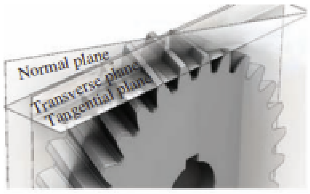
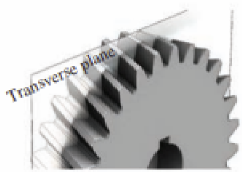
2.2 Helical Gears

2.2.1 Anatomy

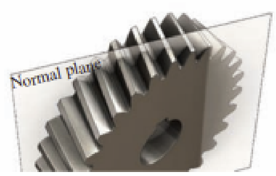


(a) The three primary planes defining helical gears

(b) The tangential plane only



(c) The transverse plane only



(d) The normal plane only

2.2.2 Nomenclature

N = number of teeth
D = pitch diameter (in)
p_t = transverse circular pitch (in)
p_n = normal circular pitch (in)
$P_d = P_t$ = diametral pitch (teeth/in)
$P_{nd} = P_n$ = normal diametral pitch (teeth/in)
p_x = axial pitch (in)
m = metric module
m_n = normal metric module
Face Contact Ratio = number of axial pitches in the face width
F = face width (in)
ψ = helix angle
ϕ_n = normal pressure angle
ϕ_t = transverse pressure angle
T = torque (lbf $\cdot$ in)
W_t = transmitted load (lbf)
W_a = axial load (lbf)
W_r = radial load (lbf)

2.2.3 Formulae

I have no clue. Use any of the random fucking formulas below to get an answer.

$$\text{angle relationship:} \quad \tan\phi_n = \tan\phi_t \cos\psi$$

$$\text{transverse circular pitch:} \quad p_t = \frac{\pi D_P}{N_P} = \frac{\pi D_G}{N_G} = \frac{\pi}{P_d}$$

$$\text{normal circular pitch: } p_n = p_t \cos\psi$$

$$\text{axial pitch: } p_x = \frac{p_t}{\tan\psi} = \frac{\pi P_d}{\tan\psi} = m\pi$$

$$\text{Face Contact Ratio} = \frac{F}{p_x} > 2.0$$

$$\text{diametral pitch: } P_d = \frac{N}{D}$$

$$\text{normal diametral pitch: } P_{nd} = \frac{P_d}{\cos\psi}$$

$$P_d p_t = \pi$$

$$P_{nd} p_n = \pi$$

$$\text{metric module: } m = \frac{D}{N}$$

$$\text{normal metric module: } m_n = \frac{1}{P_{nd}} = \frac{\cos\psi}{P_d} = \frac{D\cos\psi}{N} = m\cos\psi$$

$$W = \frac{W_t}{\cos\phi_n \cos\psi}$$

Forces and motion:

$$\text{torque: } T = \frac{63000P}{n}$$

$$\text{pitch line speed: } v_t = \frac{\pi D n}{12}$$

$$\text{tangential force: } W_t = \frac{33000P}{v_t} = \frac{126000P}{nD}$$

$$\text{radial force: } W_r = W_t \tan\phi_t$$

$$\text{axial force: } W_x = W_t \tan\psi$$

$$\text{bending stress number: } s_t = \frac{W_t P_d}{FJ} K_O K_s K_m K_B K_v$$

$$\text{contact stress number: } s_c = C_p \sqrt{\frac{W_t K_O K_s K_m K_v}{F D_p I}}$$

$$\text{allowable bending stress: } s_{at} > s_t \frac{(SF)K_R}{Y_N}$$

$$\text{allowable contact stress: } s_{ac} > s_c \frac{(SF)K_R}{Z_N}$$

2.2.4 Design Selection

1. Find the type of shock for input and output from this random place in the textbook:

   Uniform: Electric motor or constant-speed gas turbine

   Light shock: Water turbine, variable-speed drive

   Moderate shock: Multicylinder engine

   Examples of the roughness of driven machines include the following:

   Uniform: Continuous-duty generator, paper, and film winders.

   Light shock: Fans and low-speed centrifugal pumps, liquid agitators, variable-duty generators, uniformly loaded conveyors, rotary positive displacement pumps, and metal strip processing.

   Moderate shock: High-speed centrifugal pumps, reciprocating pumps and compressors, heavy-duty conveyors, machine tool drives, concrete mixers, textile machinery, meat grinders, saws, bucket elevators, freight elevators, escalators, concrete mixers, plastics molding and processing, sewage disposal equipment, winches, and cable reels.

   Heavy shock: Rock crushers, punch press drives, pulverizers, processing mills, tumbling barrels, wood chippers, vibrating screens, railroad car dumpers, log conveyors, lumber handling equipment, metal shears, hammer mills, commercial washers, heavy-duty hoists and cranes, reciprocating feeders, dredges, rubber processing, compactors, and plastics extruders.

