AGMA 908–B89
(Revision of AGMA 226.01)

April 1989
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AMERICAN GEAR MANUFACTURERS ASSOCIATION

Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth

AGMA INFORMATION SHEET

(This Information Sheet is not an AGMA Standard)

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Suggestions for the improvement of this Standard will be welcome. They should be sent to the American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, Virginia 22314.

ABSTRACT:

This Information Sheet gives the equations for calculating the pitting resistance geometry factor, *I*, for external and internal spur and helical gears, and the bending strength geometry factor, *J*, for external spur and helical gears that are generated by rack–type tools (hobs, rack cutters or generating grinding wheels) or pinion–type tools (shaper cutters). The Information Sheet also includes charts which provide geometry factors, *I* and *J*, for a range of typical gear sets and tooth forms.

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FOREWORD

[The foreword, footnotes, and appendices are provided for informational purposes only and should not be construed as part of American Gear Manufacturers Association Information Sheet 908–B89, *Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth.*]

This Information Sheet, AGMA 908–B89, was prepared to assist designers making preliminary design studies, and to present data that might prove useful for those designers without access to computer programs. The tables for geometry factors contained in this Information Sheet do not cover all tooth forms, pressure angles, and pinion and gear modifications, and are not applicable to all gear designs. However, information is also contained for determining geometry factors for other conditions and applications. It is hoped that sufficient geometry factor data is included to be of help to the majority of gear designers.

Geometry factors for strength were first published in Information Sheet AGMA 225.01, March, 1959, *Strength of Spur, Helical, Herringbone and Bevel Gear Teeth.* Additional geometry factors were later published in Standards AGMA 220.02, AGMA 221.02, AGMA 222.02, and AGMA 223.01. AGMA Technical Paper 229.07, October, 1963, *Spur and Helical Gear Geometry Factors*, contained many geometry factors not previously published. Due to the number of requests for this paper, it was decided to publish the data in the form of an Information Sheet which became AGMA 226.01, *Geometry Factors for Determining the Strength of Spur, Helical, Herringbone and Bevel Gear Teeth*.

AGMA 218.01, *AGMA Standard for Rating the Pitting Resistance and Bending Strength of Spur and Helical Involute Gear Teeth*, was published with the methods for determining the geometry factors. When AGMA 218.01 was revised as ANSI/AGMA 2001–B88, the calculation procedures for Geometry Factors, I and J, were transferred to this revision of the Geometry Factor Information Sheet. The values of I and J factors obtained using the methods of this Information sheet are the same as those of AGMA 218.01. The calculation procedure for I was simplified, but the end result is mathematically identical. Also, the calculation of J was modified to include shaper cutters and an equation was added for the addendum modification coefficient, x, previously undefined and all too often misunderstood. Appendices have been added to document the historical derivation of both I and J.

Because an analytical method for calculating the Bending Strength Geometry Factor, J, is now available, the layout procedure for establishing J has been eliminated from this document. All references to geometry factors for bevel gears have been removed. This information is now available in AGMA 2003–A86, *Rating the Pitting Resistance and Bending Strength of Generated Straight Bevel, ZEROL Bevel and Spiral Bevel Gear Teeth.*

The first draft of this Information Sheet, AGMA 908–B89, was presented to the Gear Rating Committee in August, 1987. It was approved by the AGMA Gear Rating Committee on February 24, 1989, after several revisions. It was approved for publication by the AGMA Technical Division Executive Committee on April 21,1989.

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1. Scope

The procedures in this Information Sheet describe the methods for determining Geometry Factors for Pitting Resistance, I, and Bending Strength, J. These values are then used in conjunction with the rating procedures described in AGMA 2001–B88, *Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth*, for evaluating various spur and helical gear designs produced using a generating process.

1.1 Pitting Resistance Geometry Factor, *I*. A mathematical procedure is described to determine the Geometry Factor, I, for internal and external gear sets of spur, conventional helical and low axial contact ratio, LACR, helical designs.

1.2 Bending Strength Geometry Factor, *J*. A mathematical procedure is described to determine the Geometry Factor, J, for external gear sets of spur, conventional helical and low axial contact ratio, LACR, helical design. The procedure is valid for generated root fillets, which are produced by both rack and pinion type tools.

1.3 Tables. Several tables of precalculated Geometry Factors, I and J, are provided for various combinations of gearsets and tooth forms.

1.4 Exceptions. The formulas of this Information Sheet are not valid when any of the following conditions exist:

(1) Spur gears with transverse contact ratio less than one, $m_p < 1.0$.

(2) Spur or helical gears with transverse contact ratio equal to or greater than two, $m_p \geq 2.0$. Additional information on high transverse contact ratio gears is provided in Appendix F.

(3) Interference exists between the tips of teeth and root fillets.

(4) The teeth are pointed.

(5) Backlash is zero.

(6) Undercut exists in an area above the theoretical start of active profile. The effect of this undercut is to move the highest point of single tooth contact, negating the assumption of this calculation method. However, the reduction in tooth root thickness due to protuberance below the active profile is handled correctly by this method.

(7) The root profiles are stepped or irregular. The J factor calculation uses the stress correction factors developed by Dolan and Broghamer[1]. These factors may not be valid for root forms which are not smooth curves. For root profiles which are stepped or irregular, other stress correction factors may be more appropriate.

(8) Where root fillets of the gear teeth are produced by a process other than generating.

(9) The helix angle at the standard (reference) diameter* is greater than 50 degrees.

In addition to these exceptions, the following conditions are assumed:

(a) The friction effect on the direction of force is neglected.

(b) The fillet radius is assumed smooth (it is actually a series of scallops).

1.5 Bending Stress in Internal Gears. The Lewis method [2] is an accepted method for calculating the bending stress in external gears, but there has been much research [3] which shows that Lewis' method is not appropriate for internal gears. The Lewis method models the gear tooth as a cantilever beam and is most accurate when applied to slender beams (external gear teeth with low pressure angles), and inaccurate for short, stubby beams (internal gear teeth which are wide at their base). Most industrial internal gears have thin rims, where if bending failure occurs, the fatigue crack runs radially through the rim rather than across the root of the tooth. Because of their thin rims, internal gears have ring–bending stresses which influence both the magnitude and the location of the maximum bending stress. Since the boundary conditions strongly influence the ring–bending stresses, the method by which the internal gear is constrained must be considered. Also, the time history of the bending stress at a particular point on the internal gear is important because the stresses alternate from tension to compression. Because the bending stresses in internal gears are influenced by so many variables, no simplified model for calculating the bending stress in internal gears can be offered at this time.

[ ] Numbers in brackets refer to the bibliography.

* Refer to AGMA 112.05 for further discussion of standard (reference) diameters.

2. Definitions and Symbols

2.1 Definitions. The terms used, wherever applicable, conform to the following standards:

ANSI Y10.3–1968, *Letter Symbols for Quantities Used in Mechanics of Solids*

AGMA 112.05 *Gear Nomenclature (Geometry) Terms, Definitions, Symbols, and Abbreviations*

AGMA 600.01 *Metric Usage*

2.2 Symbols. The symbols used in the pitting resistance and bending strength formulas are shown in Table 2–1.

> **NOTE:** The symbols, definitions and terminology used in this Standard may differ from other AGMA standards. The user should not assume that familiar symbols can be used without a careful study of these definitions.

Units of measure are not shown in Table 2–1 because the equations are in terms of unity normal module or unity normal diametral pitch.

Table 2–1
Symbols Used in Equations

Symbols	Terms	Where First Used
B_n	normal operating circular backlash	Eq 6.7
C	standard center distance	Eq 6.4
$C_1, C_2, \cdots, C_6$	distances along line of action (Fig 3–1)	Eq 3.11–3.16
C_{n1}, C_{n4}, C_{n6}	distances along line of action of virtual spur gear	Eq 5.15–5.17
C_h	helical factor	Eq 5.69
C_r	operating center distance	Eq 3.7
C_ψ	helical overlap factor	Eq 4.1
D_{a1}, D_{a2}	addendum diameter, pinion and gear	Eq 7.1–7.2
d	pinion operating pitch diameter	Eq 4.1
F	effective face width	Eq 3.20
H	parameter for stress correction factor	Eq 5.72
h_{ao}	nominal tool addendum	Eq 5.36
h_F	height of Lewis parabola	Eq 5.62
I	pitting resistance geometry factor	Eq 4.1
J	bending strength geometry factor	Eq 5.1
J_1	adjusted geometry factor	Eq 7.6
J_s	geometry factor from table	Eq 7.6
K_f	stress correction factor	Eq 5.1
K_ψ	helix angle factor	Eq 5.77
L	parameter for stress correction factor	Eq 5.72
L_{min}	minimum length of contact lines	Eq 3.21
M	parameter for stress correction factor	Eq 5.72
m_F	axial contact ratio	Eq 3.20
m_G	gear ratio	Eq 3.1
m_N	load sharing ratio	Eq 3.24
m_n	normal module	Eq 7.9M
m_p	transverse contact ratio	Eq 3.18
n	virtual tooth number	Eq 5.2
n_o	virtual tooth number of tool	Eq 5.29
n_1	pinion tooth number	Eq 3.1
n_2	gear tooth number	Eq 3.1

Table 2-1 (cont)
Symbols Used in Equations

Symbols	Terms	Where First Used
n_a	fractional part of m_F	Eq 3.22
n_c	tool tooth number	Eq 5.29
n_r	fractional part of m_p	Eq 3.22
P_{nd}	normal diametral pitch	Eq 7.5
p_b	transverse base pitch	Eq 3.8
p_N	normal base pitch	Eq 3.9
p_x	axial pitch	Eq 3.19
R_1, R_2	standard pitch radii, pinion and gear	Eq 3.2–3.3
R_{b1}, R_{b2}	base radii, pinion and gear	Eq 3.5–3.6
R_{bc}	base radius of tool	Eq 5.34
R_c	standard pitch radius of tool	Eq 5.33
R_{m1}	mean radius of pinion	Eq 4.3
R_{o1}, R_{o2}	addendum radii, pinion and gear, internal and external	Eq 3.12, 3.15
R_{oc}	outside radius of tool	Eq 5.36
r_n, r_{n2}	reference pitch radii of virtual spur gear	Eq 5.3, 5.12
r''_n	generating pitch radius of virtual spur gear	Eq 5.51
r_{no}	reference pitch radius of virtual tool	Eq 5.30
r''_{no}	generating pitch radius of virtual tool	Eq 5.52
r^S_{no}	radius to center "S" of tool tip radius	Eq 5.39
r_{na}, r_{na2}	virtual outside radii	Eq 5.5, 5.14
r_{nb}, r_{nb2}	virtual base radii	Eq 5.4, 5.13
r_{nbo}	virtual base radii of tool	Eq 5.31
r_{nL}	virtual load radius	Eq 5.28
s_F	tooth thickness at critical section	Eq 5.72
s_n	reference normal circular tooth thickness	Eq 5.20
s_{n1}, s_{n2}	reference normal circular tooth thickness, pinion and gear	Eq 6.1–6.2
s_{na}	tooth thickness at outside diameter	Eq 7.9
s_{no}	reference normal circular tooth thickness of tool	Eq 5.35
s_{ns}	standard tooth thickness, thinned for backlash	Eq 7.6
u_s	stock allowance per side of tooth	Eq 5.37
x	addendum modification coefficient at zero backlash	Eq 5.19
x_1, x_2	addendum modification coefficient, pinion and gear	Eq 6.5
x_g	generating rack shift coefficient	Eq 5.19
x_o	addendum modification coefficient of tool	Eq 5.35
x_{g1}, x_{g2}	generating rack shift coefficient, pinion and gear	Eq 6.1–6.2
Y	tooth form factor	Eq 5.1
y	iteration function	Eq 5.63
y'	derivative of iteration function	Eq 5.64
Z	active length of line of action	Eq 3.17

Table 2-1 (cont)
Symbols Used in Equations

Symbols	Terms	Where First Used
α_n	angle of surface, normal	Eq 5.53
α_{n1}	iteration angle	Eq 5.65
β_n	angle between tangent to fillet and tooth center line	Eq 5.59
Δs_n	amount gear tooth is thinned for backlash	Eq 5.19
δ_o	amount of protuberance, tool	Eq 5.38
δ_{ao}	amount of effective protuberance, tool	Eq 5.38
η_n	ordinate of gear fillet curve	Fig 5-8
η_{nF}	ordinate of critical point "F"	Eq 5.61
θ_n	angular displacement of gear	Eq 5.57
θ_{no}	angular displacement of tool	Eq 5.56
K_F, K_S	distance from pitch point to points "F" and "S"	Eq 5.54, 5.55
λ_{ns}	angle to center "S" of tool tip radius	Eq 5.47
μ_{no}	auxiliary angle locating point "S"	Eq 5.53
ξ_n	abscissa of gear fillet curve	Fig 5-8
ξ_{nF}	abscissa of critical point "F"	Eq 5.60
ρ_1, ρ_2	radii of curvature of profiles at point of contact stress calculation	Eq 4.1
ρ_{m1}, ρ_{m2}	radii of curvature of profile at mean radius	Eq 4.8
ρ_{ao}	tool tip radius	Eq 5.39
ρ'_F	radius of curvature of fillet curve	Eq 5.66
ρ_F	minimum radius of curvature of fillet curve	Eq 5.68
ϕ	standard transverse pressure angle	Eq 3.4
ϕ_n	standard normal pressure angle	Eq 3.4
ϕ''_n	generating pressure angle	Eq 5.48
ϕ_{nL}	load angle	Eq 5.22
ϕ_{np}	pressure angle at radius where gear tooth is pointed	Eq 5.22
ϕ_{npo}	pressure angle at radius where tool tooth is pointed	Eq 5.43
ϕ_{nr}	operating normal pressure angle	Eq 3.28
ϕ_{ns}	pressure angle at point "S" on tool	Eq 5.40
ϕ_{nW}	pressure angle at load application point	Eq 5.10
ϕ_r	operating transverse pressure angle	Eq 3.7
ψ	standard helix angle	Eq 3.2
ψ_b	base helix angle	Eq 3.10
ψ_r	operating helix angle	Eq 3.27
ω	angle of inclination of helical contact line	Eq 5.70

SUBSCRIPTS

o	tool	n	normal or virtual spur gear
1	pinion	r	operating or running
2	gear	–	absence of a subscript indicates transverse

3. Basic Gear Geometry

The following equations apply to spur and helical gears where spur gearing is a particular case with zero helix angle. Where double signs are used (e.g., $\pm$), the upper sign applies to external gears and the lower sign applies to internal gears. The equations are derived in terms of unity normal module (m_n = 1.0) or unity normal diametral pitch and are valid for any consistent set of units. All angles are given in terms of radians, unless otherwise specified.

