

ME466 Elements of Machine Design

Lecture 35
Introduction to Gears

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What purpose gears have?

- Exchange velocity for torque
- Translate rotational power

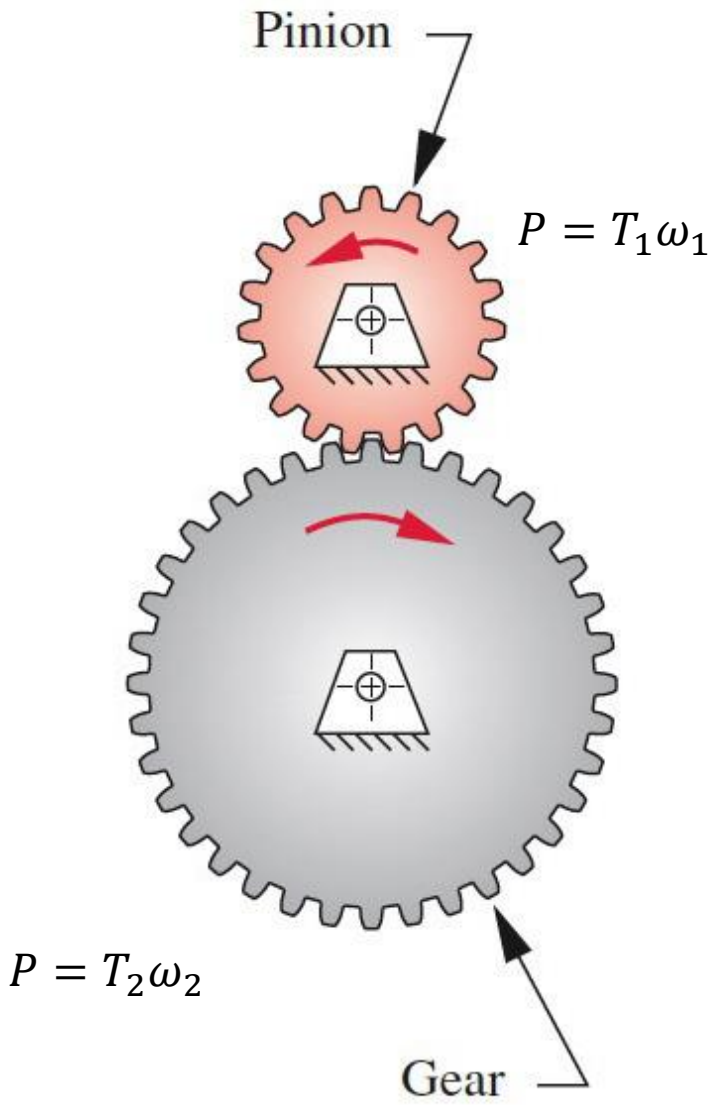
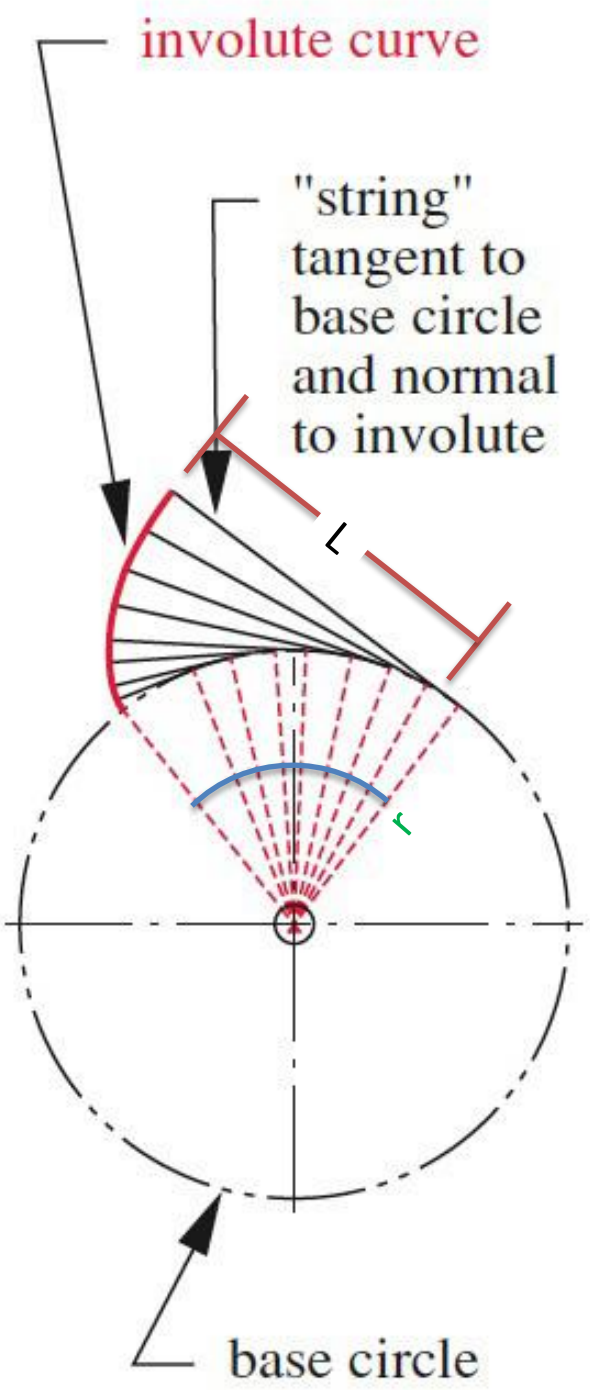


FIGURE 12-2

An External Gearset

What is an involute?