2. Get the value of K_O from here

   TABLE 9–1 Suggested Overload Factors, K_o

	Driven Machine			
Power source	**Uniform**	**Light shock**	**Moderate shock**	**Heavy shock**
Uniform	1.00	1.25	1.50	1.75
Light shock	1.20	1.40	1.75	2.25
Moderate shock	1.30	1.70	2.00	2.75

3. Take a wild fucking guess for the value of P_{nd} and N_P. The one textbook example used $P_{nd} = 12$ and $N_P = 24$ so let's just use those every single time.

4. Compute P_d and p_x

$$P_d = P_{nd} \cos \psi$$

$$p_x = \frac{\pi}{P_d \tan\psi}$$

5. Assume that n_G is given. If not then refer to the steps in the spur gear design selection guide. Use the speed ratio to get the number of teeth in the gear.

$$VR = \frac{N_G}{N_P} = \frac{n_P}{n_G}$$

6. Compute the tangential pressure angle

$$\phi_t = \arctan\left(\frac{\tan\phi_n}{\cos\psi}\right)$$

7. Compute the diameters of the gears

$$D_P = \frac{N_P}{P_d}$$
$$D_G = \frac{N_G}{P_d}$$

8. Compute the nominal face width

$$F_{\text{nom}} = 2p_x$$

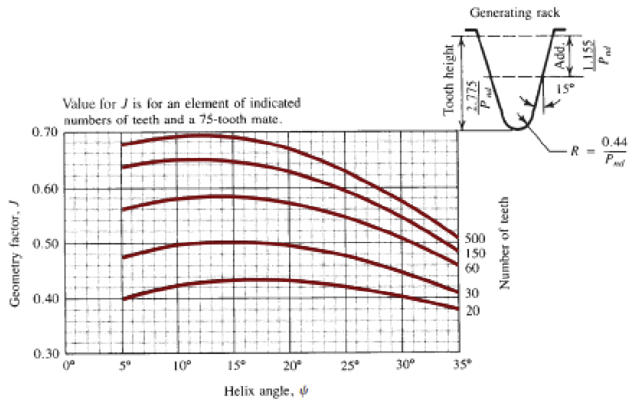
   Round it however you want so that the value is convenient.

9. Compute the center distance, pitch line speed, and transmitted load

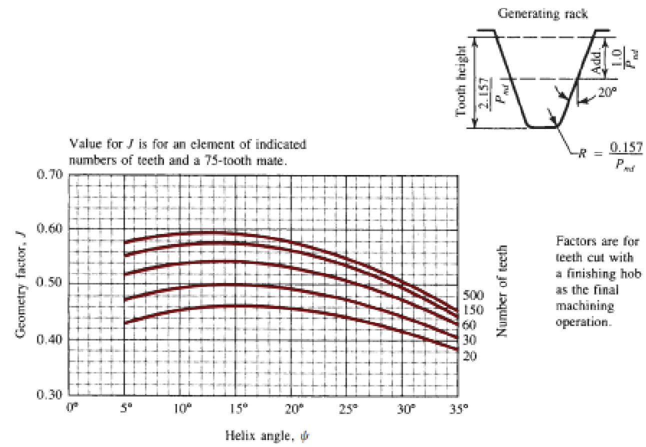
$$C = \frac{N_P + N_G}{2P_d}$$
$$v_t = \frac{\pi}{12} D_P n_P$$
$$W_t = \frac{33000P}{v_t}$$

10. Choose a material (steel) and follow the rest of the steps from the spur gear design selection to get values for $C_p, A_v, K_v, C_{pf}, C_{ma}, K_m, K_s, K_B, SF, K_R, N_c, Y_N, Z_N$.
    The only different constants will be J and I which can be gotten from the following steps.

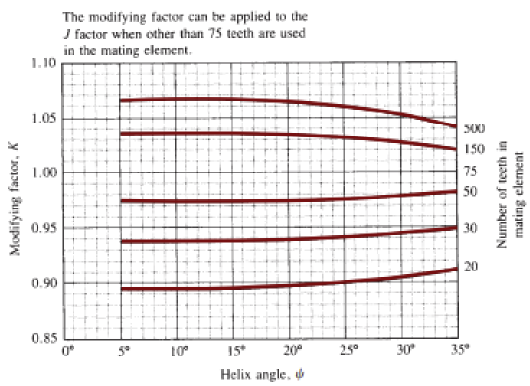
11. Choose the J_P and J_G values from one of the graphs depending on the normal pressure angle ϕ_n. (this is different from spur gears)



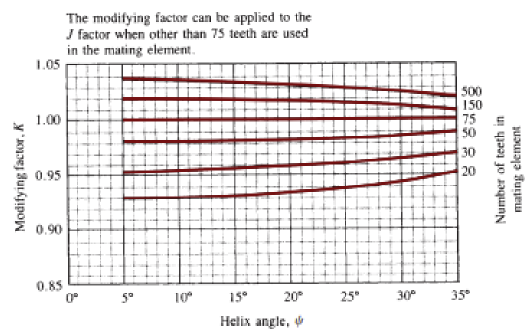
(a) Geometry factor (J) for 15° normal pressure angle and indicated addendum