The following variables must be made dimensionless by dividing with the normal module, m_n, or multiplying with the normal diametral pitch, P_{nd}. (See AGMA 112.05 for definitions of m_n or P_{nd}). The variables to be adjusted are C_r, F, R_{o1}, R_{o2}, R_{oc}, R_c, h_{ao}, δ_o, ρ_{ao}, and Δs_n.

Gear ratio, m_G

$$m_G = \frac{n_2}{n_1} \qquad \text{(Eq 3.1)}$$

where

n_2 = gear tooth number

n_1 = pinion tooth number

Standard (reference) pitch radius, R_1

$$R_1 = \frac{n_1}{2 \cos \psi} \qquad \text{(Eq 3.2)}$$

where

ψ = standard helix angle

Standard (reference) pitch radius, R_2

$$R_2 = R_1 \, m_G \qquad \text{(Eq 3.3)}$$

Standard transverse pressure angle, ϕ

$$\phi = \tan^{-1}\left(\frac{\tan \phi_n}{\cos \psi}\right) \qquad \text{(Eq 3.4)}$$

where

ϕ_n = standard normal pressure angle*

Pinion base radius, R_{b1}

$$R_{b1} = R_1 \cos \phi \qquad \text{(Eq 3.5)}$$

Gear base radius, R_{b2}

$$R_{b2} = R_{b1} \, m_G \qquad \text{(Eq 3.6)}$$

Operating transverse pressure angle, ϕ_r

$$\phi_r = \cos^{-1}\left(\frac{R_{b2} \pm R_{b1}}{C_r}\right) \qquad \text{(Eq 3.7)}$$

where

C_r = operating center distance

Transverse base pitch, p_b

$$p_b = \frac{2 \pi R_{b1}}{n_1} \qquad \text{(Eq 3.8)}$$

Normal base pitch, p_N

$$p_N = \pi \cos \phi_n \qquad \text{(Eq 3.9)}$$

Base helix angle, ψ_b

$$\psi_b = \cos^{-1}\left(\frac{p_N}{p_b}\right) \qquad \text{(Eq 3.10)}$$

Figure 3–1 is a view of the line of action in the transverse plane. The lengths, C_1 through C_6, are derived from Fig 3–1. See 1.4 item (6), referencing exceptions regarding gear tooth undercut.

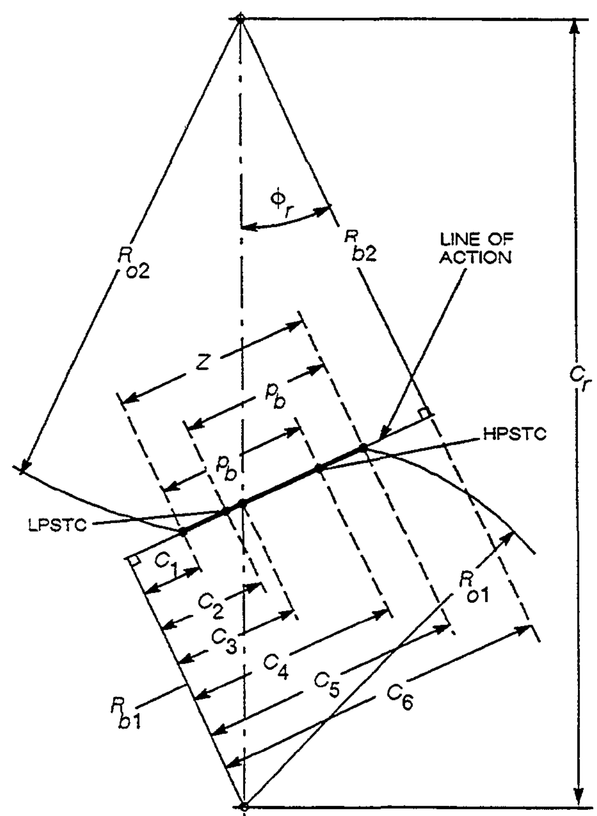


Fig 3–1 Transverse Plane View of The Line of Action

* For a complete discussion, see 9.01 of AGMA 112.05 *Gear Nomenclature (Geometry) Terms, Definitions, Symbols, and Abbreviations*

Sixth distance along line of action, C_6

$$C_6 = C_r \sin \phi_r \qquad \text{(Eq 3.11)}$$

First distance along line of action, C_1

$$C_1 = \pm [C_6 - (R_{o2}^2 - R_{b2}^2)^{0.5}] \qquad \text{(Eq 3.12)}$$

where

R_{o2} = addendum radius of gear, for internal or external gears

Third distance along line of action, C_3

$$C_3 = \frac{C_6}{m_G \pm 1} \qquad \text{(Eq 3.13)}$$

Fourth distance along line of action, C_4

$$C_4 = C_1 + p_b \qquad \text{(Eq 3.14)}$$

Fifth distance along line of action, C_5

$$C_5 = (R_{o1}^2 - R_{b1}^2)^{0.5} \qquad \text{(Eq 3.15)}$$

where

R_{o1} = addendum radius of pinion

Second distance along line of action, C_2

$$C_2 = C_5 - p_b \qquad \text{(Eq 3.16)}$$

Active length of line of contact, Z

$$Z = C_5 - C_1 \qquad \text{(Eq 3.17)}$$

Distance C_2 locates the lowest point of single tooth contact (LPSTC) and distance C_4 locates the highest point of single tooth contact (HPSTC), where C_r, R_{o1} and R_{o2} are values for $m_n = 1.0$.

3.1 Contact Ratios.

Transverse contact ratio, m_p

$$m_p = \frac{Z}{p_b} \qquad \text{(Eq 3.18)}$$

Axial pitch, p_x

$$p_x = \frac{\pi}{\sin \psi} \qquad \text{(Eq 3.19)}$$

Axial contact ratio, m_F

$$m_F = \frac{F}{p_x} \qquad \text{(Eq 3.20)}$$

where

F = effective face width at $m_n = 1.0$

For spur gears, $m_F = 0.0$

3.2 Minimum Length of the Lines of Contact.

For spur gears with $m_p < 2.0$ the minimum length of contact lines, $L_{\min}$, is:

$$L_{\min} = F \qquad \text{(Eq 3.21)}$$

For helical gears, two cases must be considered:

Case I, for $n_a \leq 1 - n_r$

$$L_{\min} = \frac{m_p F - n_a n_r p_x}{\cos \psi_b} \qquad \text{(Eq 3.22)}$$

Case II, for $n_a > 1 - n_r$

$$L_{\min} = \frac{m_p F - (1 - n_a)(1 - n_r)\, p_x}{\cos \psi_b} \qquad \text{(Eq 3.23)}$$

where

n_r = fractional part of m_p

n_a = fractional part of m_F

Example:

for a contact ratio, m_p, of 1.4, then $n_r = 0.4$

3.3 Load Sharing Ratio, m_N

For helical gears:

$$m_N = \frac{F}{L_{\min}} \qquad \text{(Eq 3.24)}$$

For spur gears with $m_p < 2.0$, (Eq 3.21) gives $L_{\min}$ = F, therefore:

$$m_N = 1.0 \qquad \text{(Eq 3.25)}$$

For LACR helicals, ($m_F \leq 1.0$), load sharing is accomodated by C_ψ, therefore:

$$m_N = 1.0 \qquad \text{(Eq 3.26)}$$

3.4 Operating Helix Angle, ψ_r

$$\psi_r = \tan^{-1}\left(\frac{\tan \psi_b}{\cos \phi_r}\right) \qquad \text{(Eq 3.27)}$$

3.5 Operating Normal Pressure Angle, ϕ_{nr}

$$\phi_{nr} = \sin^{-1}(\cos \psi_b \sin \phi_r) \qquad \text{(Eq 3.28)}$$

4. Pitting Resistance Geometry Factor, *I*

The pitting resistance geometry factor, *I*, is a dimensionless number. It takes into account the effects of:

(1) radii of curvature
(2) load sharing
(3) normal component of the transmitted load

4.1 Pitting Resistance Geometry Factor Calculation.

$$I = \frac{\cos \phi_r \; C_\psi^2}{\left(\frac{1}{\rho_1} \pm \frac{1}{\rho_2}\right) d \; m_N} \qquad \text{(Eq 4.1)}$$

where

ϕ_r = operating transverse pressure angle

C_ψ = helical overlap factor (See 4.4 and Appendix E)

d = pinion operating pitch diameter

m_N = load sharing ratio

ρ_1 = radius of curvature of pinion profile at point of contact stress calculation

ρ_2 = radius of curvature of gear profile at point of contact stress calculation

4.2 Operating Pitch Diameter of Pinion, *d*.

$$d = \frac{2\,C_r}{m_G \pm 1} \qquad \text{(Eq 4.2)}$$

where

m_G = gear ratio

4.3 Radii of Curvature of Profiles at Stress Calculation Point

4.3.1 Conventional Helical Gears. For conventional helical gears ($m_F > 1.0$) the radii of curvature are calculated at the mean radius or middle of the working profile of the pinion where:

Mean radius of pinion, R_{m1}

$$R_{m1} = \frac{1}{2}\left[R_{o1} \pm (C_r - R_{o2})\right] \qquad \text{(Eq 4.3)}$$

where

R_{o1} = addendum radius, pinion

R_{o2} = addendum radius, gear, internal or external

Radius of curvature of the pinion profile at the point of contact stress calculation, ρ_1

$$\rho_1 = \left(R_{m1}^2 - R_{b1}^2\right)^{0.5} \qquad \text{(Eq 4.4)}$$

where

R_{b1} = base radius, pinion

Radius of curvature of the gear profile at the point of contact stress calculation, ρ_2

$$\rho_2 = C_6 \mp \rho_1 \qquad \text{(Eq 4.5)}$$

where

C_6 = sixth distance along line of action (see Eq 3.11)

4.3.2 Spur and Low Axial Contact Ratio Helical Gears. For spurs and LACR helicals ($m_F \le 1.0$) the radii of curvature are calculated at the LPSTC

$$\rho_1 = C_2 \qquad \text{(Eq 4.6)}$$

where

C_2 = second distance along line of action (see Eq 3.16)

$$\rho_2 = C_6 \mp \rho_1 \qquad \text{(Eq 4.7)}$$

4.4 Helical Overlap Factor, C_ψ*

For LACR helical gears ($m_F \le 1.0$)

$$C_\psi = \left[1 - m_F\left(1 - \frac{\rho_{m1}\rho_{m2}\,Z}{\rho_1\,\rho_2\,p_N}\right)\right]^{0.5} \qquad \text{(Eq 4.8)}$$

where

Z = active length of line of action

p_N = normal base pitch

Radius of curvature of the pinion profile at the mean radius of the pinion, ρ_{m1}

$$\rho_{m1} = \left(R_{m1}^2 - R_{b1}^2\right)^{0.5} \qquad \text{(Eq 4.9)}$$

Radius of curvature of the gear profile at the mean radius of the gear, ρ_{m2}

$$\rho_{m2} = C_6 \mp \rho_{m1} \qquad \text{(Eq 4.10)}$$

For spurs and conventional helicals

$$C_\psi = 1.0 \qquad \text{(Eq 4.11)}$$

* See Appendix E for derviation of C_ψ.

5. Bending Strength Geometry Factor, *J*

The bending strength geometry factor, *J*, is a dimensionless number. It takes into account the effects of:

(1) shape of the tooth
(2) worst load position
(3) stress concentration
(4) load sharing between oblique lines of contact in helical gears

Both tangential (bending) and radial (compressive) components of the tooth load are included. This analysis applies to external gears only.

The *J* factor calculation procedure must be repeated for both the pinion and the gear using the appropriate dimensions for each.

$$J = \frac{Y\,C_\psi}{K_f\;m_N} \qquad \text{(Eq 5.1)}$$

where

Y = tooth form factor (See 5.13)

C_ψ = helical overlap factor (See 4.4)

K_f = stress correction factor (See 5.11)

m_N = load sharing ratio (See 3.3)

It is recognized that an anomaly exists when calculating the *J* factor for LACR gears where the value obtained may be greater than a conventional helical gear. For this reason, it is recommended that the *J* factor be calculated for both the LACR condition and as a conventional helical gear, using a value for *F* which is slightly greater than p_x. The resulting conservative value should be used unless otherwise justified.

5.1 Virtual Spur Gear. The following analysis is based on the work of Errichello [4] [5] [6].

Helical gears are considered to be virtual spur gears with the following virtual geometry:

Virtual tooth number, *n*

$$n = \frac{n_1}{\cos^3 \psi} \qquad \text{(Eq 5.2)}$$

Standard (reference) pitch radius of virtual spur gear, r_n

$$r_n = \frac{n}{2} \qquad \text{(Eq 5.3)}$$

Virtual base radius, r_{nb}

$$r_{nb} = r_n \cos \phi_n \qquad \text{(Eq 5.4)}$$

Virtual outside radius, r_{na}

$$r_{na} = r_n + R_{o1} - R_1 \qquad \text{(Eq 5.5)}$$

For spur gears, the actual geometry is used

$$n = n_1 \qquad \text{(Eq 5.6)}$$

$$r_n = R_1 \qquad \text{(Eq 5.7)}$$

$$r_{nb} = R_{b1} \qquad \text{(Eq 5.8)}$$

$$r_{na} = R_{o1} \qquad \text{(Eq 5.9)}$$

5.2 Pressure Angle at the Load Application Point. Spur gears develop the most critical stress when load is applied at the highest point of the tooth where a single pair of teeth is carrying all of the load. Spur gears having variations that prevent two pairs of teeth from sharing the load may be stressed most heavily when the load is applied at the tip. Table 5−1 has been used in previous standards to establish the variation in base pitch between the gear and pinion, which determines whether or not load sharing exists in steel spur gears. Values in excess of those shown in Table 5−1 require the use of tip loading.

Table 5−1
Limiting Variation in Action for Steel Spur Gears for Load Sharing
(Variation in Normal Base Pitch)

Number of Pinion Teeth	Maximum Allowable Variation in inches (mm), When Teeth Share Load — Load per Inch of Face (per mm of face)				
	500 lb (90 N)	1000 lb (175 N)	2000 lb (350 N)	4000 lb (700 N)	8000 lb (1400 N)
15	0.0004 (0.01)	0.0007 (0.02)	0.0014 (0.04)	0.0024 (0.06)	0.0042 (0.11)
20	0.0003 (0.01)	0.0006 (0.02)	0.0011 (0.03)	0.0020 (0.05)	0.0036 (0.09)
25	0.0002 (0.01)	0.0005 (0.01)	0.0009 (0.02)	0.0017 (0.04)	0.0030 (0.08)

For helical gears and spur gears that are analyzed where the load is applied at the tip of the tooth, the pressure angle at load application point, ϕ_{nW}, is given by:

$$\tan \phi_{nW} = \left[\left(\frac{r_{na}}{r_{nb}} \right)^2 - 1 \right]^{0.5} \qquad \text{(Eq 5.10)}$$

For spur gears, where the highest bending stress occurs when the load is at the highest point of single tooth contact (HPSTC), the pressure angle is given by:

$$\tan \phi_{nW} = \frac{C_4}{r_{nb}} \qquad \text{(Eq 5.11)}$$

Equation 5.11 may also be used for LACR helical gears, but distance C_4 must be based on the virtual spur gear. The following equations are developed from analogy with Eqs 3.3, 3.6, 3.11, 3.12, 3.14, 5.5 and 5.11.