- What do involutes have to do with gears?
- Why?


involute curve
"string"
tangent to
base circle
and normal
to involute
L
r
base circle

$$L = \theta r$$

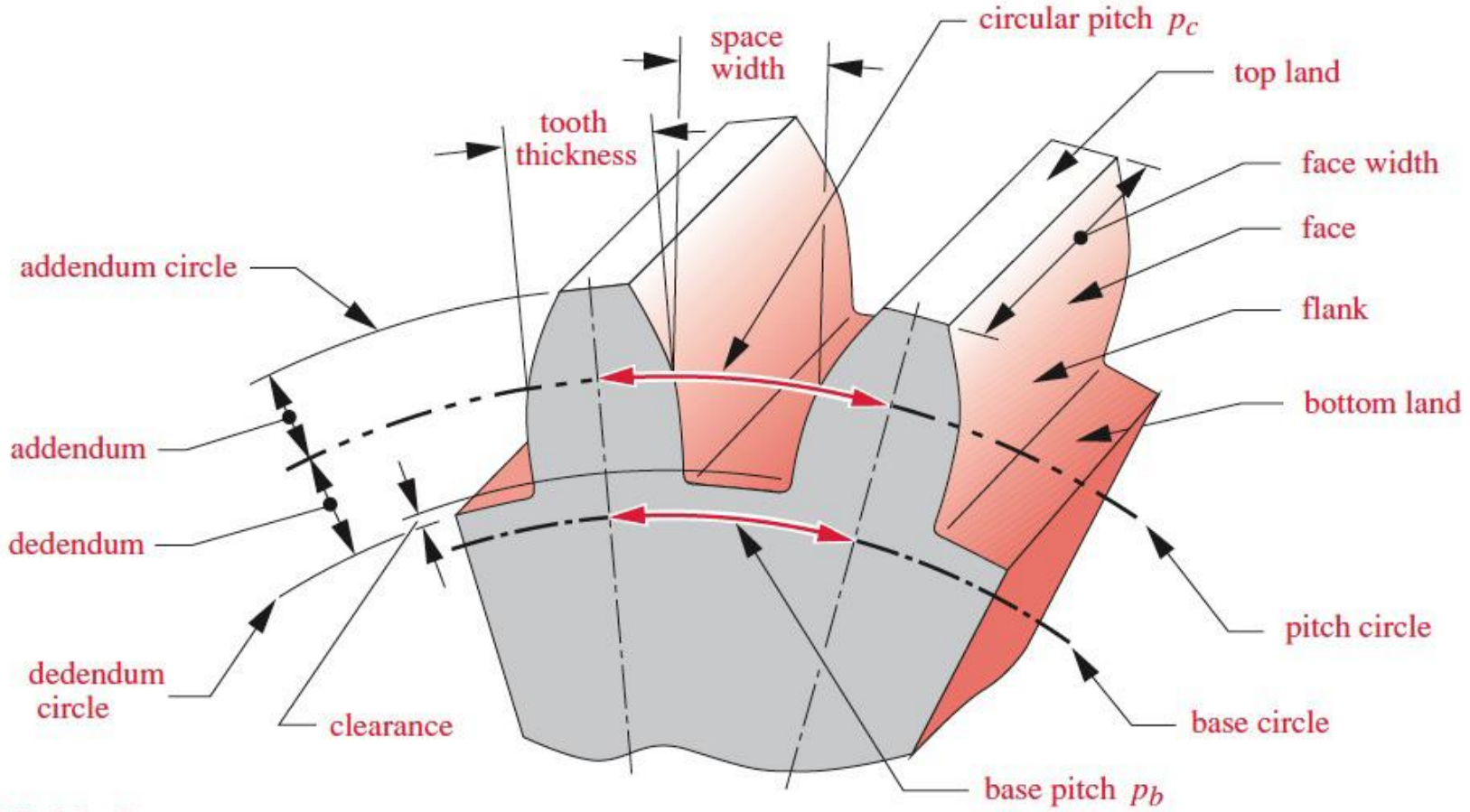


FIGURE 12-8

Pressure angle: ϕ

Diametral pitch: $p_d = \frac{N}{d}$ (US)

module: $m = \frac{25.4}{p_d} = \frac{d}{N}$ (SI)

addendum: a

dedendum: b

Radius: r

Outside diameter: $d_o = d + 2a$

Pitch circle: d

Base Circle: $d_b = d\cos(\phi)$

Root Circle: $d_r = d - 2b$

Circular tooth thickness: t

Space Width: S (MY notation)

