

SPUR AND HELICAL GEARS

- 2.00** This section covers the recommended tooth proportions and design data for fine pitch spur and helical gears.
- 2.01 Basic Rack** — The basic rack shown in Figure 2.1 is used to illustrate the tooth proportions covered by this standard. When small numbers of teeth, or special center distance situations are encountered, it is intended that long and short addendum proportions be used. This standard permits freedom of choice in making minor changes in the tooth proportions to meet special design conditions as long as the resulting gears are fully conjugate to the basic rack. Such changes may be indicated when a special contact ratio or top land is desired.
- 2.02 Spur Gears** — The basic rack shown in Figure 2.1 and the tooth proportions shown in Table 2.1 provide the basic design data for spur gear teeth.
- 2.03 Helical Gears** — The helical teeth covered by this standard are conjugated in the normal plane to the basic rack shown in Figure 2.1 and Table 2.1.
- 2.04 Standard Center Distance** — Standard center distance is given by the equation shown in Table 2.1.

- 2.05 Center Distance Systems** — There are two center distance systems in use. These are the Standard Center Distance System and the Enlarged Center-Distance System. The choice of which is used will depend on the number of teeth in the meshing gears and on other design requirements. When an enlarged pinion is to be meshed with a gear at the center distance that is standard for the numbers of teeth, the gear diameter and tooth thickness must be decreased by the amount of the pinion enlargement. When two enlarged pinions or an enlarged pinion and a standard diameter gear are meshed together, the center distance must be greater than standard.
- 2.06 Standard Center-Distance System** — (Long and short addendums.) In this system the center of distance is made standard for the number of teeth, and the pressure angle remains constant. The outside diameter and root diameter of the gear is decreased the same amount that the pinion diameter is increased.

- 2.07 Spur Pinion Enlargement** — Enlargement of Spur Pinions of 20 Degree Pressure Angle and Diametral Pitches from 20 through 120. Spur pinions having fewer than the minimum numbers of teeth shown in Table 2.2 should be enlarged to avoid objectional undercut.* Pinions of 20 degree pressure angle should be enlarged in accordance with the recommendations given in Table 2.3. The mating gear or the center distance should be adjusted as discussed in paragraph 2.05. Pinions of finer than 120 diametral pitch require special consideration since the proportionally larger clearance requires hobs which tend to produce greater undercut. In general, pinions cut by the shaping process will not have as much undercut as those cut by hobbing.

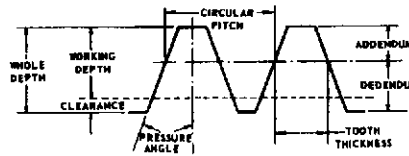


FIGURE 2.1 — BASIC RACK — (NORMAL PLANE)

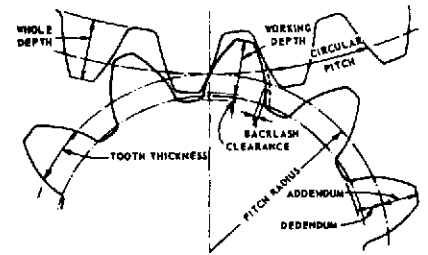


FIGURE 2.2 — SPUR, HELICAL, GEAR NOMENCLATURE

TABLE 2.1
TOOTH PROPORTIONS AND FORMULAS FOR
DIAMETERS AND STANDARD CENTER DISTANCE

(All values in millimeters)