Standard (reference) pitch radius of virtual spur gear, r_{n2}

$$r_{n2} = r_n \; m_G \qquad \text{(Eq 5.12)}$$

Virtual base radius, r_{nb2}

$$r_{nb2} = r_{nb} \; m_G \qquad \text{(Eq 5.13)}$$

Virtual outside radius, r_{na2}

$$r_{na2} = r_{n2} + R_{o2} - R_2 \qquad \text{(Eq 5.14)}$$

Sixth distance along line of action, C_{n6}, of virtual spur gear

$$C_{n6} = (r_{nb2} + r_{nb}) \tan \phi_{nr} \qquad \text{(Eq 5.15)}$$

First distance along line of action, C_{n1}, of virtual spur gear

$$C_{n1} = \left[C_{n6} - \left(r_{na2}^2 - r_{nb2}^2 \right)^{0.5} \right] \qquad \text{(Eq 5.16)}$$

Fourth distance along line of action, C_{n4}, of virtual spur gear

$$C_{n4} = C_{n1} + p_N \qquad \text{(Eq 5.17)}$$

The pressure angle at load application point, ϕ_{nW}

$$\tan \phi_{nW} = \frac{C_{n4}}{r_{nb}} \qquad \text{(Eq 5.18)}$$

5.3 Generating Rack Shift Coefficient. The generating rack shift coefficient, x_g, applies to the completely finished teeth. It includes the rack shift for addendum modification plus the rack shift for thinning the gear teeth to obtain backlash:

$$x_g = x - \frac{\Delta s_n}{2 \tan \phi_n} \qquad \text{(Eq 5.19)}$$

where

x = addendum modification coefficient at zero backlash

Δs_n = amount gear tooth is thinned for backlash

$$x = \frac{s_n + \Delta s_n - \pi/2}{2 \tan \phi_n} \qquad \text{(Eq 5.20)}$$

where

s_n = normal circular tooth thickness measured on the Standard (reference) pitch cylinder

$$s_n = \frac{\pi}{2} + 2 \, x_g \tan \phi_n \qquad \text{(Eq 5.21)}$$

5.4 Load Angle and Load Radius. Figure 5–1 defines the load angle, ϕ_{nL}, and the load radius, r_{nL}. The load is shown applied at an arbitrary point "W", such that:

$$\phi_{nL} = \tan \phi_{nW} - \text{inv} \, \phi_{np} \qquad \text{(Eq 5.22)}$$

where

ϕ_{np} = pressure angle at radius where gear tooth is pointed. see Fig 5–2

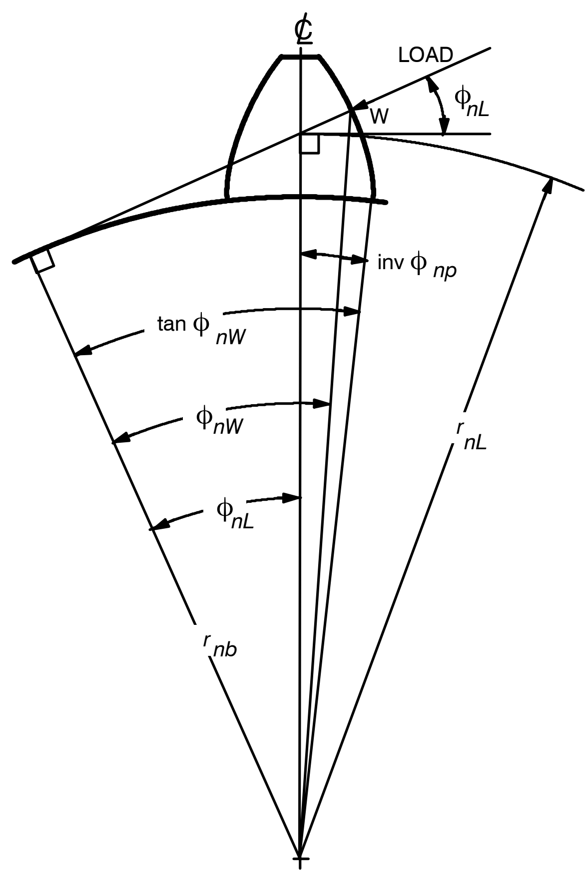


Fig 5–1 Load Angle and Load Radius

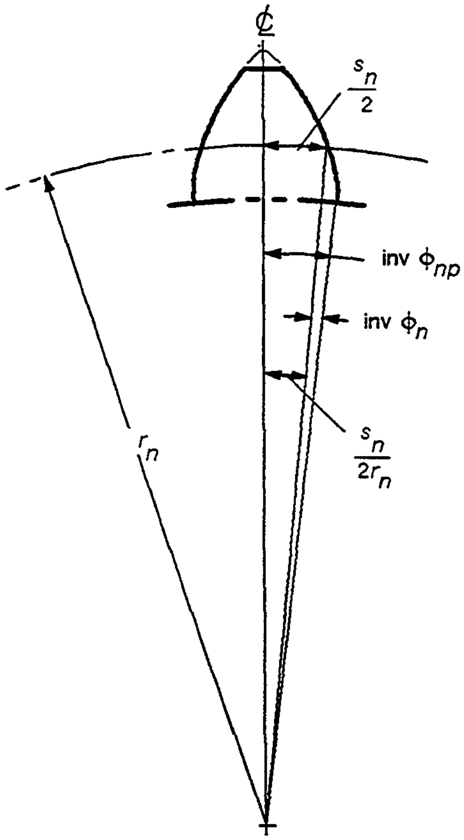


Fig 5-2 Pressure Angle Where Tooth Comes to Point

$$\text{inv}\,\phi_{np} = \text{inv}\,\phi_n + \frac{s_n}{2r_n} \quad \text{(Eq 5.23)}$$

but

$$\text{inv}\,\phi_n = \tan\phi_n - \phi_n \quad \text{(Eq 5.24)}$$

$$2r_n = n \quad \text{(Eq 5.25)}$$

$$\text{inv}\,\phi_{np} = \tan\phi_n - \phi_n + \frac{s_n}{n} \quad \text{(Eq 5.26)}$$

Substituting this value in Eq 5.22 gives:

$$\phi_{nL} = \tan\phi_{nW} - \tan\phi_n + \phi_n - \frac{s_n}{n} \quad \text{(Eq 5.27)}$$

Equation 5.27 gives the load angle for any load position specified by $\tan\phi_{nW}$.

From Fig 5-1, the virtual load radius, r_{nL}, is:

$$r_{nL} = \frac{r_{nb}}{\cos\phi_{nL}} \quad \text{(Eq 5.28)}$$

5.5 Tool Geometry. The following analysis is based on pinion type generating tools commonly referred to as shaper cutters. However, the method applies equally well to rack-type generating tools by letting the tooth number of the tool equal a large number such as n_c = 10 000. When exact cutter dimensions are not known, refer to Appendix D. Helical gears are considered to be generated by a virtual shaper cutter with the following virtual geometry:

Virtual tooth number of tool, n_o

$$n_o = \frac{n_c}{\cos^3\psi} \quad \text{(Eq 5.29)}$$

where

n_c = tool tooth number

Standard (reference) pitch radius of virtual tool, r_{no}

$$r_{no} = \frac{n_o}{2} \quad \text{(Eq 5.30)}$$

Virtual base radii of tool, r_{nbo}

$$r_{nbo} = r_{no}\cos\phi_n \quad \text{(Eq 5.31)}$$

For spur gears, the actual cutter geometry is used

$$n_o = n_c \quad \text{(Eq 5.32)}$$

$$r_{no} = R_c \quad \text{(Eq 5.33)}$$

where

R_c = standard pitch radius of tool

$$r_{nbo} = R_{bc} \quad \text{(Eq 5.34)}$$

where

R_{bc} = base radius of tool

Figure 5-3 shows a shaper cutter with protuberance, δ_o. A tool without protuberance is a particular case for which $\delta_o = 0$. The center of the tip radius, point "S", is located by radius r_{no}^s and angle $\lambda_{ns}/2$. The nominal tool addendum is h_{ao}. The reference addendum related to the virtual radius, r_{no}, is $h_{ao} + x_o$, where x_o is the addendum modification coefficient corresponding to the present sharpening condition of the cutter. The addendum modification coefficient of the tool, x_o, relates the actual normal circular tooth thickness of the tool, s_{no}, to the nominal value of $\pi/2$. If s_{no} is known from measurements of the tool, x_o may be calculated from:

$$x_o = \frac{s_{no} - \pi/2}{2 \tan \phi_n} \qquad \text{(Eq 5.35)}$$

where

s_{no} = reference normal circular tooth thickness of tool

NOTE: x_o is positive when $s_{no} > \pi/2$ (corresponding to a new shaper cutter), or negative when $s_{no} < \pi/2$ (corresponding to a used shaper cutter). Near the mid–life of the cutter, its tooth thickness equals $\pi/2$ and $x_o = 0.0$.

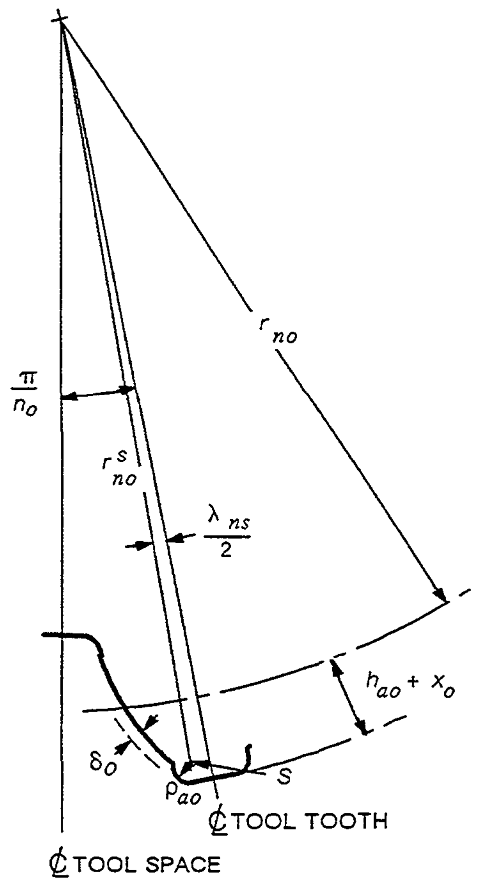


Fig 5–3 Shaper Cutter with Protuberance

The nominal tool addendum is defined as the addendum where the normal circular tooth thickness of the tool equals the nominal value of $\pi/2$. If the outside radius of the tool is known from measurements, the nominal tool addendum, h_{ao}, may be calculated from:

$$h_{ao} = R_{oc} - R_c - x_o \qquad \text{(Eq 5.36)}$$

where

R_{oc} = outside radius of tool

where s_{no}, u_s, R_{oc}, and R_c are values for $m_n = 1.0$.

Finishing hobs usually have $s_{no} = \pi/2$ in which case $x_o = 0$. A pre–grind hob which has teeth thinner than $\pi/2$ to provide stock allowance for grinding usually has a tooth thickness of:

$$s_{no} = \frac{\pi}{2} - 2u_s \qquad \text{(Eq 5.37)}$$

where

u_s = stock allowance per side of the gear tooth

Since u_s is removed during grinding, the basic rack corresponding to the finished gear teeth is used for the analysis; i.e., let $s_{no} = \pi/2$ and reduce the amount of protuberance:

$$x_o = 0$$

$$\delta_{ao} = \delta_o - u_s \cos \phi_n \qquad \text{(Eq 5.38)}$$

where

δ_{ao} = amount of effective protuberance, tool

δ_o = amount of protuberance, tool

from Fig 5–3

$$r^s_{no} = r_{no} + h_{ao} + x_o - \rho_{ao} \qquad \text{(Eq 5.39)}$$

where

r^s_{no} = radius to center "S" of tool tip radius

ρ_{ao} = tool tip radius

Figure 5–4 shows an involute drawn through point "S". The pressure angle at point "S" on tool, ϕ_{ns}, is:

$$\phi_{ns} = \cos^{-1}\left(\frac{r_{nbo}}{r^s_{no}}\right) \qquad \text{(Eq 5.40)}$$

$$\text{inv}\,\phi_{ns} = \tan \phi_{ns} - \phi_{ns} \qquad \text{(Eq 5.41)}$$

The reference circular tooth thickness of the cutter is:

$$s_{no} = \frac{\pi}{2} + 2x_o \tan \phi_n \qquad \text{(Eq 5.42)}$$

In Fig 5–5, ϕ_{npo} is the pressure angle where the cutter tooth comes to a point. It is given by:

$$\text{inv}\,\phi_{npo} = \text{inv}\,\phi_n + \frac{s_{no}}{2r_{no}} \qquad \text{(Eq 5.43)}$$

but:

$$\text{inv}\,\phi_n = \tan\phi_n - \phi_n \qquad \text{(Eq 5.44)}$$

$$2r_{no} = n_o \qquad \text{(Eq 5.45)}$$

$$\text{inv}\,\phi_{npo} = \tan\phi_n - \phi_n + \frac{s_{no}}{n_o} \qquad \text{(Eq 5.46)}$$

from Fig 5-6

$$\frac{\lambda_{ns}}{2} = \text{inv}\phi_{npo} - \text{inv}\,\phi_{ns} + \frac{(\delta_{ao} - \rho_{ao})}{r_{nbo}} \qquad \text{(Eq 5.47)}$$

where

λ_{ns} = angle to center "S" of tool tip radius

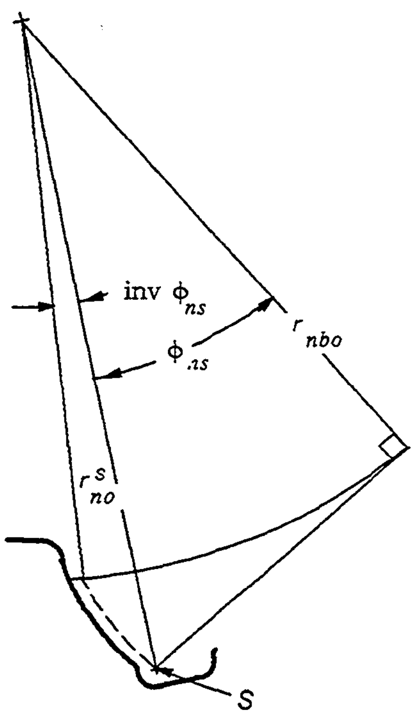


Fig 5-4 Involute Drawn Through Point "S"