Backlash: S-t

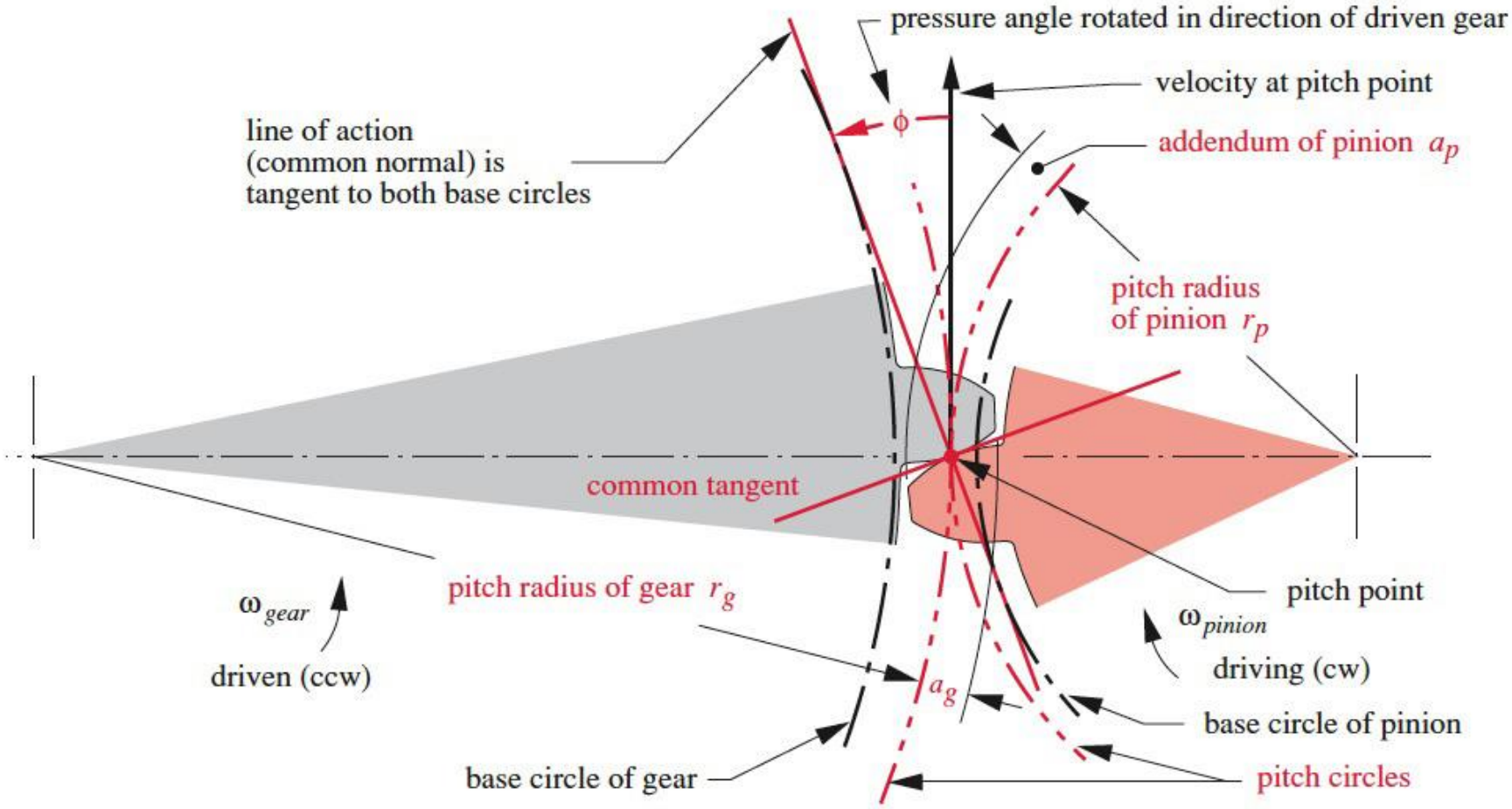


FIGURE 12-4

Contact Geometry and Pressure Angle of Involute Gear Teeth

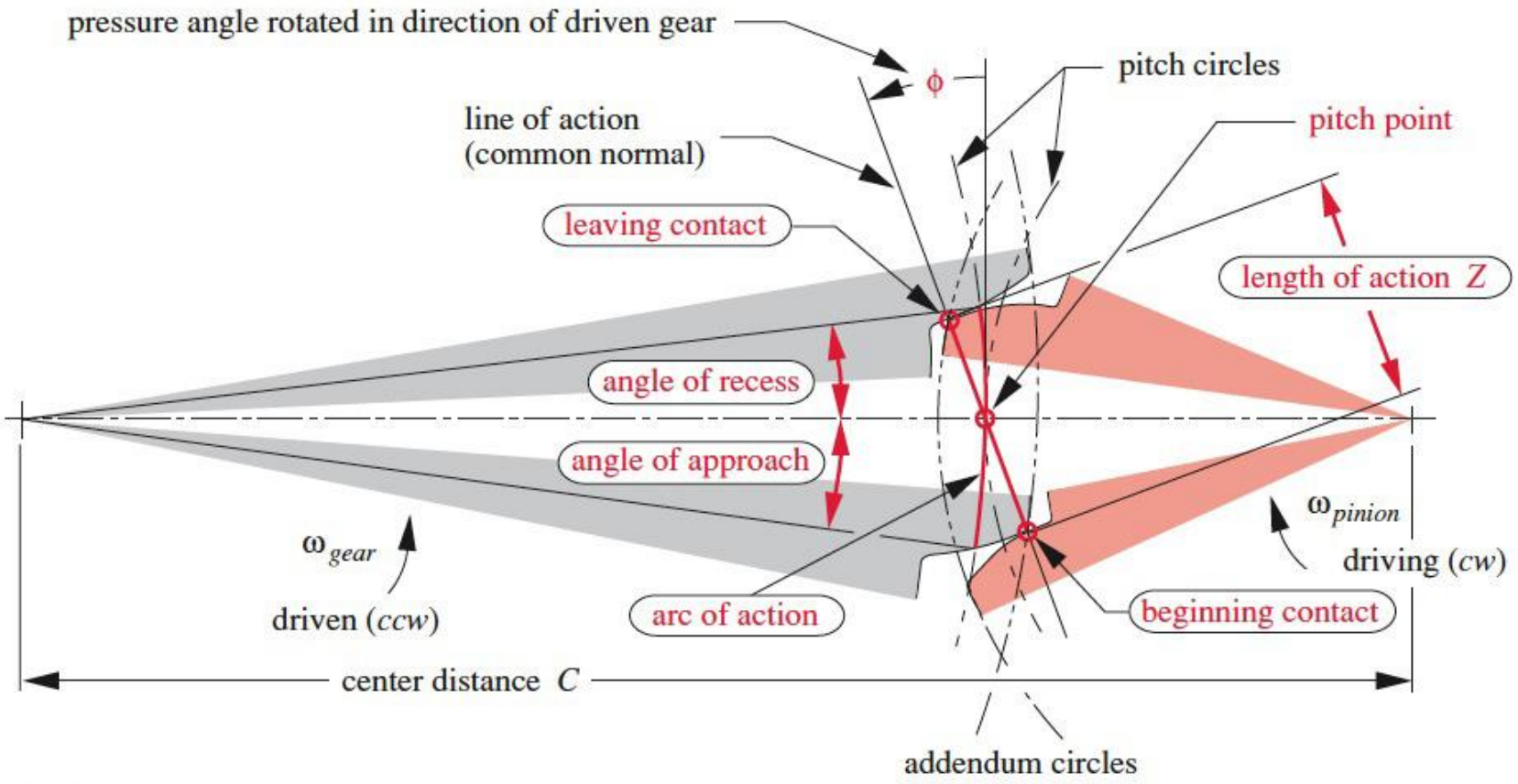
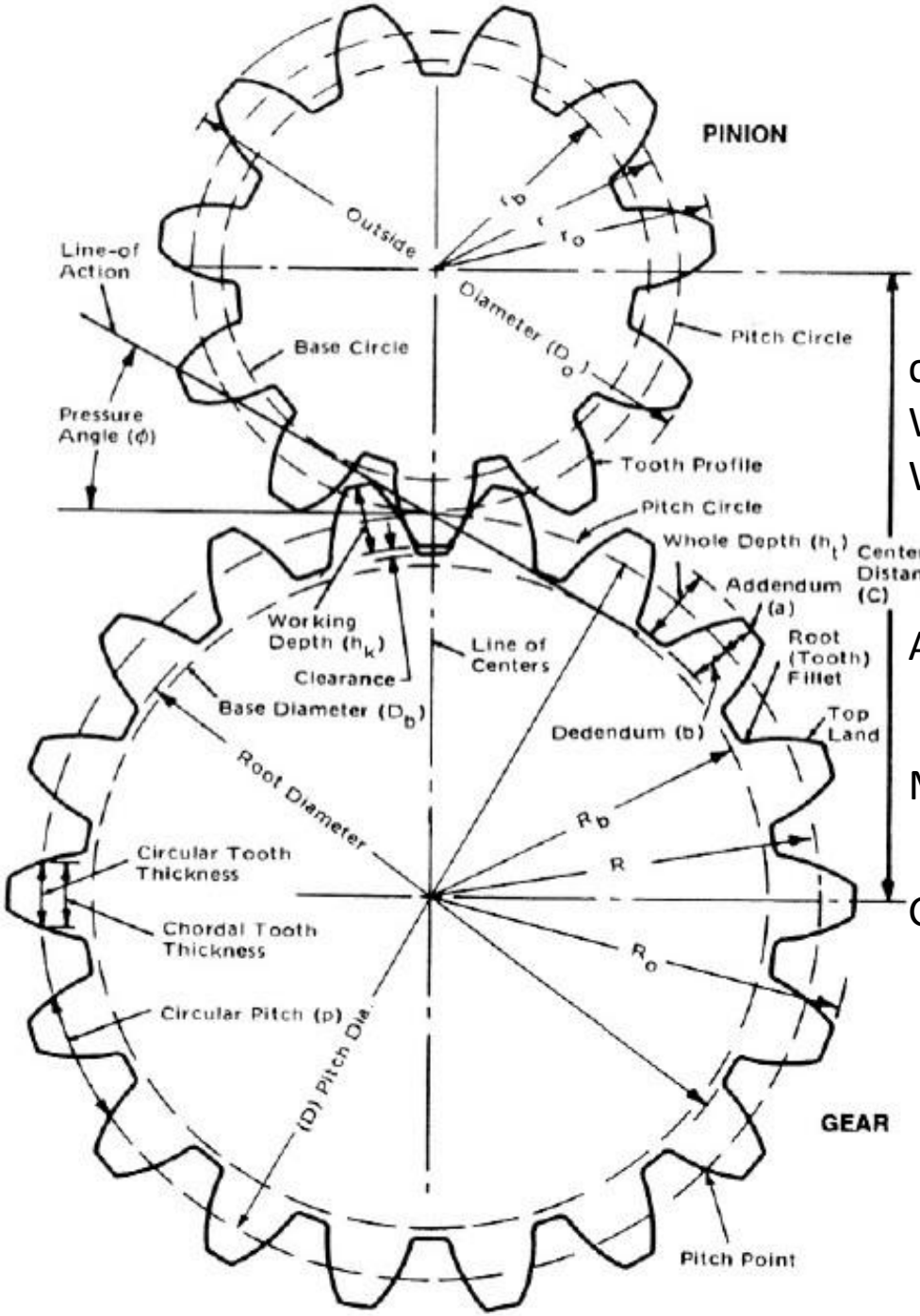


FIGURE 12-5

Length of Action, Arc of Action, and Angles of Approach and Recess During the Meshing of a Gear and Pinion



clearance: $c = b - a$

Whole depth: $h_t = a + b$

Working depth: $h_k = h_t - c = 2a$

Angular velocity ratio: $m_V = \frac{\omega_{out}}{\omega_{in}} = \pm\frac{r_{in}}{r_{out}}$

Mechanical Advantage: $m_A = \frac{1}{m_V} = \frac{r_{out}}{r_{in}} = \frac{T_{out}}{T_{in}}$

