Gear Tooth Nomenclature

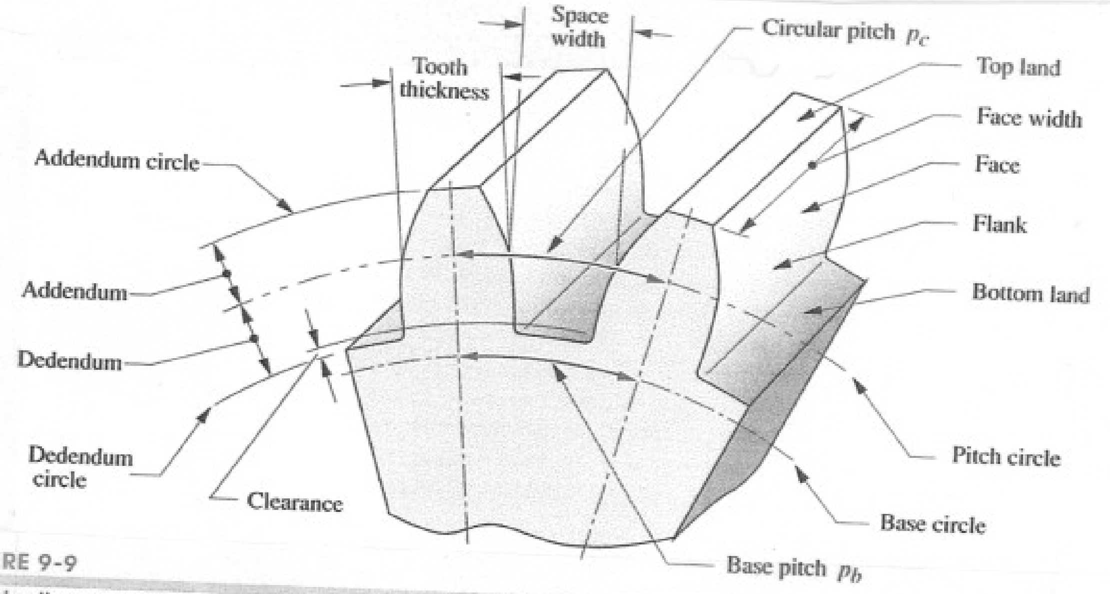

FIGURE 9-9
Gear tooth nomenclature

- Pitch circle - Is the circle that represents the size of corresponding rolling cylinders (pp. 8-1) that could replace the gear.
- Pitch point - Is the point of contact of the two pitch circles.
- Circular Pitch - Is the distance measured along the pitch circle from a point on one tooth to the corresponding point on the adjacent tooth of the gear.
- Face width - Is the length of the gear tooth parallel with the shaft axis.
- Addendum - Is the radial distance from the pitch circle to the top of the gear tooth.
- Dedendum - Is the radial distance from the pitch circle to the bottom of the gear tooth.
- Clearance - Is the amount the dedendum exceeds the addendum. This is the room between the top of the gear tooth and the bottom of the mating gear tooth.
- Tooth Thickness - Is the thickness of the tooth measured along the pitch circle.

The circular pitch is the arc length along the pitch circle from one tooth to the next

$$P_c = \frac{\pi d}{N}$$

d = diameter of the pitch circle
N = # of teeth (integer value)

- Diametral Pitch - is the # of teeth divided by pitch diameter

$$P_d = \frac{N}{d} = \frac{\pi}{P_c}$$

For metric gears, the "module" is the reciprocal of diametral pitch (in mm)

$$m = \frac{d}{N} = \frac{25.4}{P_d}$$ ← (inches)

Substituting the diametral pitch into the equations on p 8-3

$$\text{Velocity ratio} = m_V = \pm \frac{d_{in}}{d_{out}} = \pm \frac{N_{in}}{N_{out}}$$

$$\text{torque ratio} = m_T = \pm \frac{d_{out}}{d_{in}} = \pm \frac{N_{out}}{N_{in}}$$

- The diametral pitch can theoretically be any size, however there are standards prescribed by the American Gear Manufacturers Association (AGMA). The diametral pitch of meshing gears must be the same!

TABLE 9-1 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

- The standards are defined based on standard gear cutting tools.