5.6 Generating Pressure Angle. The generating pressure angle, ϕ_n'', depends on the virtual center distance between the cutter and the gear which is determined by x_g and x_o. The generating pressure angle, ϕ_n'', is obtained from:

$$\text{inv}\phi_n'' = \text{inv}\phi_n + \frac{2(x_g + x_o)\tan\phi_n}{n + n_o} \qquad \text{(Eq 5.48)}$$

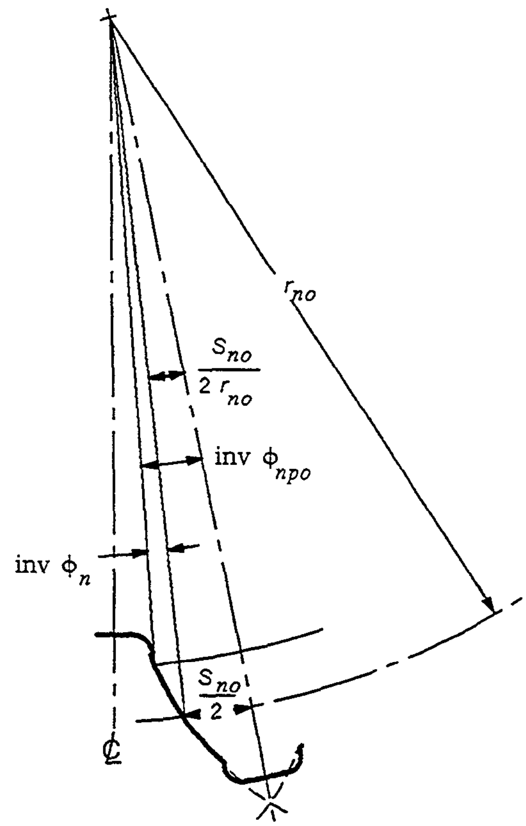


Fig 5-5 Pressure Angle Where Cutter Tooth Comes to a Point

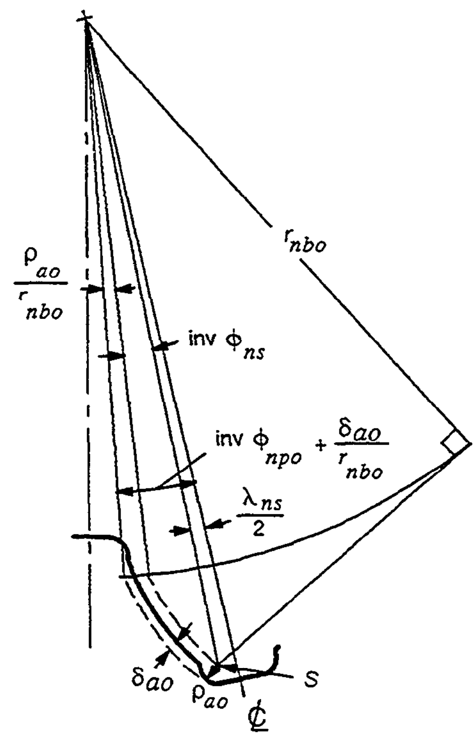


Fig 5-6 Angle to Center, *S*, of Tool Tip Radius (Effective Cutter)

Arc involute may be solved by iteration.[5] Let the first trial value for ϕ''_n be:

$$\phi''_{ni} = (3\ \text{inv}\ \phi''_n)^{0.33} \qquad \text{(Eq 5.49)}$$

This trial value is successively improved upon using:

$$\phi''_{n(i+1)} = \phi''_{ni} + \frac{\text{inv}\phi''_n + \phi''_{ni} - \tan\phi''_{ni}}{\tan^2\phi''_{ni}} \qquad \text{(Eq 5.50)}$$

5.6.1 Generating Pitch Radii. The generating pitch radius of virtual spur gear, r''_n, is:

$$r''_n = \frac{r_n \cos\phi_n}{\cos\phi''_n} \qquad \text{(Eq 5.51)}$$

The generating pitch radius of virtual tool, r''_{no}, is:

$$r''_{no} = \frac{r_{no} \cos\phi_n}{\cos\phi''_n} \qquad \text{(Eq 5.52)}$$

5.7 Algorithm for Determining the Critical Point. Figure 5–7 shows the critical point of maximum bending stress located at the intersection of the Lewis parabola and the gear tooth fillet. To locate this point, we consider the relative motion between the shaper cutter and the generated gear tooth. Figure 5–8 shows the shaper cutter generating an arbitrary point "F" on the gear tooth fillet. From the law of conjugate gear tooth action, point "F" lies on a line which extends from the generating pitch point "P" through the center of the tool tip radius, point "S". The fillet coordinates are best expressed by selecting the angle α_n as the independent parameter. Then for $\alpha_n = \pi/2$, generating starts at the lowest point on the fillet and proceeds up the fillet as α_n is diminished corresponding to clockwise rotation of the tool and counter-clockwise rotation of the gear.

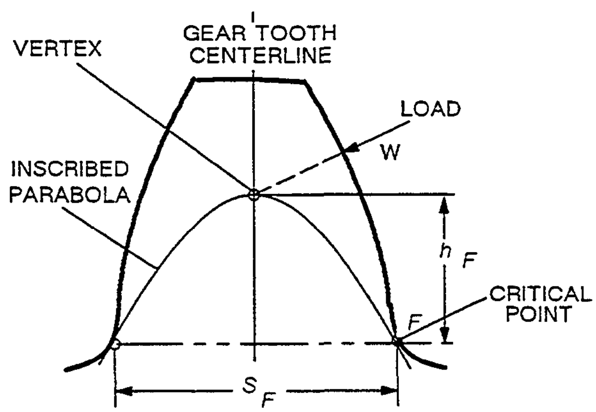


Fig 5–7 Critical Point of Maximum Bending Stress

From Fig 5–8 the auxiliary angle locating point "S", μ_{no}, is:

$$\mu_{no} = \cos^{-1}\left(\frac{r''_{no}\cos\alpha_n}{r^s_{no}}\right) - \alpha_n \qquad \text{(Eq 5.53)}$$

where

α_n = angle of surface normal

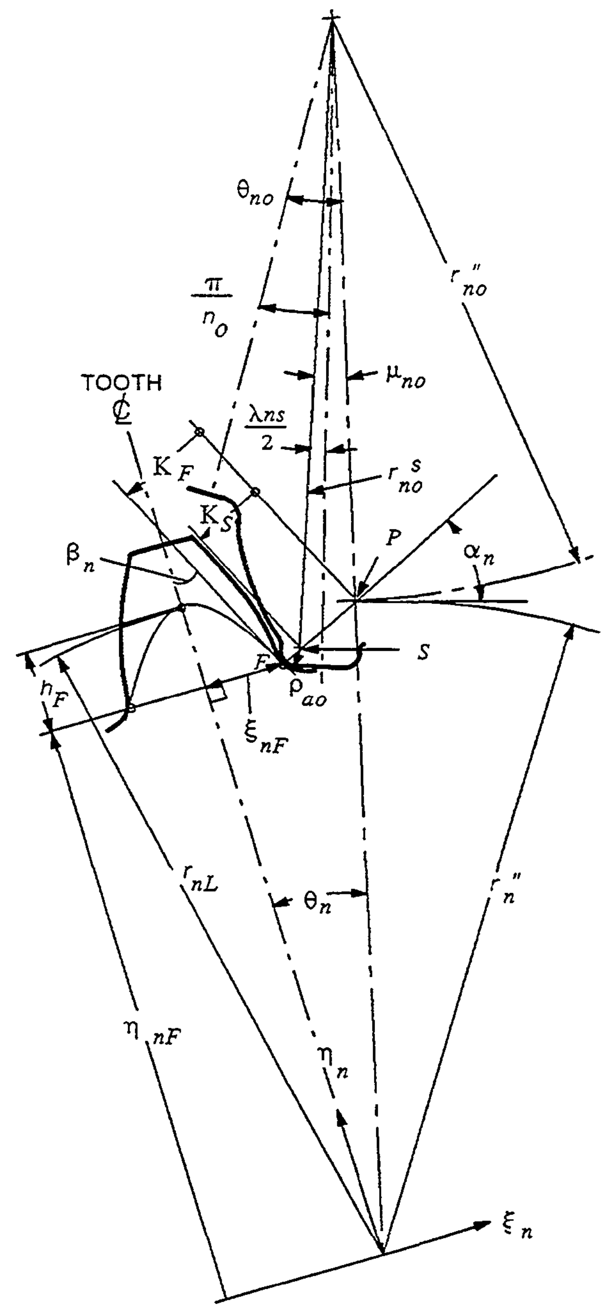


Fig 5–8 Shaper Cutter Generation

Distance from pitch point to point "S", K_S , is:

$$K_S = r''_{no} \sin \alpha_n - r^s_{no} \sin (\alpha_n + \mu_{no}) \qquad \text{(Eq 5.54)}$$

The distance from pitch point to point "F", K_F, is:

$$K_F = K_S - \rho_{ao} \qquad \text{(Eq 5.55)}$$

K_F and K_S are vectors and may be positive or negative.

The angular displacement of tool, θ_{no}, is:

$$\theta_{no} = \mu_{no} - \frac{\lambda_{ns}}{2} + \frac{\pi}{n_o} \qquad \text{(Eq 5.56)}$$

The gear rotation angle is:

$$\theta_n = \frac{n_o}{n} \theta_{no} \qquad \text{(Eq 5.57)}$$

where

θ_n = angular displacement of gear

$$\theta_n = \frac{n_o}{n} \left(\mu_{no} - \frac{\lambda_{ns}}{2} + \frac{\pi}{n_o} \right) \qquad \text{(Eq 5.58)}$$

The slope of the line tangent to the fillet at point "F" is:

$$\beta_n = \alpha_n - \theta_n \qquad \text{(Eq 5.59)}$$

where

β_n = angle between tangent to fillet and tooth center line

The coordinates of critical point "F" are:

The abscissa of critical point "F", ξ_{nF}

$$\xi_{nF} = r''_n \sin \theta_n + K_F \cos \beta_n \qquad \text{(Eq 5.60)}$$

The ordinate of critical point "F", η_{nF}

$$\eta_{nF} = r''_n \cos \theta_n + K_F \sin \beta_n \qquad \text{(Eq 5.61)}$$

Let

$$h_F = r_{nL} - \eta_{nF} \qquad \text{(Eq 5.62)}$$

For point "F" to be on the Lewis parabola, the following equation must be satisfied:

$$y = 2 h_F \tan \beta_n - \xi_{nF} = 0 \qquad \text{(Eq 5.63)}$$

where

y = iteration function

h_F = height of Lewis parabola

Differentiating Eq 5.63 gives:

$$y' = \frac{2 h_F}{\cos^2 \beta_n} - K_F \sin \beta_n + \frac{n_o}{n} \left[\frac{r''_{no} \sin \alpha_n}{r^s_{no} \sin (\alpha_n + \mu_{no})} - 1 \right] \left\{ 2 \xi_{nF} \tan \beta_n - \eta_{nF} - \frac{2 h_F}{\cos^2 \beta_n} \right\} - r''_{no} \left[\cos \alpha_n - \frac{\sin \alpha_n}{\tan (\alpha_n + \mu_{no})} \right] \left\{ \frac{1 + \sin^2 \beta_n}{\cos \beta_n} \right\} \qquad \text{(Eq 5.64)}$$

where

y' = derivative of iteration function

Assuming an initial approximation for $\alpha_n = \pi/4$, it is successively improved upon by using Newton's Method of iteration.

$$\alpha_{n1} = \alpha_n - \frac{y}{y'} \qquad \text{(Eq 5.65)}$$

On each iteration, α_n is set equal to α_{n1} and Eq 5.53 through Eq 5.65 are iterated until $|y|$ in Eq 5.63 is a negligible tolerance.

5.8 Iteration Convergence. Equation 5.63, expressing the function $y = f(\alpha_n)$, is plotted in Fig 5-9 for a typical case. By selecting $\alpha_n = \pi/4$ as the initial approximation, rapid convergence to the proper root is obtained, usually within 3 to 5 iterations. This choice for the initial value prevents convergence to the incorrect root which exists closer to $\alpha_n = 0$. This incorrect root corresponds to the case where the Lewis parabola is inverted, opening upward rather than downward.

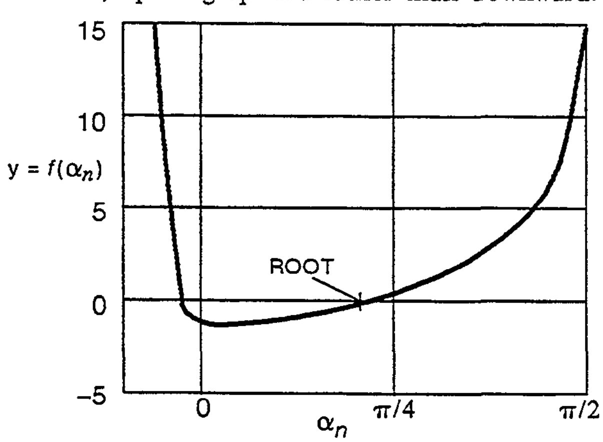


Fig 5-9 Iteration Function

5.9 Radius of Curvature of Root Fillet. The radius of curvature of the fillet curve, ρ'_F, at any point defined by α_n is given by:

$$\rho'_F = \rho_{ao} + \frac{K_S^2}{\dfrac{r''_n \, r''_{no} \sin \alpha_n}{r''_n + r''_{no}} - K_S} \qquad \text{(Eq 5.66)}$$

$$K_S = r''_{no} - r^s_{no} \qquad \text{(Eq 5.67)}$$

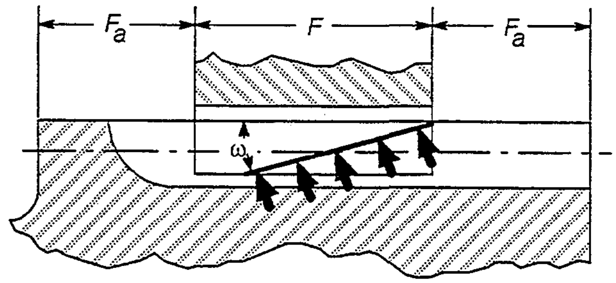
The J factor uses the minimum radius of curvature which occurs at the point where the fillet curve is tangent to the root circle, where $\alpha_n = \pi/2$ and $\mu_{no} = 0$.