Gear Ratio: $m_G = |m_V| \; or \; |m_A|$
$such \; that \; m_G > 1$

Effect of Pressure Angle

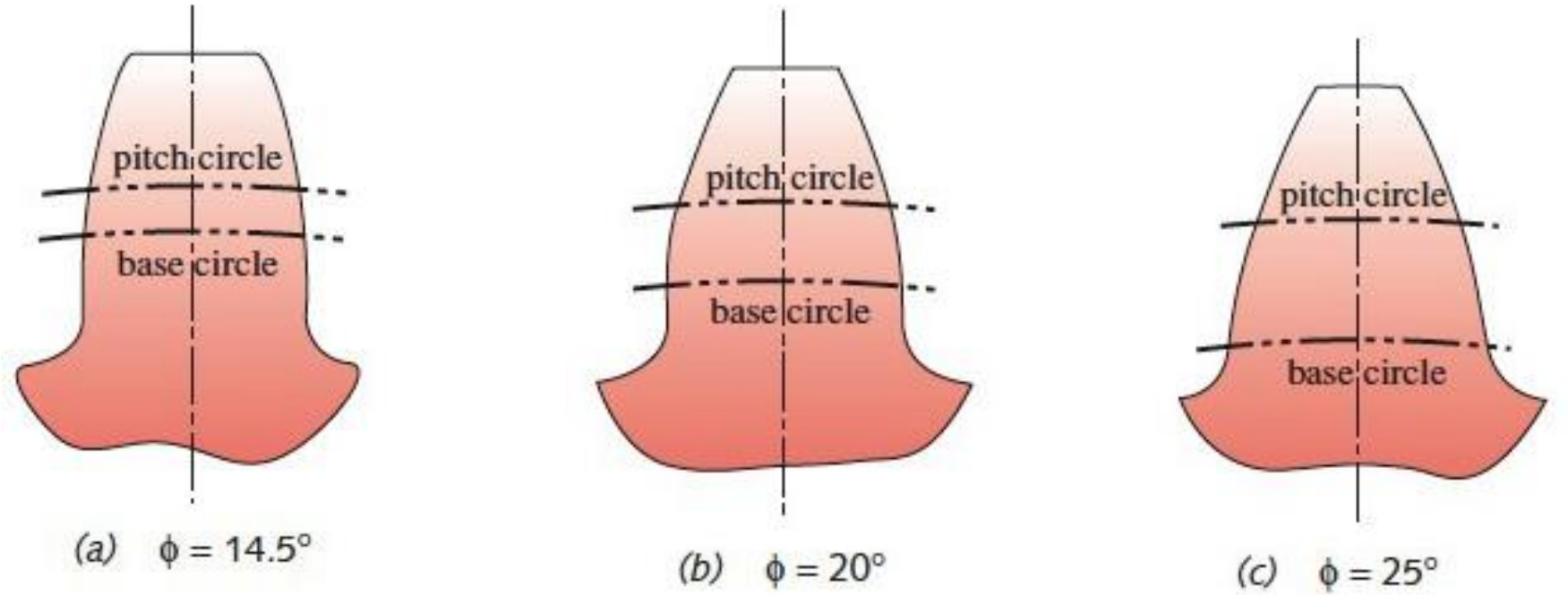


FIGURE 12-9

AGMA Full-Depth Tooth Profiles for Three Pressure Angles

Effect of diametral pitch

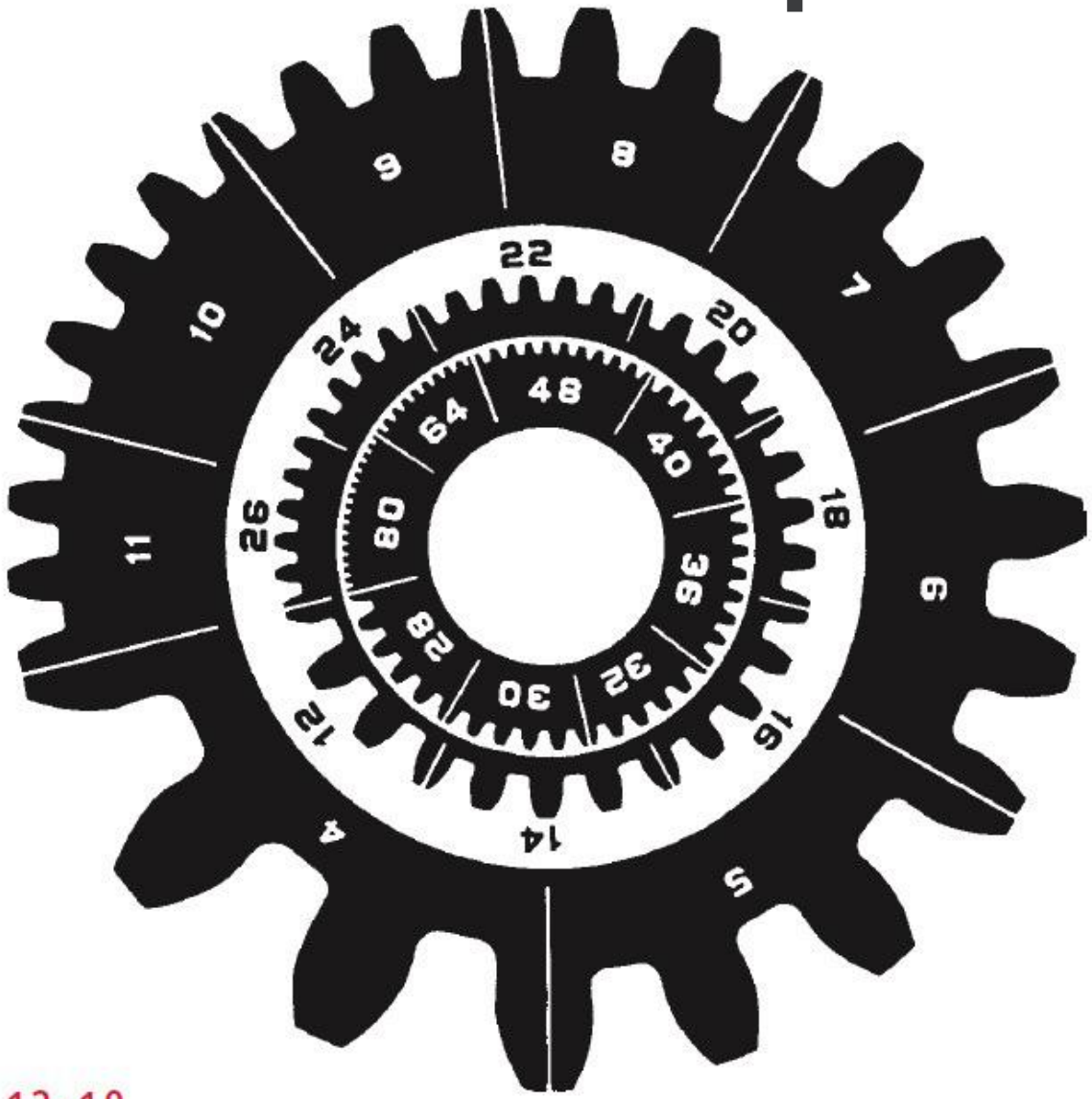


FIGURE 12-10

Actual Gear Tooth Sizes for Various Diametral Pitches *Courtesy of Barber-Colman Co., Loves Park, Ill.*