Shapes of the gear teeth for three different pressure ∡'s 9-3

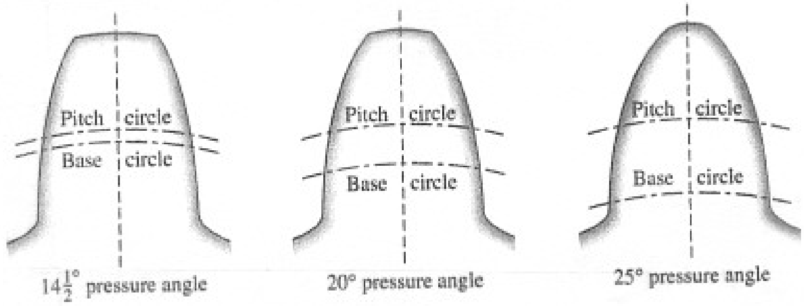

Figure 10.7 Pressure angle influence on tooth shapes.

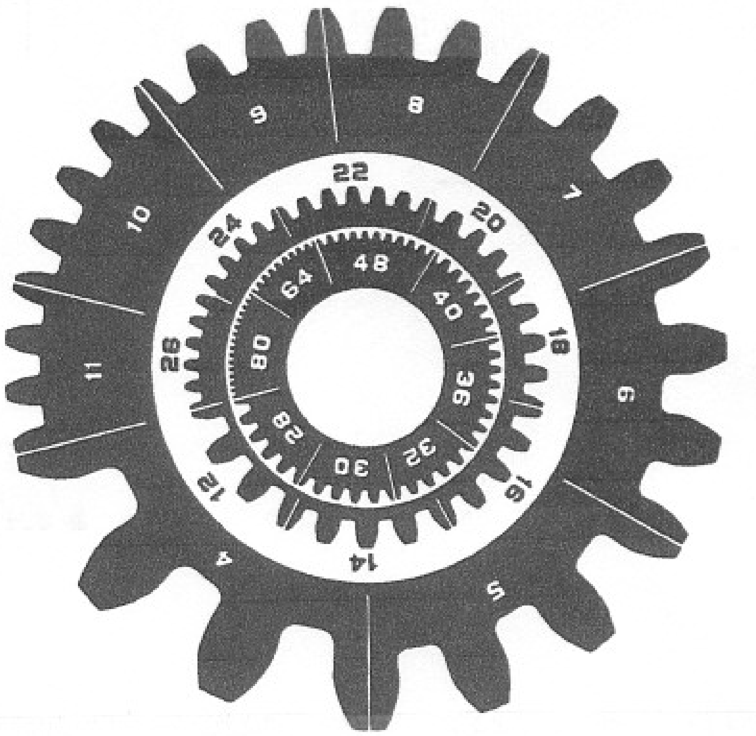

FIGURE 9-11

Actual tooth sizes for various diametral pitches *Courtesy of Barber-Colman Co., Loves Park, IL*

TABLE 9-2
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	

Interference - In some cases the dedendum will extend below the base circle. If so the portion of the tooth below the base circle will not be involute and will interfere with the tip of the mating tooth. The cutting tool will also interfere with the portion of the tooth below the base circle and will result in "undercutting". This problem can be prevented by avoiding gears with too few teeth.

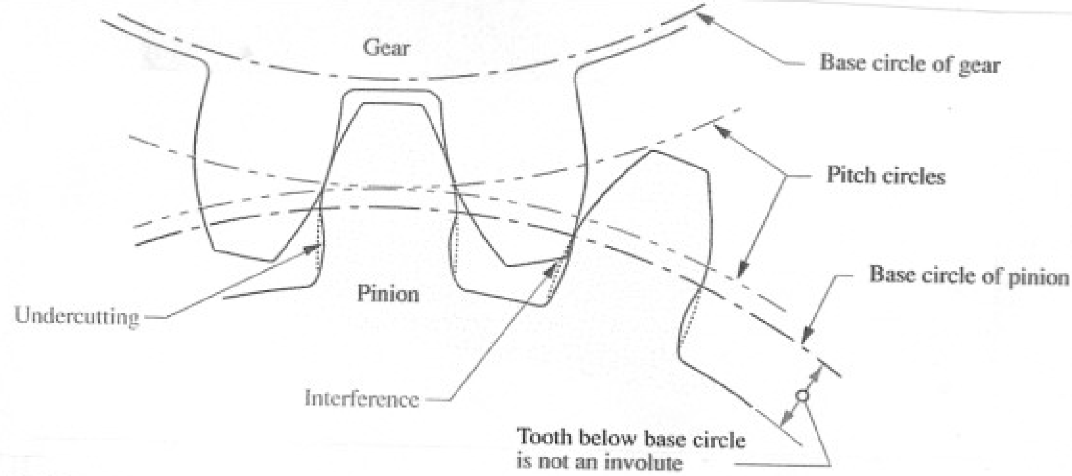

FIGURE 9-12
Interference and undercutting of teeth below the base circle

Table 9-4 and 9-5 (p 474-475) of Norton's text show the minimum number of pinion teeth and the maximum number of gear teeth to avoid undercutting.