TOOTH PROPORTIONS		
Item	Spur	Helical
Addendum (a)	M	M_n
Dedendum (b)	$M + c = 1.16M$	$M_n + c = 1.16M_n$
Working Depth (h_w)	2.000M	2.000 M_n
Whole Depth (h)	2.16M	2.16 M_n
Clearance (c)	.1M to .3M (.166M typically)	.1 M_n to .3 M_n (.166 M_n typically)
Tooth Thickness (t) at Pitch Diameter	$t = \frac{\pi M}{2}$	$t_n = \frac{\pi M_n}{2}$
FORMULAS		
Metric Module (M)	D/N	
Circular Pitch (p)	$p = \pi M$ or $\pi \frac{D}{N}$	$p_n = \pi M_n$ or $\pi \frac{D}{N}$
Pitch Diameter (D)	NM	$\frac{NM}{\cos \psi}$
Outside Diameter (D_o)	$(N + 2)M$	$\left(\frac{N}{\cos \psi} + 2 \right) M_n$
Center Distance (C)	$\frac{(N + n)M}{2}$	$\left(\frac{N + n}{2 \cos \psi} \right) M_n$

Where M = Metric Module
 M_n = Normal Metric Module
 t_n = Normal Tooth Thickness at Pitch Diameter
 p = Circular Pitch
 p_n = Normal Circular Pitch
 ψ = Helix Angle
 N = Number of Gear Teeth
 n = Number of Pinion Teeth
 D = Pitch Diameter

(All values in inches)

TOOTH PROPORTIONS		
Item	Spur	Helical
Addendum (a)	$\frac{1.000}{P}$	$\frac{1.000}{P_n}$
Dedendum (b)	$\frac{1.200}{P} + 0.002$ (min.)	$\frac{1.200}{P_n} + 0.002$ (min.)
Working Depth (h_w)	$\frac{2.000}{P}$	$\frac{2.000}{P_n}$
Whole Depth (h)	$\frac{2.200}{P} + 0.002$ (min.)	$\frac{2.200}{P_n} + 0.002$ (min.)
Clearance (c) (Standard)	$\frac{0.200}{P} + 0.002$ (min.)	$\frac{0.200}{P_n} + 0.002$ (min.)
(Shaved or Ground Teeth)	$\frac{0.350}{P} + 0.002$ (min.)	$\frac{0.350}{P_n} + 0.002$ (min.)
Tooth Thickness (t) at Pitch Diameter	$t = \frac{1.5708}{P}$	$t_n = \frac{1.5708}{P_n}$
FORMULAS		
Circular Pitch (p)	$p = \frac{\pi D}{N}$ or $\frac{\pi d}{n}$	$P_n = \frac{\pi}{P_n}$
Pitch Diameter Pinion (d)	$\frac{n}{P}$	$\frac{n}{P_n \cos \psi}$
Pitch Diameter Gear (D)	$\frac{N}{P}$	$\frac{N}{P_n \cos \psi}$
Outside Diameter Pinion (d_o)	$\frac{n + 2}{P}$	$\frac{1}{P_n} \left(\frac{n}{\cos \psi} + 2 \right)$
Outside Diameter Gear (D_o)	$\frac{N + 2}{P}$	$\frac{1}{P_n} \left(\frac{N}{\cos \psi} + 2 \right)$
Center Distance (C)	$\frac{N + n}{2P}$	$\frac{N + n}{2P_n \cos \psi}$

Where P = Transverse Diametral Pitch
 P_n = Normal Diametral Pitch
 t_n = Normal Tooth Thickness
 at Pitch Diameter
 P_n = Normal Circular Pitch
 ψ = Helix Angle
 n = Number of Pinion Teeth
 N = Number of Gear Teeth

TECHNICAL SECTION

SECTION 2. Basic Gear Formulas

SPUR AND HELICAL GEARS

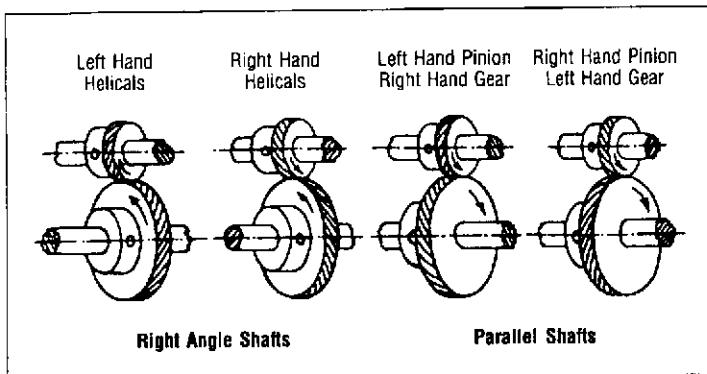


FIGURE 2.3 — HELICAL GEARS OF THE SAME HAND MESH AT RIGHT ANGLES
— HELICAL GEARS OF THE OPPOSITE HAND MESH ON PARALLEL SHAFTS