Table 12-1 AGMA Full-Depth Gear Tooth Specifications

Parameter	Coarse Pitch ($p_d < 20$)	Fine Pitch ($p_d \geq 20$)
Pressure angle ϕ	20° or 25°	20°
Addendum a	$1.000 / p_d$	$1.000 / p_d$
Dedendum b	$1.250 / p_d$	$1.250 / p_d$
Working depth	$2.000 / p_d$	$2.000 / p_d$
Whole depth	$2.250 / p_d$	$2.200 / p_d + 0.002$ in
Circular tooth thickness	$1.571 / p_d$	$1.571 / p_d$
Fillet radius—basic rack	$0.300 / p_d$	not standardized
minimum basic clearance	$0.250 / p_d$	$0.200 / p_d + 0.002$ in
minimum width of top land	$0.250 / p_d$	not standardized
Clearance (shaved or ground teeth)	$0.350 / p_d$	$0.350 / p_d + 0.002$ in

Table 12-2

Standard Diametral Pitches

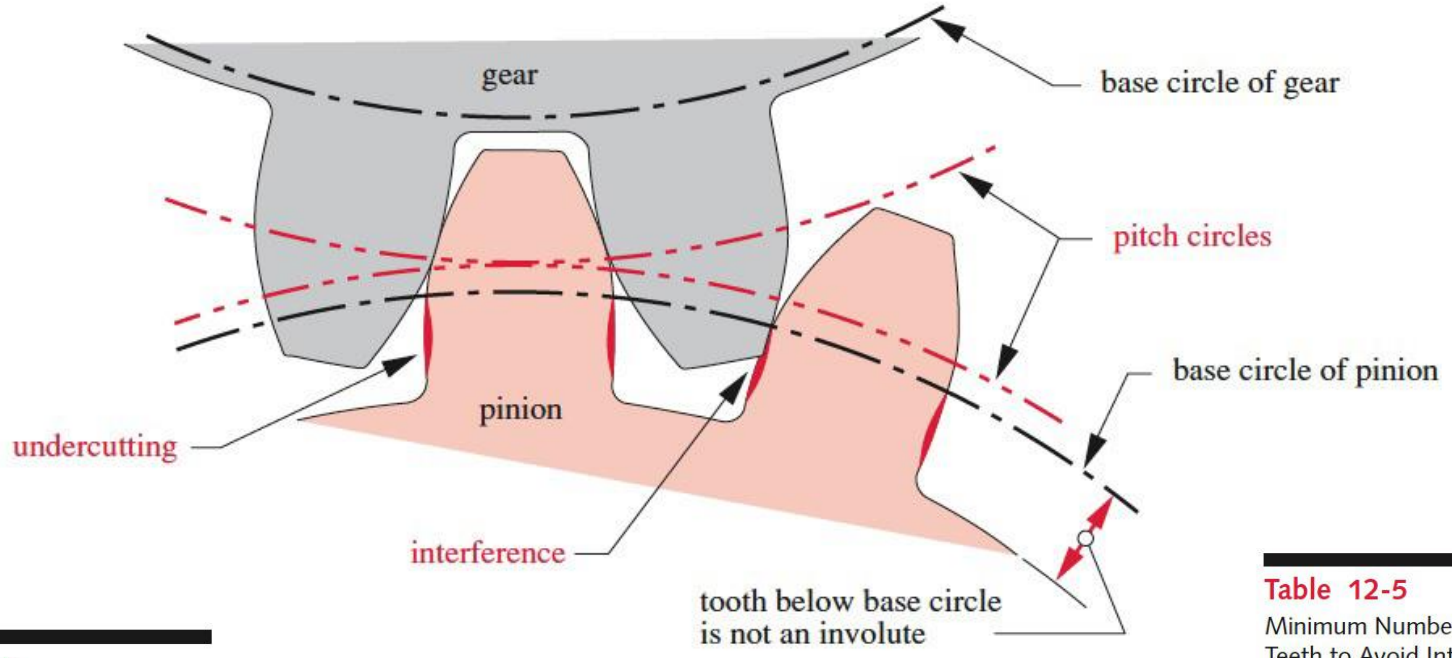
Coarse ($p_d < 20$)	Fine ($p_d \geq 20$)
1	20
1.25	24
1.5	32
1.75	48
2	64
2.5	72
3	80
4	96
5	120
6	
8	
10	
12	
14	
16	
18	

Table 12-3

Standard Metric Modules

Metric Module (mm)	Equivalent p_d (in^{-1})
0.3	84.67
0.4	63.50
0.5	50.80
0.8	31.75
1	25.40
1.25	20.32
1.5	16.93
2	12.70
3	8.47
4	6.35
5	5.08
6	4.23
8	3.18
10	2.54
12	2.12
16	1.59
20	1.27
25	1.02

Undercutting (interference)



eeth Below the Base Circle

Table 12-4
Minimum Number of Pinion Teeth to Avoid Interference Between a Full-Depth Pinion and a Full-Depth Rack

Pressure Angle (deg)	Minimum Number of Teeth
14.5	32
20	18
25	12

Table 12-5
Minimum Number of Pinion Teeth to Avoid Interference Between a 20° Full-Depth Pinion and Full-Depth Gears of Various Sizes

Minimum Pinion Teeth	Maximum Gear Teeth
17	1 309
16	101
15	45
14	26
13	16

Other gears:

- Helical
  - Parallel
  - Crossed
- Bevel
  - Straight
  - Spiral
- Worm

Parallel Helical Gears

- Quieter operation
- Less vibration
- Smoother gear contact
- Relatively Stronger

Parallel Axes
Opposite-handed mesh

Crossed Helical Gears

- Point Contact (instead of line)
- Not as strong as Parallel gears
- Useful for “turning” power transmission

Crossed Axes
Same-handed mesh

Helical Gears

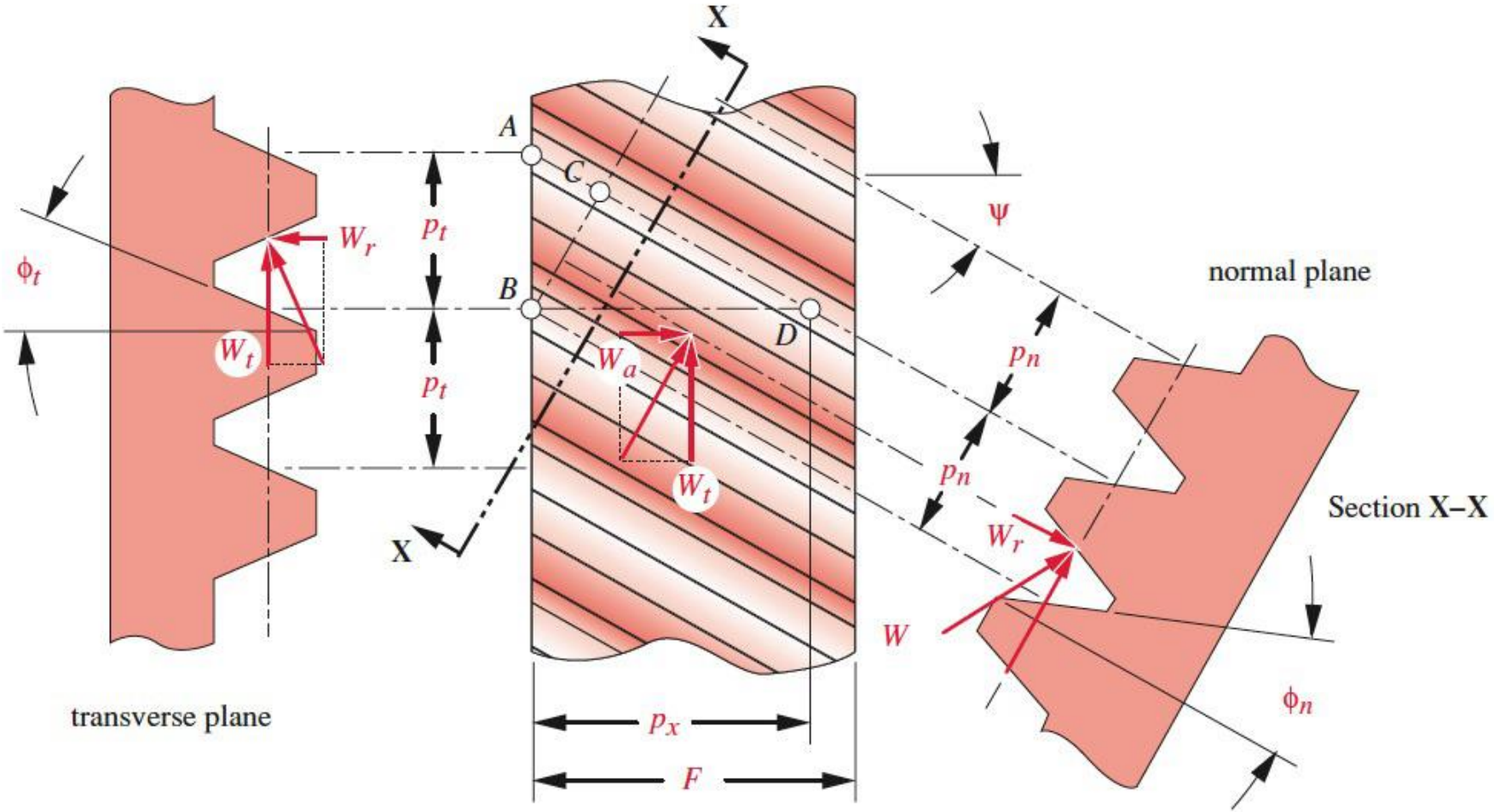
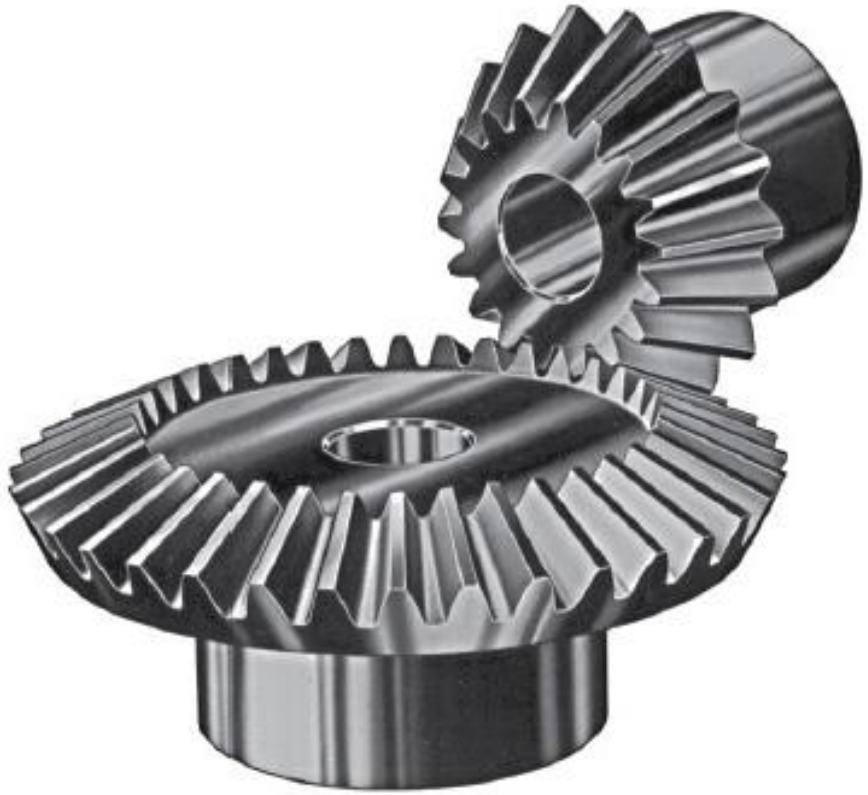