Subsituting, the minimum radius of curvature of fillet curve, ρ_F, is:

$$\rho_F = \rho_{ao} + \frac{(r''_{no} - r^s_{no})^2}{\dfrac{r''_n \, r''_{no}}{r''_n + r''_{no}} - (r''_{no} - r^s_{no})} \qquad \text{(Eq 5.68)}$$

5.10 Helical Factor, C_h. The helical factor, C_h, is the ratio of the root bending moment produced by tip loading to the root bending moment produced by the same intensity of loading applied along the oblique helical contact line. It is based on the work of Wellauer and Seireg [7].

If the worst condition of load occurs where full buttressing exists, the value of C_h may be increased by 10 percent. Full buttressing exists when the face of the tooth extends at least one addendum beyond the loaded portion (see Fig 5-10)



NOTE: Full Buttressing Exists When $F_a \geq$ One Addendum

Fig 5-10 Oblique Contact Line

For Spur and LACR Helical Gears($m_F \leq 1.0$), a unity value is used,

$$C_h = 1.0 \qquad \text{(Eq 5.69)}$$

For Conventional Helical Gears, when $m_F > 1.0$

$$C_h = \frac{1}{1 - \left[\dfrac{\omega}{100}\left(1 - \dfrac{\omega}{100}\right)\right]^{0.5}} \qquad \text{(Eq 5.70)}$$

where

ω = angle of inclination of helical contact line in degrees

$\omega = \tan^{-1}(\tan\psi \sin\phi_n)$ (Eq 5.71)

Equation 5.70 is valid for $\psi < 50°$.

C_h values can be taken from Fig 5-11

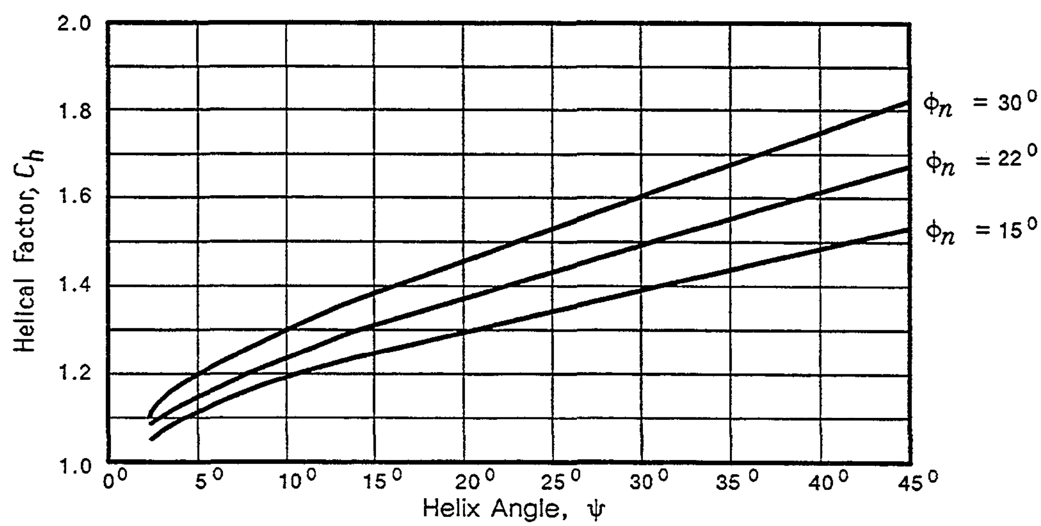


Fig 5-11 Helical Factor, C_h

The helical factor, C_h, is based on the work of Wellauer and Seireg [7].

5.11 Stress Correction Factor, K_f. The stress correction factor, K_f, includes the effects of stress concentration and load location, based on the work of Dolan and Broghamer [1]. It is given by:

$$K_f = H + \left(\frac{s_F}{\rho_F}\right)^L \left(\frac{s_F}{h_F}\right)^M \qquad \text{(Eq 5.72)}$$

where

s_F = tooth thickness at critical section

= $2\xi_{nF}$ (Eq 5.73)

ρ_F = minimum radius of curvature of fillet curve

h_F = height of Lewis parabola

H = $0.331 - 0.436\phi_n$ (Eq 5.74)

L = $0.324 - 0.492\phi_n$ (Eq 5.75)

M = $0.261 + 0.545\phi_n$ (Eq 5.76)

where

ϕ_n = standard normal pressure angle

Note: In order to calculate an accurate value for K_f, the significant decimal places in Eq 5.74 through 5.76 are necessary. The resulting values of H, L and M may be rounded to two decimal places.

5.12 Helix Angle Factor, K_ψ. The helix angle factor, K_ψ, depends on the type of gear.

For Spur and LACR Helical Gears($m_F \leq 1.0$), a unity value is used, $K_\psi = 1.0$

For Conventional Helical Gears, when $m_F > 1.0$

$$K_\psi = \cos\psi_r \cos\psi \qquad \text{(Eq 5.77)}$$

5.13 Tooth Form Factor, Y. The tooth form factor, Y, is calculated by:

$$Y = \frac{K_\psi}{\dfrac{\cos\phi_{nL}}{\cos\phi_{nr}}\left[\dfrac{6h_F}{s_F^2 C_h} - \dfrac{\tan\phi_{nL}}{s_F}\right]} \qquad \text{(Eq 5.78)}$$

6. Determining Addendum Modification Coefficients

In order to use Section 5, x_1 and x_2 must be determined. If these values are not known, this Section provides a method for determining them.

6.1 Generating Rack Shift Coefficients. If the normal circular tooth thicknesses are known, the generating rack shift coefficients are found from Eqs 6.1 and 6.2.

$$x_{g1} = \frac{s_{n1} - \frac{\pi}{2}}{2\tan\phi_n} \qquad \text{(Eq 6.1)}$$

$$x_{g2} = \pm\left(\frac{s_{n2} - \frac{\pi}{2}}{2\tan\phi_n}\right) \qquad \text{(Eq 6.2)}$$

$$\Sigma x_g = x_{g2} \pm x_{g1} \qquad \text{(Eq 6.3)}$$

where

x_{g1} = generating rack shift coefficient, pinion

x_{g2} = generating rack shift coefficient, gear

Σx_g = sum of generating rack shift coefficients

s_{n1} = reference normal circular tooth thickness, pinion (see Eq 5.21)

s_{n2} = reference normal circular tooth thickness, gear (see Eq 5.21)

6.2 Sum of Addendum Modification Coefficients for Zero Backlash. Although the amount of tooth thinning applied to each gear may be unknown, the sum of the addendum modification coefficients for the gear pair, Σx, can be established.

$$\Sigma x = \frac{C\,(\text{inv}\,\phi_r - \text{inv}\,\phi)}{\tan\phi} \qquad \text{(Eq 6.4)}$$

$$\Sigma x = x_2 \pm x_1 \qquad \text{(Eq 6.5)}$$

$$C = R_2 \pm R_1 \qquad \text{(Eq 6.6)}$$

where

x_1 = addendum modification coefficient, pinion

x_2 = addendum modification coefficient, gear

C = standard center distance

R_1 = standard pitch radius, pinion

R_2 = standard pitch radius, gear

6.3 Tooth Thinning for Backlash. It is usually impossible to determine the ratio $\Delta s_{n1}/\Delta s_{n2}$ that was used for existing gears. The following analysis is based on common practice where $\Delta s_{n1} = \Delta s_{n2}$, in which case:

$$B_n = \pm \frac{2\, C_r \tan \phi_n}{C} (\Sigma x - \Sigma x_g) \qquad \text{(Eq 6.7)}$$

$$\Delta s_{n1} = \Delta s_{n2} = \frac{B_n}{2}\left(\frac{C}{C_r}\right) \qquad \text{(Eq 6.8)}$$

where

B_n = normal operating circular backlash

C_r = operating center distance

Δs_{n1} = tooth thinning for backlash, pinion

Δs_{n2} = tooth thinning for backlash, gear

6.4 Addendum Modification Coefficients. The addendum modification coefficients, x_1 and x_2, can be established from Eq 6.9 and 6.10.

$$x_1 = x_{g1} + \frac{\Delta s_{n1}}{2 \tan \phi_n} \qquad \text{(Eq 6.9)}$$

$$x_2 = x_{g2} \pm \frac{\Delta s_{n2}}{2 \tan \phi_n} \qquad \text{(Eq 6.10)}$$

7. Geometry Factor Tables

The following tables provide the Geometry Factor for Pitting Resistance, I, and the Geometry Factor for Bending Strength, J, for a range of typical pairs of gears. The tables were prepared by computer, programmed in accordance with Section 5. The values were rounded to two significant figures. The tables cover various combinations of helix angle, pressure angle, whole depth, tool edge radius, tooth load point and addendum modification. The Tables do not cover all tooth forms, pressure angles, and pinion or gear modifications, and are not applicable to all gear designs. In addition to the basic geometry, the criteria listed in 7.1 through 7.10 were used in calculating the table values.

The following paragraphs and equations use dimensionless numbers to describe the gear geometry. To make actual measurements dimensionless, they are converted to ratios by multiplying them by diametral pitch, dividing them by module, or comparing them to a π (3.1416) circular pitch at the standard pitch diameter. Any consistent system of units can be used for this conversion, see Section 3.

7.1 Using the Tables. Each table of I and J values was generated for a specific tool form (basic rack) defined by whole depth factor, normal pressure (profile) angle and tool edge (tip) radius. Each tool form was used to generate 66 tables of values:

For spur gears:

- Loaded at Tip
  - $x_1 = x_2 = 0$
  - $x_1 = 0.25$, $x_2 = -0.25$
  - $x_1 = 0.50$, $x_2 = -0.50$
- Loaded at HPSTC
  - $x_1 = x_2 = 0$
  - $x_1 = 0.25$, $x_2 = -0.25$
  - $x_1 = 0.50$, $x_2 = -0.50$

For helical gears:

- 10 degree standard helix angle
  - $x_1 = x_2 = 0$
  - $x_1 = 0.25$, $x_2 = -0.25$
  - $x_1 = 0.50$, $x_2 = -0.50$
- 15 degree standard helix angle
  - $x_1 = x_2 = 0$
  - $x_1 = 0.25$, $x_2 = -0.25$
  - $x_1 = 0.50$, $x_2 = -0.50$
- 20 degree standard helix angle
  - $x_1 = x_2 = 0$
  - $x_1 = 0.25$, $x_2 = -0.25$
  - $x_1 = 0.50$, $x_2 = -0.50$
- 25 degree standard helix angle
  - $x_1 = x_2 = 0$
  - $x_1 = 0.25$, $x_2 = -0.25$
  - $x_1 = 0.50$, $x_2 = -0.50$
- 30 degree standard helix angle
  - $x_1 = x_2 = 0$
  - $x_1 = 0.25$, $x_2 = -0.25$
  - $x_1 = 0.50$, $x_2 = -0.50$

To obtain values for I and J, enter the table for the appropriate whole depth factor tool, helix angle, loading condition and addendum modification factor and select values for the numbers of pinion and gear teeth. If the exact values for your gearset are not listed, the calculation method of Section 5 is recommended. Interpolation is not recommended.

A "U" in the tables indicates a gear tooth combination which should be avoided due to undercutting.

A "T" in the tables indicates a gear tooth combination which should be avoided due to pointed pinion teeth.

7.2 Whole Depth. Whole depth is expressed in the Tables as a "whole depth factor", the whole depth of a basic rack for 1 normal diametral pitch or 1 normal module. The actual generated depths are slightly greater due to tooth thinning for backlash.

7.3 Outside Diameter. The tabulated values are calculated for gears having an outside diameter (addendum diameter) equal to (in terms of m_n = 1.0):

$$D_{a1} = \frac{n_1}{\cos \psi} + 2\,(1 + x_1) \qquad \text{(Eq 7.1)}$$

$$D_{a2} = \frac{n_2}{\cos \psi} + 2\,(1 + x_2) \qquad \text{(Eq 7.2)}$$

where

n_1 = pinion tooth number

n_2 = gear tooth number

ψ = standard helix angle, degrees

D_{a1} = pinion addendum diameter

D_{a2} = gear addendum diameter

7.4 Type of Gearing. The tables apply to external gears only. An analytical method for determining the Bending Strength Geometry Factor, J, for internal gears is beyond the scope of this Standard.

7.5 Center Distance. The tables apply to gearsets that operate on a standard center distance. This center distance is the tight mesh center distance for gears not yet thinned for backlash. See 7.6.

$$C = \frac{n_1 + n_2}{2 \cos \psi} \qquad \text{(Eq 7.3)}$$

where

C = standard center distance.

For this center distance the sum of the addendum modification coefficients is zero (See 5.3 for definitions).

$$x_1 + x_2 = 0 \qquad \text{(Eq 7.4)}$$

where

x_1 = addendum modification coefficient, pinion

x_2 = addendum modification coefficient, gear

7.6 Tooth Thickness Backlash Allowance. The values in the tables are calculated based on a backlash allowance. The circular tooth thicknesses for the pinion and the gear are each thinned by an amount, $\Delta\, s_n$, shown in Eq 7.5.

$$\Delta\, s_n = \frac{0.024}{P_{nd}} = 0.024 \qquad \text{(Eq 7.5)}$$

If the gears being evaluated have different minimum tooth thicknesses, the Bending Strength Geometry Factor, J, can be approximated using Eq 7.6. The Pitting Resistance Geometry Factor, I, is unaffected by variations in tooth thickness.

$$\frac{J_1}{J_s} = \left(\frac{s_{n1}}{s_{ns}}\right)^2 \qquad \text{(Eq 7.6)}$$

where

J_1 = adjusted geometry factor

J_s = geometry factor from table

s_{n1} = adjusted circular tooth thickness

s_{ns} = standard tooth thickness, thinned per Eq 7.5

Example:

From the table at the top of page 32 for 20° pressure angle spur gears, loaded at the highest point of single tooth contact, the J factor for a 21 tooth pinion operating with a 35 tooth gear is found to be 0.34. The table is based on a circular tooth thickness of:

$$\frac{\pi}{2} - 0.024 = \frac{3.1416}{2} - 0.024 = 1.547$$

(from Sections 7 and 7.3)

For a 10 normal diametral pitch gear or pinion, the equivalent circular tooth thickness would be:

$$\frac{1.547}{10} = 0.155$$

If a value for J for a 0.010 inch thinner pinion, having a circular thickness of
0.155 − 0.010 = 0.145 inch
is required, the approximate value is:

$$0.34 \left(\frac{0.145}{0.155}\right)^2 = 0.30 \qquad \text{(Eq 7.7)}$$

A 6.5% reduction in tooth thickness reduces J by 12%.