Any gear will mesh and run with any other gear of the same pitch. Recommend meshing stainless steel with aluminum gears for smoother running, longer life and silent operation. For best operation helical gears should run with thrust washers — see PIC standard stock thrust washers on page 6-11 and reference below.

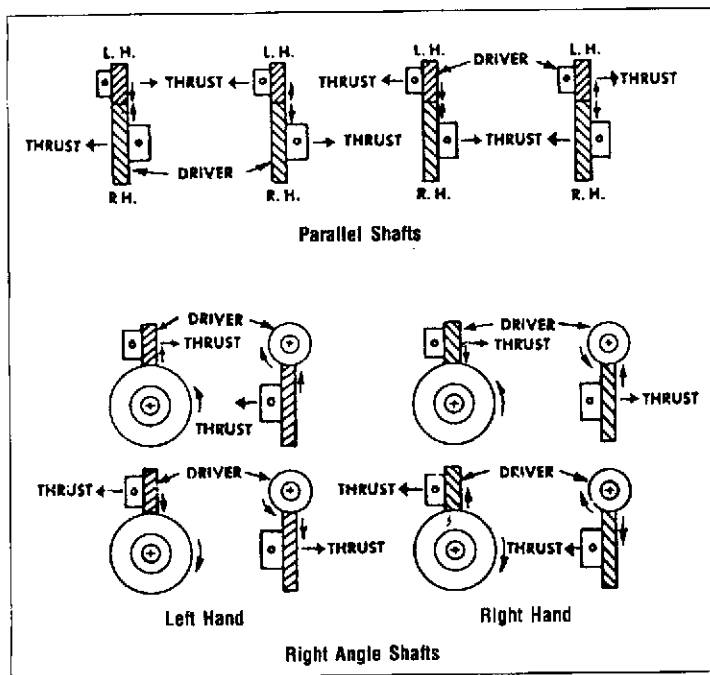


FIGURE 2.4 — THRUST LOADING DETAILS

TABLE 2.2
MINIMUM NUMBER OF PINION TEETH VS. PRESSURE ANGLE AND HELIX ANGLE
HAVING NO OBJECTIONABLE UNDERCUT

Helix Angle, Degrees	Minimum Number of Teeth to Avoid Undercut, Normal Pressure Angle, ϕ_n , degrees		
	14 1/2	20	25
0 (Spur Gears)	32	18	12
5	32	17	12
10	31	17	11
15	29	16	11
20	27	15	10
23	26	14	10
25	25	14	9
30	22	12	8
35	19	10	7
40	15	9	6
45	12	7	5

TABLE 2.3
20-DEGREE PRESSURE ANGLE INVOLUTE FINE-PITCH SYSTEM FOR MODIFIED
17 TEETH OR LESS SPUR PINIONS

(All tabular dimensions are given in inches for 1 diametral pitch. For other pitches divide tabular values by diametral pitch.)