FIGURE 13-2

Basic Helical Rack Showing Normal and Transverse Planes and Resolution of Forces

Straight Bevel Gears

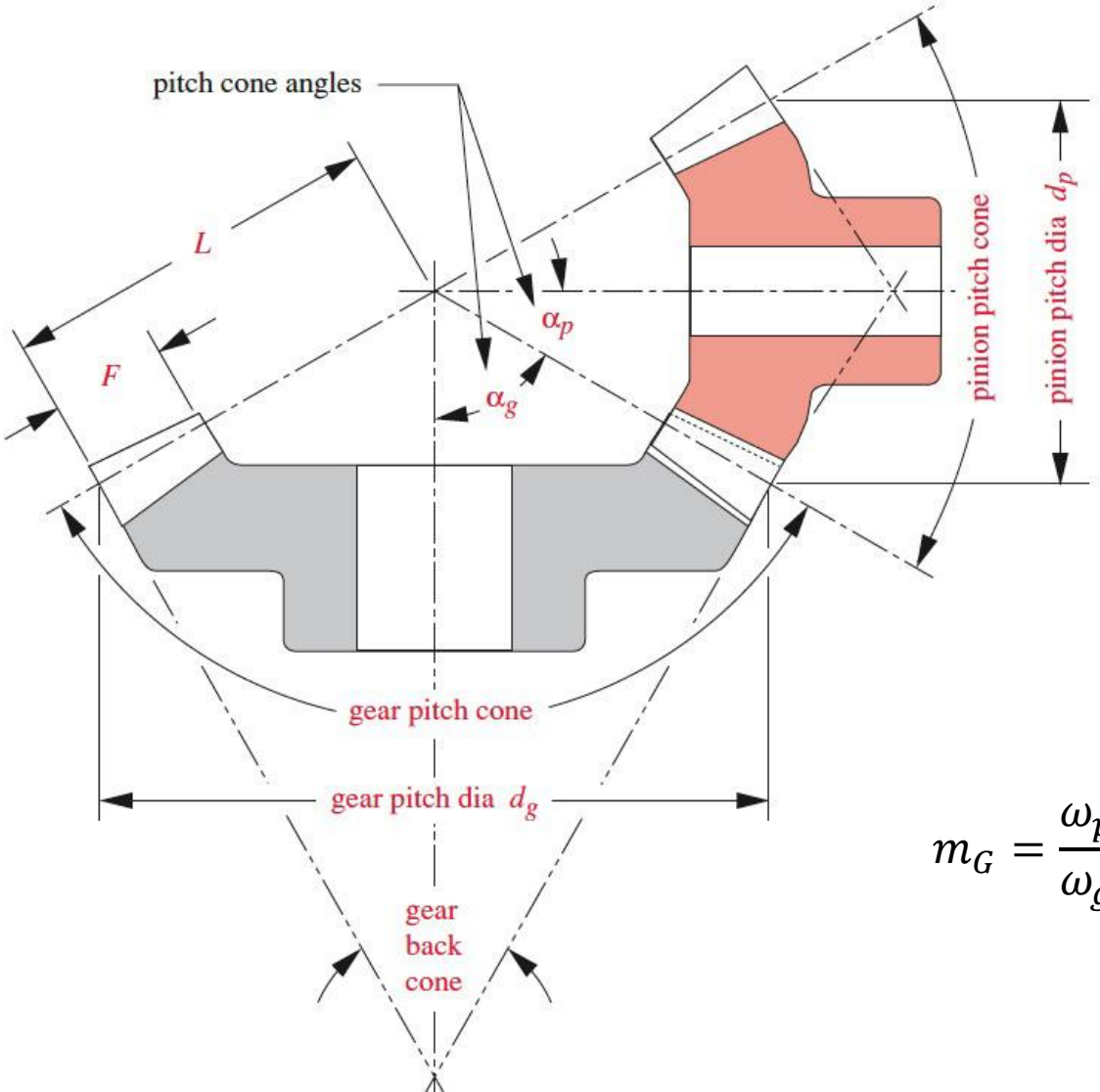
- Analogous to Spur Gears



Spiral Bevel Gears

- Analogous to Helical Gears

Bevel Gears



$$L = \frac{d_p}{2\sin\alpha_p} = \frac{d_g}{2\sin\alpha_g}$$

For a 90^o bevel set:

$$m_G = \frac{\omega_p}{\omega_g} = \frac{N_g}{N_p} = \frac{d_g}{d_p} = \tan\alpha_g = \cot\alpha_p$$

Worm Gearsets

- Worms often only have one tooth
- Analogous to Power Screws
- Worm typically requires hardened steel

$$p_x = \frac{L}{N_w} = p_c = \frac{\pi d_g}{N_g}$$

$p_x = axial\ pitch, L = Lead, N_w = \#\ of\ starts$

$p_c = circular\ pitch, d_g = pitch\ diameter, N_g = \#\ of\ teeth\ on\ the\ gear$

Recommended Speed Ratios

- Spur Gears: 10:1
- Helical Gears: 10:1
- Bevel Gears (speed reduction): 10:1
- Bevel Gears (speed increase): 5:1
- Worm Gears: up to 360:1
  - Common ratios range from 1:1 to 100:1