7.7 Undercutting. The tables do not include geometry factors when an undercutting condition exists in either of the two gears. This condition can be evaluated using Eq 7.8 and Fig 7–1 where the generating rack shift coefficient, x_g, must be equal to or greater than the expression in Eq 7.8.

$$x_{g\,\min} = h_{ao} - \rho_{ao}(1 - \sin\phi_n) - \frac{n}{2}\sin^2\phi_n \qquad \text{(Eq 7.8)}$$

where

h_{ao} = nominal tool addendum

ρ_{ao} = tool tip radius

n = pinion or gear tooth number

7.8 Top Land. The tables do not include geometry factors when either the pinion or gear tooth top land is less than the value expressed in Eq 7.9.

$$s_{na}\min \geq \frac{0.3}{P_{nd}} \qquad \text{(Eq 7.9)}$$

$$s_{na\,\min} \geq 0.3 m_n \qquad \text{(Eq 7.9M)}$$

where

s_{na} = tooth thickness at outside diameter, in (mm)

7.9 Cutter Geometry. The hob geometry used in the calculation of I and J is as follows:

n_c = 10 000

s_{no} = 1.5708

x_o = 0.0

δ_o = 0.0

where

n_c = tool tooth number

s_{no} = reference normal circular tooth thickness of tool

x_o = addendum modification coefficient of tool

δ_o = amount of protuberance

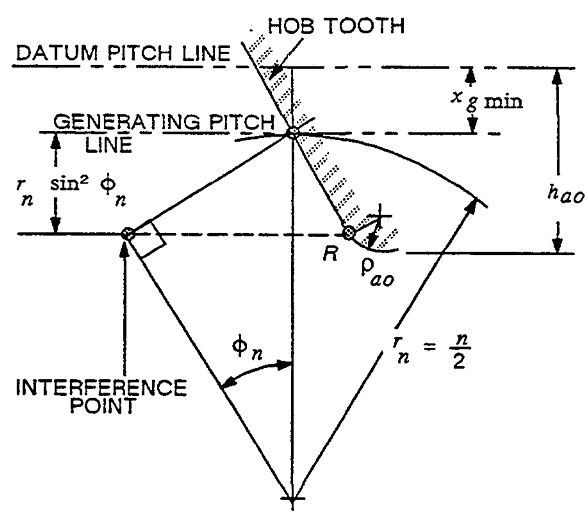


Fig 7–1 Undercutting Criteria

7.10 Axial Contact Ratio. The I and J factors for helical gears are calculated using an axial contact ratio, m_F, equal to 2.0. When the axial contact ratio is other than 2.0, the resulting values for I and J may be reduced by as much as 10%.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT TIP

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I																
	J	U	U	U	U	U	U	U	U	U	U						
35	I											0.061					
	J	U	U	U	U	U	U	U	U	U	U	0.18	0.18				
55	I											0.074		0.061			
	J	U	U	U	U	U	U	U	U	U	U	0.18	0.19	0.19	0.19		
135	I											0.096		0.088		0.061	
	J	U	U	U	U	U	U	U	U	U	U	0.18	0.20	0.19	0.20	0.20	0.20

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION ($x_1 = 0.25$)

25 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.25$)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I									0.060							
	J	U	U	U	U	U	U	U	U	0.20	0.16						
35	I									0.071		0.059					
	J	U	U	U	U	U	U	U	U	0.20	0.17	0.20	0.17				
55	I									0.087		0.077		0.060			
	J	U	U	U	U	U	U	U	U	0.20	0.18	0.20	0.18	0.20	0.18		
135	I									0.111		0.106		0.092		0.060	
	J	U	U	U	U	U	U	U	U	0.20	0.19	0.20	0.19	0.20	0.19	0.20	0.19

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION ($x_1 = 0.50$)

50 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.50$)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I							0.056									
	J	U	U	U	U	U	U	0.21	0.12								
26	I							0.067		0.056							
	J	U	U	U	U	U	U	0.21	0.13	0.21	0.13						
35	I							0.081		0.071		0.056					
	J	U	U	U	U	U	U	0.21	0.15	0.21	0.15	0.21	0.15				
55	I							0.100		0.091		0.078		0.057			
	J	U	U	U	U	U	U	0.21	0.17	0.21	0.17	0.21	0.17	0.21	0.17		
135	I							0.127		0.123		0.114		0.096		0.060	
	J	U	U	U	U	U	U	0.21	0.19	0.21	0.19	0.21	0.19	0.21	0.19	0.21	0.19

PINION TEETH (column headings 12 through 135)

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT HIGHEST POINT OF SINGLE TOOTH CONTACT

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I																
	J	U	U	U	U	U	U	U	U	U	U						
35	I											0.061					
	J	U	U	U	U	U	U	U	U	U	U	0.29	0.29				
55	I											0.074		0.061			
	J	U	U	U	U	U	U	U	U	U	U	0.30	0.31	0.33	0.33		
135	I											0.096		0.088		0.061	
	J	U	U	U	U	U	U	U	U	U	U	0.31	0.34	0.35	0.35	0.38	0.38

PINION TEETH (column headings 12 through 135)

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT HIGHEST POINT OF SINGLE TOOTH CONTACT

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I									0.060							
	J	U	U	U	U	U	U	U	U	0.32	0.22						
35	I									0.071		0.059					
	J	U	U	U	U	U	U	U	U	0.32	0.24	0.34	0.24				
55	I									0.087		0.077		0.060			
	J	U	U	U	U	U	U	U	U	0.33	0.27	0.35	0.27	0.37	0.29		
135	I									0.111		0.106		0.092		0.060	
	J	U	U	U	U	U	U	U	U	0.35	0.29	0.36	0.30	0.39	0.32	0.41	0.35

1 The letter “U” indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT HIGHEST POINT OF SINGLE TOOTH CONTACT

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I							0.056									
	J	U	U	U	U	U	U	0.35	0.15								
26	I							0.067		0.056							
	J	U	U	U	U	U	U	0.36	0.17	0.37	0.17						
35	I							0.081		0.071		0.056					
	J	U	U	U	U	U	U	0.36	0.19	0.37	0.20	0.38	0.20				
55	I							0.100		0.091		0.078		0.057			
	J	U	U	U	U	U	U	0.37	0.22	0.38	0.23	0.39	0.24	0.41	0.25		
135	I					0.127		0.123		0.114		0.096		0.060			
	J	U	U	U	U	U	U	0.38	0.26	0.39	0.26	0.40	0.27	0.42	0.29	0.43	0.32

1 The letter “U” indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

14.5 DEG. PRESSURE ANGLE
10.0 DEG. HELIX ANGLE
0.157 TOOL EDGE RADIUS
EQUAL ADDENDUM ($x_1 = x_2 = 0$)

2.157 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I																
	J	U	U	U	U	U	U	U	U	U	U						
35	I											0.122					
	J	U	U	U	U	U	U	U	U	U	U	0.43	0.43				
55	I											0.155		0.132			
	J	U	U	U	U	U	U	U	U	U	U	0.45	0.46	0.48	0.48		
135	I											0.212		0.197		0.145	
	J	U	U	U	U	U	U	U	U	U	U	0.47	0.50	0.50	0.52	0.55	0.55

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5 DEG. PRESSURE ANGLE
10.0 DEG. HELIX ANGLE
0.157 TOOL EDGE RADIUS
25 PERCENT LONG ADDENDUM PINION ($x_1 = 0.25$)
25 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.25$)

2.157 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I									0.107							
	J	U	U	U	U	U	U	U	U	0.43	0.34						
35	I									0.137		0.117					
	J	U	U	U	U	U	U	U	U	0.44	0.38	0.46	0.39				
55	I									0.181		0.159		0.129			
	J	U	U	U	U	U	U	U	U	0.45	0.41	0.47	0.43	0.50	0.45		
135	I									0.250		0.233		0.206		0.144	
	J	U	U	U	U	U	U	U	U	0.47	0.46	0.49	0.47	0.52	0.49	0.56	0.53

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
10.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS	LOADED AT TIP	

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I					0.054											
	J	U	U	U	U	0.42	0.20										
21	I					0.085		0.071									
	J	U	U	U	U	0.42	0.24	0.44	0.25								
26	I					0.117		0.101		0.086							
	J	U	U	U	U	0.43	0.27	0.44	0.28	0.46	0.29						
35	I					0.160		0.141		0.124		0.102					
	J	U	U	U	U	0.43	0.30	0.45	0.31	0.46	0.32	0.48	0.34				
55	I					0.218		0.198		0.179		0.154		0.120			
	J	U	U	U	U	0.44	0.34	0.46	0.35	0.47	0.37	0.49	0.38	0.51	0.41		
135	I					0.300		0.282		0.264		0.242		0.208		0.141	
	J	U	U	U	U	0.45	0.39	0.46	0.40	0.48	0.42	0.50	0.44	0.52	0.46	0.56	0.51

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
15.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS	LOADED AT TIP	

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I																
	J	U	U	U	U	U	U	U	U	U	U						
35	I											0.124					
	J	U	U	U	U	U	U	U	U	U	U	0.43	0.43				
55	I											0.156		0.133			
	J	U	U	U	U	U	U	U	U	U	U	0.45	0.46	0.48	0.48		
135	I											0.214		0.198		0.146	
	J	U	U	U	U	U	U	U	U	U	U	0.47	0.50	0.50	0.52	0.54	0.54

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
15.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I									0.109							
	J	U	U	U	U	U	U	U	U	0.43	0.35						
35	I									0.138		0.118					
	J	U	U	U	U	U	U	U	U	0.44	0.38	0.46	0.39				
55	I									0.182		0.161		0.130			
	J	U	U	U	U	U	U	U	U	0.45	0.41	0.47	0.43	0.50	0.45		
135	I									0.250		0.233		0.206		0.145	
	J	U	U	U	U	U	U	U	U	0.47	0.46	0.49	0.47	0.52	0.49	0.55	0.53

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
15.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I					0.059											
	J	U	U	U	U	0.42	0.21										
21	I					0.090		0.075									
	J	U	U	U	U	0.43	0.25	0.44	0.26								
26	I					0.121		0.104		0.089							
	J	U	U	U	U	0.43	0.27	0.45	0.28	0.46	0.29						
35	I					0.162		0.144		0.126		0.105					
	J	U	U	U	U	0.44	0.31	0.45	0.32	0.46	0.33	0.48	0.35				
55	I					0.219		0.199		0.180		0.156		0.122			
	J	U	U	U	U	0.44	0.35	0.46	0.36	0.47	0.37	0.49	0.39	0.51	0.41		
135	I					0.299		0.281		0.264		0.242		0.209		0.142	
	J	U	U	U	U	0.45	0.39	0.47	0.40	0.48	0.42	0.50	0.44	0.52	0.46	0.56	0.51

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

14.5 DEG. PRESSURE ANGLE
20.0 DEG. HELIX ANGLE
0.157 TOOL EDGE RADIUS
EQUAL ADDENDUM ($x_1 = x_2 = 0$)

2.157 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I																
	J	U	U	U	U	U	U	U	U	U	U						
35	I											0.125					
	J	U	U	U	U	U	U	U	U	U	U	0.43	0.43				
55	I											0.158		0.134			
	J	U	U	U	U	U	U	U	U	U	U	0.44	0.45	0.47	0.47		
135	I											0.215		0.199		0.146	
	J	U	U	U	U	U	U	U	U	U	U	0.46	0.49	0.49	0.50	0.53	0.53

1 The letter “U” indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5 DEG. PRESSURE ANGLE
20.0 DEG. HELIX ANGLE
0.157 TOOL EDGE RADIUS
25 PERCENT LONG ADDENDUM PINION ($x_1 = 0.25$)
25 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.25$)

2.157 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I							0.104									
	J	U	U	U	U	U	U	0.40	0.32								
26	I							0.126		0.111							
	J	U	U	U	U	U	U	0.41	0.34	0.43	0.35						
35	I							0.156		0.140		0.120					
	J	U	U	U	U	U	U	0.42	0.37	0.43	0.38	0.45	0.39				
55	I							0.198		0.183		0.162		0.131			
	J	U	U	U	U	U	U	0.43	0.40	0.44	0.41	0.46	0.42	0.49	0.44		
135	I							0.262		0.250		0.234		0.207		0.145	
	J	U	U	U	U	U	U	0.44	0.43	0.46	0.44	0.48	0.46	0.50	0.48	0.53	0.51

1 The letter “U” indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
20.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION ($x_1 = 0.50$)

50 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.50$)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I					0.065											
	J	U	U	U	U	0.41	0.22										
21	I					0.095		0.081									
	J	U	U	U	U	0.42	0.25	0.43	0.26								
26	I					0.125		0.109		0.094							
	J	U	U	U	U	0.42	0.28	0.43	0.29	0.45	0.30						
35	I					0.166		0.147		0.130		0.108					
	J	U	U	U	U	0.43	0.31	0.44	0.32	0.45	0.33	0.47	0.34				
55	I					0.220		0.201		0.182		0.158		0.124			
	J	U	U	U	U	0.43	0.34	0.45	0.35	0.46	0.37	0.47	0.38	0.50	0.41		
135	I					0.297		0.280		0.264		0.242		0.209		0.143	
	J	U	U	U	U	0.44	0.38	0.45	0.40	0.47	0.41	0.48	0.43	0.50	0.45	0.54	0.49

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
25.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT TIP

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I									0.121							
	J	U	U	U	U	U	U	U	U	0.38	0.38						
35	I									0.142		0.127					
	J	U	U	U	U	U	U	U	U	0.39	0.40	0.41	0.41				
55	I									0.174		0.160		0.135			
	J	U	U	U	U	U	U	U	U	0.40	0.42	0.42	0.43	0.45	0.45		
135	I									0.225		0.218		0.201		0.147	
	J	U	U	U	U	U	U	U	U	0.42	0.45	0.44	0.46	0.47	0.48	0.50	0.50

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
25.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I							0.108									
	J	U	U	U	U	U	U	0.39	0.31								
26	I							0.129		0.115							
	J	U	U	U	U	U	U	0.40	0.33	0.41	0.34						
35	I							0.158		0.143		0.123					
	J	U	U	U	U	U	U	0.40	0.36	0.42	0.36	0.43	0.38				
55	I							0.200		0.185		0.164		0.133			
	J	U	U	U	U	U	U	0.41	0.38	0.43	0.39	0.44	0.40	0.46	0.42		
135	I							0.262		0.250		0.234		0.208		0.146	
	J	U	U	U	U	U	U	0.42	0.41	0.44	0.42	0.45	0.44	0.47	0.46	0.50	0.48

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
25.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I			0.057													
	J	U	U	0.38	0.19												
17	I			0.086		0.073											
	J	U	U	0.39	0.22	0.40	0.23										
21	I			0.117		0.102		0.087									
	J	U	U	0.39	0.24	0.40	0.25	0.41	0.26								
26	I			0.148		0.131		0.114		0.099							
	J	U	U	0.39	0.27	0.40	0.28	0.42	0.29	0.43	0.29						
35	I			0.188		0.170		0.151		0.134		0.112					
	J	U	U	0.40	0.29	0.41	0.30	0.42	0.31	0.43	0.32	0.45	0.34				
55	I			0.240		0.222		0.203		0.185		0.161		0.127			
	J	U	U	0.40	0.32	0.41	0.33	0.42	0.34	0.44	0.35	0.45	0.37	0.47	0.39		
135	I			0.311		0.295		0.279		0.263		0.242		0.210		0.144	
	J	U	U	0.41	0.36	0.42	0.37	0.43	0.38	0.44	0.39	0.46	0.41	0.48	0.43	0.51	0.47