Pinion Dimensions			Standard Center-Distance System (Long and Short Addendum) Gear Dimensions ¹				Enlarged Center-Distance System Standard Mating Gear Diameter ²	
Number of Teeth n	Outside Diameter	Cir. Tooth Thickness at Standard Pitch Diameter $\Delta t_p = \Delta d \tan \phi$	Decrease in Standard Outside Diameter	Cir. Tooth Thickness at Standard Pitch Diameter $\Delta t_g = \Delta D \tan \phi$	Recommended Minimum Number of Teeth (N)	Contact Ratio, n Mating With N ³	Increase Over Standard Center Distance	Contact Ratio Two Equal Pinions ³
10	12.8302	1.8730	0.8302	1.2686	33	1.419	0.4151	1.135
11	13.7132	1.8304	0.7132	1.3112	30	1.450	0.3566	1.186
12	14.5963	1.7878	0.5963	1.3538	27	1.473	0.2982	1.238
13	15.4793	1.7452	0.4793	1.3964	25	1.493	0.2397	1.290
14	16.3623	1.7027	0.3623	1.4389	23	1.508	0.1812	1.344
15	17.2453	1.6601	0.2453	1.4815	21	1.516	0.1227	1.398
16	18.1284	1.6175	0.1284	1.5241	19	1.519	0.0642	1.436
17	19.0114	1.5749	0.0114	1.5667	18	1.522	0.0057	1.511

The outside diameters of small pinions are enlarged to avoid undercut. Enlargements are based on addendum proportions of the basic rack, Figure 2.1, of $\frac{1.000}{P}$. When different proportions are used, the outside diameter must be adjusted accordingly.

- To maintain standard center distances when using enlarged pinions, the mating gear diameters must be decreased by the amount of the pinion enlargement.
- If mating gears are made with standard tooth proportions, the center distances must be increased as shown.
- Nominal Values: will vary due to effects of tolerances.

STRAIGHT BEVEL GEARS

- 2.08** This section covers recommended tooth proportions and dimensions of blanks for generated straight bevel gears of tooth ratios in general industrial use.
- 2.09 Bevel Gears** in this system have unequal addendums and unequal tooth thicknesses, except for pairs having equal numbers of teeth. This is different from the common practice for spur gearing. In bevel gear cutting, the tooth thickness is controlled by machine adjustments instead of by the tools, making it possible to obtain tooth thicknesses according to requirements for balance of strength in gear and pinion. Consideration has been given to both surface durability and beam strength in determining the tooth proportions.
- 2.10 An Advantage** in designing bevel gears according to this system is that tables are available giving tooth data and machine settings, thus minimizing calculations.* If other tooth designs are used, the data must be determined specially.
- 2.11 Angular Bevel Gears** are bevel gears whose shafts are set at an angle other than 90 degrees.
- 2.12 Backlash** — Table 2.4 gives the recommended backlash when the gear and pinion are finished and assembled ready to run. Quality numbers referred to in the Table are defined by the AGMA Gear Classification Manual, AGMA 390.02.

TABLE 2.4 RECOMMENDED BACKLASH

Diametral Pitch	Backlash	
	AGMA Quality Number	
	4 thru 6	7 thru 13
20 to 50	0.000 - 0.002	0.000 - 0.002
50 to 80	0.000 - 0.001	0.000 - 0.001
80 and finer	0.000 - 0.0007	0.000 - 0.0007

* These tables are available through Gleason Works, Rochester, New York.