Contact Ratio

- The contact ratio defines the average number of teeth in contact at any one time

$$\text{contact ratio} = m_p = \frac{Z}{p_b} = \frac{Z}{p_c \cos\phi} = \frac{P_d Z}{\pi \cos\phi}$$

base pitch ↗ (p_b)

where P_d = diametral pitch, p_c = circular pitch, ϕ = pressure ∡

Z = length of action = distance along the line of action between the begining and leaving contact points within the mesh (see p 8-4 for the definition of the terms)

$$Z = \sqrt{(r_p + a_p)^2 - (r_p\cos\phi)^2} + \sqrt{(r_g + a_g)^2 - (r_g\cos\phi)^2} - C\sin\phi$$

- If the contact ratio = 1, then one tooth is leaving contact just as the next is begining contact. This is not desirable because errors in tooth spacing will cause oscillations in the velocity, vibration and noise. →

→ For spur gears, the load will be applied at the tip of the tooth leading to a large bending moment and stress. The minimum acceptable contact ratio for smooth operation 1.2, but 1.4 or larger is better.

Example

A pinion with a diametral pitch of 6, 20° pressure angle, and 19 teeth is meshed with a 37 tooth gear.

Find: gear ratio, circular pitch, base pitch, pitch diameters, center distance, addendum, dedendum, whole depth, clearance outside diameter, contact ratio

Solution:

a) $m_G = \text{gear ratio} = \dfrac{N_{gear}}{N_{pinion}} = \dfrac{37}{19} = 1.947$

Note: the gear ratio is always > 1 $m_G = |m_V|$ or $|m_T|$

b) $\text{circular pitch} = P_c = \dfrac{\pi}{P_d} = \dfrac{\pi}{6} = 0.524 \text{ in.}$

c) $\text{base pitch} = P_c \cos\phi = 0.524 \cos(20°) = 0.492 \text{ in.}$

d) $\text{pinion pitch diameter} = d_p = \dfrac{\#\text{ of teeth}}{\text{diametral pitch}} = \dfrac{N_p}{P_d} = \dfrac{19}{6} = 3.167''$

$\text{gear pitch diameter} = d_g = \dfrac{N_g}{P_d} = \dfrac{37}{6} = 6.167''$

e) center distance = gear pitch radius + pinion pitch radius

$C = \dfrac{d_g}{2} + \dfrac{d_p}{2} = \dfrac{6.167}{2} + \dfrac{3.167}{2} = 4.667''$

f) To determine the addendum and dedendum we can use Table 9-1

$$a = \text{addendum} = \frac{1}{P_d} = \frac{1}{6} = 0.167''$$

$$b = \text{dedendum} = \frac{1.25}{P_d} = \frac{1.25}{6} = 0.208''$$

g) whole depth = $h_t = a + b = 0.167 + 0.208 = 0.375''$

h) clearance = $b - a = 0.208 - 0.167 = 0.042''$

working depth = whole depth − clearance = $0.375 - 0.042 = .333''$

i) outside diameter of pinion = $d_p + 2(a) = 3.167 + 2(.167) = 3.5''$

outside diameter of gear = $d_g + 2(a) = 6.167 + 2(.167) = 6.5''$

j) contact ratio = $\frac{P_d Z}{\pi \cos\phi} = \frac{Z}{P_b} = m_p$

$$Z = \sqrt{(r_p + a_p)^2 - (r_p \cos\phi)^2} + \sqrt{(r_g + a_g)^2 - (r_g \cos\phi)^2} - C\sin\phi$$

$$Z = \sqrt{(1.583 + 0.167)^2 - (1.583\cos 20^\circ)^2} + \sqrt{(3.083 + 0.167)^2 - (3.083\cos 20)^2}$$

$$- 4.667 \sin 20 = 0.798''$$

contact ratio = $m_p = \frac{Z}{P_b} = \frac{0.798}{0.492} = 1.62$ = contact ratio