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

14.5 DEG. PRESSURE ANGLE
30.0 DEG. HELIX ANGLE
0.157 TOOL EDGE RADIUS
EQUAL ADDENDUM ($x_1 = x_2 = 0$)

2.157 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I																
	J	U	U	U	U	U	U	U	U								
26	I									0.123							
	J	U	U	U	U	U	U	U	U	0.36	0.36						
35	I									0.145		0.129					
	J	U	U	U	U	U	U	U	U	0.37	0.37	0.38	0.38				
55	I									0.177		0.163		0.137			
	J	U	U	U	U	U	U	U	U	0.38	0.39	0.39	0.40	0.41	0.41		
135	I									0.227		0.220		0.202		0.148	
	J	U	U	U	U	U	U	U	U	0.39	0.42	0.41	0.43	0.43	0.44	0.46	0.46

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

14.5 DEG. PRESSURE ANGLE
30.0 DEG. HELIX ANGLE
0.157 TOOL EDGE RADIUS
25 PERCENT LONG ADDENDUM PINION ($x_1 = 0.25$)
25 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.25$)

2.157 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I					0.105											
	J	U	U	U	U	0.35	0.27										
21	I					0.126		0.112									
	J	U	U	U	U	0.35	0.29	0.37	0.30								
26	I					0.147		0.133		0.118							
	J	U	U	U	U	0.36	0.31	0.37	0.32	0.38	0.33						
35	I					0.176		0.161		0.146		0.126					
	J	U	U	U	U	0.36	0.33	0.38	0.34	0.39	0.34	0.40	0.36				
55	I					0.216		0.201		0.187		0.166		0.135			
	J	U	U	U	U	0.37	0.35	0.38	0.36	0.40	0.37	0.41	0.38	0.43	0.39		
135	I					0.272		0.261		0.250		0.235		0.209		0.147	
	J	U	U	U	U	0.38	0.38	0.39	0.39	0.41	0.39	0.42	0.41	0.44	0.42	0.46	0.45

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:

14.5	DEG. PRESSURE ANGLE	2.157	WHOLE DEPTH FACTOR
30.0	DEG. HELIX ANGLE	.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS	LOADED AT TIP	

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.055															
	J	0.35	0.17														
14	I	0.078		0.068													
	J	0.35	0.19	0.36	0.20												
17	I	0.107		0.095		0.082											
	J	0.35	0.21	0.36	0.22	0.37	0.23										
21	I	0.138		0.125		0.110		0.095									
	J	0.36	0.24	0.37	0.24	0.37	0.25	0.38	0.26								
26	I	0.168		0.154		0.137		0.120		0.105							
	J	0.36	0.25	0.37	0.26	0.38	0.27	0.39	0.28	0.40	0.29						
35	I	0.206		0.191		0.174		0.156		0.139		0.117					
	J	0.36	0.28	0.37	0.28	0.38	0.29	0.39	0.30	0.40	0.31	0.41	0.32				
55	I	0.256		0.241		0.223		0.205		0.187		0.164		0.130			
	J	0.37	0.30	0.38	0.31	0.39	0.32	0.40	0.33	0.40	0.34	0.42	0.35	0.43	0.37		
135	I	0.320		0.307		0.292		0.277		0.262		0.242		0.211		0.145	
	J	0.37	0.33	0.38	0.33	0.39	0.35	0.40	0.36	0.41	0.37	0.42	0.38	0.44	0.40	0.46	0.43

I AND *J* FACTORS FOR:[1]

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS	LOADED AT TIP	

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I							0.078									
	J	U	U	U	U	U	U	0.24	0.24								
26	I							0.084		0.079							
	J	U	U	U	U	U	U	0.24	0.25	0.25	0.25						
35	I							0.091		0.088		0.080					
	J	U	U	U	U	U	U	0.24	0.26	0.25	0.26	0.26	0.26				
55	I							0.102		0.101		0.095		0.080			
	J	U	U	U	U	U	U	0.24	0.28	0.25	0.28	0.26	0.28	0.28	0.28		
135	I							0.118		0.121		0.120		0.112		0.080	
	J	U	U	U	U	U	U	0.24	0.29	0.25	0.29	0.26	0.29	0.28	0.29	0.29	0.29

1 The letter “U” indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I					0.080											
	J	U	U	U	U	0.27	0.19										
21	I					0.087		0.080									
	J	U	U	U	U	0.27	0.21	0.27	0.21								
26	I					0.094		0.088		0.080							
	J	U	U	U	U	0.27	0.22	0.27	0.22	0.28	0.22						
35	I					0.103		0.098		0.092		0.080					
	J	U	U	U	U	0.27	0.24	0.27	0.24	0.28	0.24	0.28	0.24				
55	I					0.115		0.113		0.108		0.099		0.080			
	J	U	U	U	U	0.27	0.26	0.27	0.26	0.28	0.26	0.28	0.26	0.29	0.26		
135	I					0.131		0.134		0.133		0.129		0.116		0.080	
	J	U	U	U	U	0.27	0.28	0.27	0.28	0.28	0.28	0.28	0.28	0.29	0.28	0.30	0.28

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	T	T														
14	I			0.080													
	J	T	T	0.30	0.12												
17	I			0.088		0.080											
	J	T	T	0.30	0.15	0.30	0.15										
21	I			0.097		0.090		0.080									
	J	T	T	0.30	0.17	0.30	0.17	0.31	0.17								
26	I			0.105		0.099		0.090		0.080							
	J	T	T	0.30	0.19	0.30	0.19	0.31	0.19	0.31	0.19						
35	I			0.116		0.111		0.103		0.094		0.080					
	J	T	T	0.30	0.21	0.30	0.21	0.31	0.21	0.31	0.21	0.30	0.21				
55	I			0.130		0.127		0.122		0.114		0.101		0.080			
	J	T	T	0.30	0.24	0.30	0.24	0.31	0.24	0.31	0.24	0.30	0.24	0.30	0.24		
135	I			0.148		0.149		0.148		0.145		0.136		0.120		0.080	
	J	T	T	0.30	0.27	0.30	0.27	0.31	0.27	0.31	0.27	0.30	0.27	0.30	0.27	0.30	0.27

1 The letter "T" indicates a gear tooth combination which produces pointed teeth with a top land less than $0.3/P_{nd}$ in one or both components and should be avoided. See Section 7.

I AND *J* FACTORS FOR:[1]

20.0 DEG. PRESSURE ANGLE
0.0 DEG. HELIX ANGLE
0.250 TOOL EDGE RADIUS
EQUAL ADDENDUM ($x_1 = x_2 = 0$)

2.250 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT HIGHEST POINT OF SINGLE TOOTH CONTACT

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I							0.078									
	J	U	U	U	U	U	U	0.33	0.33								
26	I							0.084		0.079							
	J	U	U	U	U	U	U	0.33	0.35	0.35	0.35						
35	I							0.091		0.088		0.080					
	J	U	U	U	U	U	U	0.34	0.37	0.36	0.38	0.39	0.39				
55	I							0.102		0.101		0.095		0.080			
	J	U	U	U	U	U	U	0.34	0.40	0.37	0.41	0.40	0.42	0.43	0.43		
135	I							0.118		0.121		0.120		0.112		0.080	
	J	U	U	U	U	U	U	0.35	0.43	0.38	0.44	0.41	0.45	0.45	0.47	0.49	0.49

1 The letter “U” indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

20.0 DEG. PRESSURE ANGLE
0.0 DEG. HELIX ANGLE
0.250 TOOL EDGE RADIUS
25 PERCENT LONG ADDENDUM PINION ($x_1 = 0.25$)
25 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.25$)

2.250 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT HIGHEST POINT OF SINGLE TOOTH CONTACT

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I					0.080											
	J	U	U	U	U	0.36	0.24										
21	I					0.087		0.080									
	J	U	U	U	U	0.37	0.26	0.39	0.27								
26	I					0.094		0.088		0.080							
	J	U	U	U	U	0.37	0.29	0.39	0.29	0.41	0.30						
35	I					0.103		0.098		0.092		0.080					
	J	U	U	U	U	0.37	0.32	0.40	0.32	0.41	0.33	0.43	0.34				
55	I					0.115		0.113		0.108		0.099		0.080			
	J	U	U	U	U	0.38	0.35	0.40	0.36	0.42	0.36	0.44	0.37	0.47	0.39		
135	I					0.131		0.134		0.133		0.129		0.116		0.080	
	J	U	U	U	U	0.39	0.39	0.41	0.40	0.43	0.41	0.45	0.42	0.48	0.44	0.51	0.46

1 The letter “U” indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT HIGHEST POINT OF SINGLE TOOTH CONTACT

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	T	T														
14	I			0.080													
	J	T	T	0.40	0.14												
17	I			0.088		0.080											
	J	T	T	0.41	0.17	0.42	0.18										
21	I			0.097		0.090		0.080									
	J	T	T	0.41	0.20	0.43	0.21	0.44	0.21								
26	I			0.105		0.099		0.090		0.080							
	J	T	T	0.41	0.23	0.43	0.23	0.45	0.24	0.46	0.24						
35	I			0.116		0.111		0.103		0.094		0.080					
	J	T	T	0.42	0.26	0.43	0.27	0.45	0.27	0.46	0.28	0.48	0.29				
55	I			0.130		0.127		0.122		0.114		0.101		0.080			
	J	T	T	0.42	0.30	0.44	0.31	0.45	0.31	0.47	0.32	0.48	0.33	0.50	0.34		
135	I			0.148		0.149		0.148		0.145		0.136		0.120		0.080	
	J	T	T	0.43	0.34	0.44	0.35	0.46	0.36	0.47	0.37	0.49	0.38	0.50	0.40	0.52	0.43

1 The letter "T" indicates a gear tooth combination which produces pointed teeth with a top land less than $0.3/P_{nd}$ in one or both components and should be avoided. See Section 7.

I AND *J* FACTORS FOR:[1]

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
10.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT TIP

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I																
	J	U	U	U	U	U	U										
21	I							0.127									
	J	U	U	U	U	U	U	0.46	0.46								
26	I							0.143		0.131							
	J	U	U	U	U	U	U	0.47	0.49	0.49	0.49						
35	I							0.164		0.153		0.136					
	J	U	U	U	U	U	U	0.48	0.52	0.50	0.53	0.54	0.54				
55	I							0.195		0.186		0.170		0.143			
	J	U	U	U	U	U	U	0.49	0.55	0.52	0.56	0.55	0.57	0.59	0.59		
135	I							0.241		0.237		0.228		0.209		0.151	
	J	U	U	U	U	U	U	0.50	0.60	0.53	0.61	0.57	0.62	0.60	0.63	0.65	0.65

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:[1]

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
10.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I			0.109													
	J	U	U	0.46	0.30												
17	I			0.129		0.116											
	J	U	U	0.47	0.34	0.49	0.35										
21	I			0.151		0.137		0.122									
	J	U	U	0.47	0.38	0.50	0.38	0.52	0.39								
26	I			0.172		0.157		0.142		0.127							
	J	U	U	0.48	0.41	0.50	0.42	0.53	0.42	0.55	0.43						
35	I			0.200		0.185		0.170		0.155		0.134					
	J	U	U	0.48	0.44	0.51	0.45	0.53	0.46	0.55	0.47	0.58	0.49				
55	I			0.236		0.223		0.209		0.194		0.173		0.141			
	J	U	U	0.49	0.49	0.52	0.50	0.54	0.51	0.56	0.52	0.59	0.53	0.62	0.55		
135	I			0.286		0.276		0.266		0.255		0.240		0.214		0.151	
	J	U	U	0.50	0.54	0.53	0.55	0.55	0.56	0.57	0.57	0.60	0.58	0.63	0.60	0.66	0.63

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
10.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I	0.077															
	J	0.51	0.18														
14	I	0.099		0.088													
	J	0.51	0.22	0.53	0.22												
17	I	0.126		0.113		0.099											
	J	0.51	0.26	0.53	0.26	0.55	0.27										
21	I	0.154		0.141		0.125		0.109									
	J	0.52	0.30	0.53	0.30	0.55	0.31	0.57	0.32								
26	I	0.182		0.168		0.151		0.134		0.118							
	J	0.52	0.33	0.54	0.34	0.55	0.35	0.57	0.36	0.58	0.37						
35	I	0.217		0.203		0.185		0.167		0.150		0.127					
	J	0.53	0.37	0.54	0.38	0.56	0.39	0.57	0.40	0.59	0.41	0.61	0.43				
55	I	0.263		0.248		0.231		0.213		0.196		0.172		0.137			
	J	0.53	0.42	0.55	0.43	0.56	0.44	0.58	0.45	0.59	0.47	0.61	0.48	0.63	0.50		
135	I	0.321		0.309		0.295		0.280		0.266		0.247		0.216		0.149	
	J	0.54	0.48	0.55	0.49	0.57	0.50	0.58	0.52	0.60	0.53	0.62	0.55	0.64	0.57	0.67	0.61

I AND *J* FACTORS FOR:[1]

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
15.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT TIP

EQUAL ADDENDUM $(x_1 = x_2 = 0)$

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I					0.124											
	J	U	U	U	U	0.43	0.43										
21	I					0.139		0.128									
	J	U	U	U	U	0.44	0.46	0.47	0.47								
26	I					0.154		0.143		0.132							
	J	U	U	U	U	0.45	0.49	0.48	0.50	0.50	0.50						
35	I					0.175		0.165		0.154		0.137					
	J	U	U	U	U	0.46	0.52	0.49	0.53	0.51	0.53	0.54	0.54				
55	I					0.204		0.196		0.187		0.171		0.143			
	J	U	U	U	U	0.47	0.55	0.50	0.56	0.53	0.57	0.56	0.58	0.59	0.59		
135	I					0.244		0.241		0.237		0.229		0.209		0.151	
	J	U	U	U	U	0.48	0.59	0.51	0.60	0.54	0.61	0.57	0.62	0.61	0.64	0.65	0.65

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:[1]

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
15.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION $(x_1 = 0.25)$