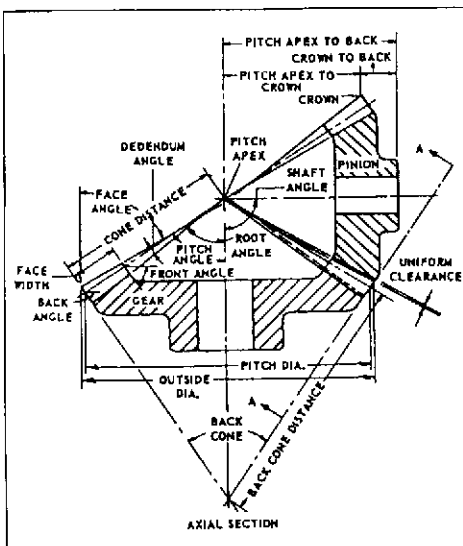


FIGURE 2.5 — BEVEL GEAR NOMENCLATURE

WORMGEARING

- 2.13 Wormgearing** is generally divided into two categories, fine-pitch worm gearing and coarse-pitch worm gearing. Fine-pitch worm gearing is segregated from coarse-pitch worm gearing for the following reasons:
- 2.14 Fine-Pitch Wormgears** are used largely to transmit motion rather than power. Tooth strength, except at the coarser end of the fine-pitch range, is seldom an important factor. Durability and accuracy, as they affect the transmission of uniform angular motion, are of greater importance. Housing constructions and lubricating methods are generally radically different in fine-pitch wormgearing.
- 2.15 Profile Deviations** and tooth bearings cannot be determined to the same degree of accuracy as those of coarse-pitch worms and wormgears, because of their small size.
- 2.16 Wormgear cutting equipment** generally available for fine-pitch gears has definite restrictions which limit the diameter and lead range, degree of accuracy and kind of tooth bearing obtainable.

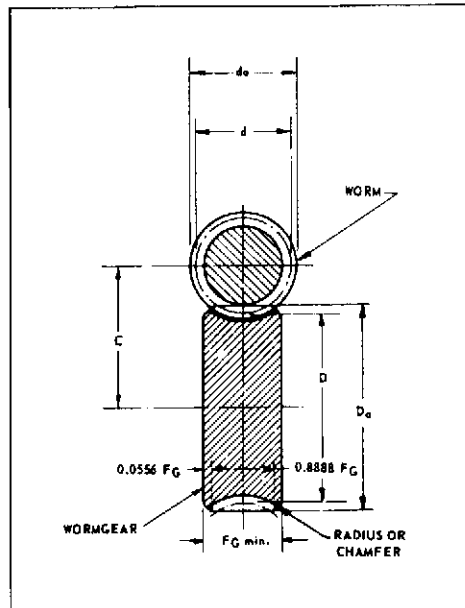


FIGURE 2.6 — WORM & WORMGEAR

- 2.17 Special Consideration** must be given to top lands in fine-pitch hardened worms and in gear cutting tools.
- 2.18 In Fine-Pitch Worms and Wormgears**, interchangeability and high production are important factors. Individual matching of the worm to the gear, as is frequently practiced with coarse-pitch precision worms, is impractical in the case of worms of fine pitch.
- 2.19 The Methods** of production and inspection of fine-pitch wormgears are generally different from those of coarse pitch.
- 2.20 Proportions** of worms and wormgears are given in Table 2.5. The pitch relations are expressed by the following formulas:

TABLE 2.5
PROPORTIONS OF FINE PITCH WORMS
AND WORMGEARS
Worm Dimensions

Term	Symbol	Formula (in.)
Lead	l	πP_x
Pitch Diameter	d	$1 + (\pi \tan \lambda)$
Outside Diameter	d_o	$d + 2a$
Safe Minimum Length of Threaded Portion of Worm	F_w	$\sqrt{D_o^2 - D^2}$

* This formula allows a sufficient length for fine-pitch worms.

Wormgear Dimensions

Pitch Diameter	D	$N_p + \pi$
Outside Diameter	D_o	$2C - d + 2a$
Minimum Face Width of Wormgear	$F_{g\ min}$	$1.125 \sqrt{(d_o + 2c)^2 - (d - 4a)^2}$

Data Relating to Worm and Wormgear

Addendum	a	$0.3183 P_n$
Whole Depth	h_i	$0.7003 P_n + 0.002$
Working Depth	h_k	$0.6366 P_n$
Clearance	c	$h_i - h_k$
Tooth Thickness	t	$0.5 P_n$
Approximate Normal Pressure Angle	ϕ_n	20 deg
Center Distance	C	$0.5 (d + D)$

Where p = Circular Pitch of Wormgear
 P_x = Axial Pitch of Worm
 P_n = Normal Circular Pitch of Worm and Wormgear
 $= P_x \cos \lambda = p \cos \psi$
 λ = Lead Angle of Worm
 ψ = Helix Angle of Wormgear
 n = Number of Threads in Worm
 N = Number of Teeth in Wormgear