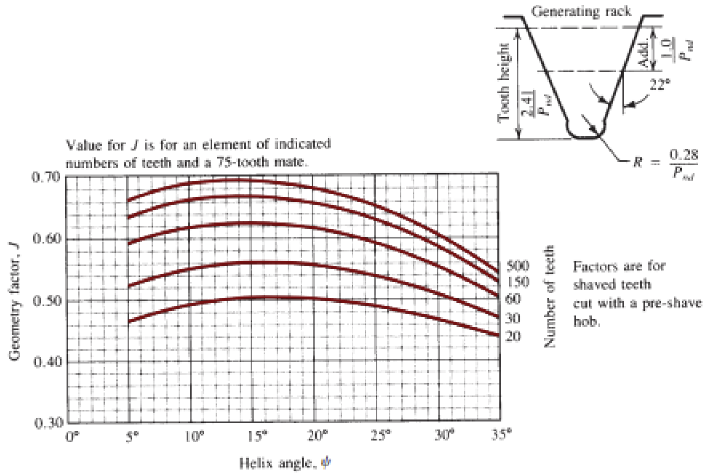
(a) Geometry factor (J) for 20° normal pressure angle, standard addendum, and finishing hob



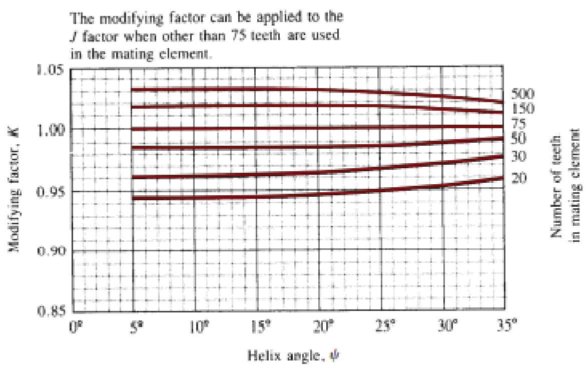
(b) J factor multipliers



(b) J factor multipliers



(a) Geometry factor (J), for 22° normal pressure angle, standard addendum, and pre-shave hob



(b) J factor multipliers

12. Choose the pitting geometry factor, I, from one of these tables.

TABLE 10–1 Geometry Factors for Pitting Resistance, *I*, for Helical Gears with 20° Normal Pressure Angle and Standard Addendum

A. Helix angle $\psi = 15.0°$

Gear teeth	Pinion teeth 17	21	26	35	55
17	0.124				
21	0.139	0.128			
26	0.154	0.143	0.132		
35	0.175	0.165	0.154	0.137	
55	0.204	0.196	0.187	0.171	0.143
135	0.244	0.241	0.237	0.229	0.209

B. Helix angle $\psi = 25.0°$

Gear teeth	Pinion teeth 14	17	21	26	35	55
14	0.123					
17	0.137	0.126				
21	0.152	0.142	0.130			
26	0.167	0.157	0.146	0.134		
35	0.187	0.178	0.168	0.156	0.138	
55	0.213	0.207	0.199	0.189	0.173	0.144
135	0.248	0.247	0.244	0.239	0.230	0.210

Source: Extracted from AGMA Standard 908-B89 (R 1999), *Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth,* with the permission of the publisher, American Gear Manufacturers Association, 1001 North Fairfax Street, 5th floor, Alexandria, VA 22314.

TABLE 10–2 Geometry Factors for Pitting Resistance, *I*, for Helical Gears with 25° Normal Pressure Angle and Standard Addendum

A. Helix angle $\psi = 15.0°$

Gear teeth	Pinion teeth 14	17	21	26	35	55
14	0.130					
17	0.144	0.133				
21	0.160	0.149	0.137			
26	0.175	0.165	0.153	0.140		
35	0.195	0.186	0.175	0.163	0.143	
55	0.222	0.215	0.206	0.195	0.178	0.148
135	0.257	0.255	0.251	0.246	0.236	0.214

B. Helix angle $\psi = 25.0°$

Gear teeth	Pinion teeth 12	14	17	21	26	35	55
12	0.129						
14	0.141	0.132					
17	0.155	0.146	0.135				
21	0.170	0.162	0.151	0.138			
26	0.185	0.177	0.166	0.154	0.141		
35	0.203	0.197	0.188	0.176	0.163	0.144	
55	0.227	0.223	0.216	0.207	0.196	0.178	0.148
135	0.259	0.258	0.255	0.251	0.246	0.235	0.213

Source: Extracted from AGMA Standard 908-B89, *Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth,* with the permission of the publisher, American Gear Manufacturers Association, 1001 North Fairfax Street, 5th floor, Alexandria, VA 22314.

13. Compute s_{tP} and s_{tG} and follow the remaining steps in the spur gear design selection guide.