25 PERCENT SHORT ADDENDUM GEAR $(x_2 = -0.25)$

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I			0.111													
	J	U	U	0.47	0.32												
17	I			0.131		0.117											
	J	U	U	0.48	0.35	0.50	0.36										
21	I			0.152		0.138		0.123									
	J	U	U	0.48	0.39	0.51	0.40	0.53	0.40								
26	I			0.173		0.158		0.143		0.128							
	J	U	U	0.49	0.42	0.51	0.43	0.53	0.44	0.55	0.44						
35	I			0.200		0.186		0.171		0.155		0.134					
	J	U	U	0.50	0.45	0.52	0.46	0.54	0.47	0.56	0.48	0.58	0.49				
55	I			0.236		0.223		0.209		0.195		0.174		0.142			
	J	U	U	0.50	0.49	0.53	0.50	0.55	0.51	0.57	0.53	0.59	0.54	0.62	0.56		
135	I			0.285		0.275		0.265		0.255		0.240		0.214		0.151	
	J	U	U	0.51	0.54	0.54	0.55	0.56	0.56	0.58	0.58	0.60	0.59	0.63	0.61	0.67	0.63

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:

20.0 DEG. PRESSURE ANGLE — 2.250 WHOLE DEPTH FACTOR
15.0 DEG. HELIX ANGLE — 0.024 TOOTH THINNING FOR BACKLASH
0.250 TOOL EDGE RADIUS — LOADED AT TIP
50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)
50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I	0.081															
	J	0.52	0.20														
14	I	0.102		0.091													
	J	0.52	0.23	0.53	0.24												
17	I	0.128		0.116		0.102											
	J	0.52	0.27	0.54	0.28	0.55	0.28										
21	I	0.156		0.143		0.127		0.111									
	J	0.53	0.31	0.54	0.31	0.56	0.32	0.57	0.33								
26	I	0.183		0.169		0.152		0.135		0.119							
	J	0.53	0.34	0.55	0.35	0.56	0.36	0.58	0.37	0.59	0.38						
35	I	0.218		0.203		0.186		0.168		0.151		0.128					
	J	0.54	0.38	0.55	0.39	0.57	0.40	0.58	0.41	0.60	0.42	0.61	0.44				
55	I	0.262		0.248		0.231		0.213		0.196		0.173		0.138			
	J	0.54	0.43	0.55	0.44	0.57	0.45	0.59	0.46	0.60	0.48	0.62	0.49	0.64	0.51		
135	I	0.319		0.307		0.294		0.279		0.265		0.246		0.216		0.149	
	J	0.55	0.49	0.56	0.50	0.58	0.51	0.59	0.52	0.61	0.54	0.62	0.55	0.65	0.58	0.67	0.61

I AND *J* FACTORS FOR:[1]

20.0 DEG. PRESSURE ANGLE — 2.250 WHOLE DEPTH FACTOR
20.0 DEG. HELIX ANGLE — 0.024 TOOTH THINNING FOR BACKLASH
0.250 TOOL EDGE RADIUS — LOADED AT TIP
EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I					0.125											
	J	U	U	U	U	0.44	0.44										
21	I					0.140		0.129									
	J	U	U	U	U	0.45	0.46	0.47	0.47								
26	I					0.156		0.145		0.133							
	J	U	U	U	U	0.45	0.49	0.48	0.49	0.50	0.50						
35	I					0.177		0.167		0.155		0.138					
	J	U	U	U	U	0.46	0.51	0.49	0.52	0.51	0.53	0.54	0.54				
55	I					0.205		0.197		0.188		0.172		0.144			
	J	U	U	U	U	0.47	0.54	0.50	0.55	0.52	0.56	0.55	0.57	0.58	0.58		
135	I					0.245		0.242		0.238		0.229		0.209		0.151	
	J	U	U	U	U	0.48	0.58	0.51	0.59	0.54	0.60	0.57	0.61	0.60	0.62	0.64	0.64

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:

20.0 DEG. PRESSURE ANGLE — 2.250 WHOLE DEPTH FACTOR
20.0 DEG. HELIX ANGLE — 0.024 TOOTH THINNING FOR BACKLASH
0.250 TOOL EDGE RADIUS — LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

GEAR TEETH		PINION TEETH 12 P	G	14 P	G	17 P	G	21 P	G	26 P	G	35 P	G	55 P	G	135 P	G
12	I	0.108															
	J	0.45	0.29														
14	I	0.124		0.114													
	J	0.45	0.32	0.47	0.33												
17	I	0.144		0.133		0.119											
	J	0.46	0.35	0.48	0.36	0.50	0.37										
21	I	0.165		0.154		0.140		0.125									
	J	0.47	0.39	0.48	0.39	0.51	0.40	0.53	0.41								
26	I	0.186		0.174		0.160		0.145		0.130							
	J	0.47	0.41	0.49	0.42	0.51	0.43	0.53	0.44	0.55	0.45						
35	I	0.212		0.201		0.187		0.172		0.156		0.135					
	J	0.48	0.44	0.50	0.45	0.52	0.46	0.54	0.47	0.55	0.48	0.58	0.49				
55	I	0.246		0.236		0.223		0.209		0.195		0.175		0.142			
	J	0.48	0.48	0.50	0.49	0.52	0.50	0.54	0.51	0.56	0.52	0.58	0.53	0.61	0.55		
135	I	0.291		0.284		0.274		0.265		0.255		0.240		0.214		0.151	
	J	0.49	0.53	0.51	0.53	0.53	0.54	0.55	0.56	0.57	0.57	0.59	0.58	0.62	0.60	0.65	0.62

I AND *J* FACTORS FOR:

20.0 DEG. PRESSURE ANGLE — 2.250 WHOLE DEPTH FACTOR
20.0 DEG. HELIX ANGLE — 0.024 TOOTH THINNING FOR BACKLASH
0.250 TOOL EDGE RADIUS — LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR TEETH		PINION TEETH 12 P	G	14 P	G	17 P	G	21 P	G	26 P	G	35 P	G	55 P	G	135 P	G
12	I	0.086															
	J	0.52	0.21														
14	I	0.106		0.095													
	J	0.52	0.24	0.53	0.25												
17	I	0.132		0.120		0.105											
	J	0.52	0.28	0.53	0.29	0.55	0.29										
21	I	0.159		0.146		0.130		0.114									
	J	0.53	0.32	0.54	0.32	0.55	0.33	0.57	0.34								
26	I	0.185		0.171		0.155		0.138		0.121							
	J	0.53	0.35	0.54	0.36	0.56	0.37	0.57	0.38	0.58	0.38						
35	I	0.219		0.204		0.187		0.170		0.152		0.130					
	J	0.53	0.39	0.54	0.39	0.56	0.40	0.57	0.41	0.59	0.43	0.60	0.44				
55	I	0.261		0.248		0.231		0.214		0.197		0.173		0.139			
	J	0.54	0.43	0.55	0.44	0.56	0.45	0.58	0.46	0.59	0.47	0.61	0.49	0.63	0.51		
135	I	0.317		0.305		0.292		0.278		0.265		0.246		0.216		0.150	
	J	0.54	0.48	0.55	0.49	0.57	0.50	0.58	0.52	0.60	0.53	0.61	0.55	0.63	0.57	0.66	0.60

I AND *J* FACTORS FOR:[1]

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
25.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS	LOADED AT TIP	

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I			0.123													
	J	U	U	0.40	0.40												
17	I			0.137		0.126											
	J	U	U	0.41	0.43	0.43	0.43										
21	I			0.152		0.142		0.130									
	J	U	U	0.41	0.45	0.44	0.45	0.46	0.46								
26	I			0.167		0.157		0.146		0.134							
	J	U	U	0.42	0.47	0.44	0.47	0.47	0.48	0.49	0.49						
35	I			0.187		0.178		0.168		0.156		0.138					
	J	U	U	0.43	0.49	0.45	0.50	0.48	0.50	0.50	0.51	0.52	0.52				
55	I			0.213		0.207		0.199		0.189		0.173		0.144			
	J	U	U	0.44	0.52	0.46	0.52	0.49	0.53	0.51	0.54	0.53	0.55	0.56	0.56		
135	I			0.248		0.247		0.244		0.239		0.230		0.210		0.151	
	J	U	U	0.45	0.55	0.47	0.56	0.50	0.56	0.52	0.57	0.54	0.58	0.57	0.59	0.61	0.61

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
25.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS	LOADED AT TIP	

25 PERCENT LONG ADDENDUM PINION ($x_1 = 0.25$)

25 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.25$)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I	0.112															
	J	0.44	0.30														
14	I	0.127		0.116													
	J	0.45	0.33	0.46	0.33												
17	I	0.146		0.135		0.122											
	J	0.45	0.36	0.47	0.36	0.49	0.37										
21	I	0.167		0.156		0.142		0.127									
	J	0.46	0.38	0.47	0.39	0.49	0.40	0.51	0.41								
26	I	0.187		0.176		0.161		0.146		0.131							
	J	0.46	0.41	0.48	0.41	0.50	0.42	0.51	0.43	0.53	0.44						
35	I	0.213		0.202		0.188		0.173		0.158		0.137					
	J	0.47	0.44	0.48	0.44	0.50	0.45	0.52	0.46	0.53	0.47	0.55	0.48				
55	I	0.246		0.236		0.224		0.210		0.196		0.175		0.143			
	J	0.47	0.47	0.49	0.48	0.51	0.48	0.53	0.49	0.54	0.50	0.56	0.51	0.58	0.53		
135	I	0.289		0.282		0.273		0.264		0.254		0.240		0.214		0.151	
	J	0.48	0.51	0.50	0.51	0.52	0.52	0.53	0.53	0.55	0.54	0.57	0.56	0.59	0.57	0.62	0.59

I AND *J* FACTORS FOR:

20.0 DEG. PRESSURE ANGLE
25.0 DEG. HELIX ANGLE
0.250 TOOL EDGE RADIUS
2.250 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP
50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)
50 PERCENT SHORT ADDENDUM GEAR (x_2 = – 0.50)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.092															
	J	0.50	0.23														
14	I	0.112		0.100													
	J	0.50	0.25	0.51	0.26												
17	I	0.136		0.124		0.109											
	J	0.51	0.29	0.52	0.29	0.53	0.30										
21	I	0.162		0.149		0.133		0.117									
	J	0.51	0.32	0.52	0.33	0.53	0.34	0.55	0.34								
26	I	0.187		0.174		0.157		0.140		0.124							
	J	0.51	0.35	0.52	0.36	0.54	0.36	0.55	0.37	0.56	0.38						
35	I	0.219		0.206		0.189		0.171		0.154		0.132					
	J	0.52	0.38	0.53	0.39	0.54	0.40	0.55	0.41	0.56	0.42	0.58	0.43				
55	I	0.260		0.247		0.231		0.214		0.197		0.174		0.140			
	J	0.52	0.42	0.53	0.43	0.54	0.44	0.55	0.45	0.57	0.46	0.58	0.48	0.60	0.49		
135	I	0.313		0.302		0.290		0.276		0.263		0.245		0.216		0.150	
	J	0.52	0.47	0.53	0.48	0.55	0.49	0.56	0.50	0.57	0.51	0.58	0.53	0.60	0.55	0.62	0.57

I AND *J* FACTORS FOR:[1]

20.0 DEG. PRESSURE ANGLE
30.0 DEG. HELIX ANGLE
0.250 TOOL EDGE RADIUS
EQUAL ADDENDUM ($x_1 = x_2 = 0$)
2.250 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I			0.125													
	J	U	U	0.39	0.39												
17	I			0.139		0.128											
	J	U	U	0.39	0.41	0.41	0.41										
21	I			0.154		0.144		0.132									
	J	U	U	0.40	0.43	0.42	0.43	0.44	0.44								
26	I			0.169		0.159		0.148		0.135							
	J	U	U	0.41	0.44	0.43	0.45	0.45	0.46	0.46	0.46						
35	I			0.189		0.180		0.170		0.158		0.139					
	J	U	U	0.41	0.46	0.43	0.47	0.45	0.48	0.47	0.48	0.49	0.49				
55	I			0.215		0.208		0.200		0.190		0.174		0.145			
	J	U	U	0.42	0.49	0.44	0.49	0.46	0.50	0.48	0.50	0.50	0.51	0.52	0.52		
135	I			0.250		0.248		0.245		0.240		0.231		0.210		0.151	
	J	U	U	0.43	0.51	0.45	0.52	0.47	0.53	0.49	0.53	0.51	0.54	0.53	0.55	0.56	0.56

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
30.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.115															
	J	0.42	0.30														
14	I	0.130		0.119													
	J	0.43	0.32	0.44	0.33												
17	I	0.149		0.138		0.124											
	J	0.43	0.35	0.45	0.35	0.46	0.36										
21	I	0.169		0.158		0.144		0.129									
	J	0.44	0.37	0.45	0.38	0.47	0.39	0.48	0.39								
26	I	0.188		0.177		0.163		0.148		0.133							
	J	0.44	0.39	0.45	0.40	0.47	0.41	0.48	0.42	0.50	0.42						
35	I	0.213		0.202		0.189		0.174		0.159		0.138					
	J	0.45	0.42	0.46	0.42	0.47	0.43	0.49	0.44	0.50	0.45	0.52	0.46				
55	I	0.245		0.236		0.224		0.210		0.196		0.176		0.144			
	J	0.45	0.44	0.46	0.45	0.48	0.46	0.49	0.47	0.51	0.48	0.52	0.49	0.54	0.50		
135	I	0.286		0.280		0.272		0.263		0.253		0.239		0.213		0.151	
	J	0.46	0.48	0.47	0.48	0.49	0.49	0.50	0.50	0.51	0.51	0.53	0.52	0.55	0.53	0.57	0.55

I AND *J* FACTORS FOR:

20.0	DEG. PRESSURE ANGLE	2.250	WHOLE DEPTH FACTOR
30.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.250	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.098															
	J	0.47	0.24														
14	I	0.117		0.106													
	J	0.48	0.26	0.48	0.27												
17	I	0.141		0.128		0.114											
	J	0.48	0.29	0.49	0.30	0.50	0.30										
21	I	0.166		0.153		0.137		0.121									
	J	0.48	0.32	0.49	0.32	0.50	0.33	0.51	0.34								
26	I	0.190		0.176		0.160		0.143		0.127							
	J	0.48	0.34	0.49	0.35	0.50	0.36	0.51	0.37	0.52	0.37						
35	I	0.220		0.207		0.190		0.173		0.156		0.134					
	J	0.49	0.37	0.49	0.38	0.51	0.39	0.52	0.40	0.52	0.40	0.54	0.42				
55	I	0.259		0.246		0.231		0.214		0.198		0.175		0.141			
	J	0.49	0.40	0.50	0.41	0.51	0.42	0.52	0.43	0.53	0.44	0.54	0.45	0.55	0.47		
135	I	0.309		0.299		0.287		0.274		0.262		0.244		0.215		0.150	
	J	0.49	0.44	0.50	0.45	0.51	0.46	0.52	0.47	0.53	0.48	0.54	0.49	0.56	0.51	0.57	0.53

I AND *J* FACTORS FOR:[1]

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS	LOADED AT TIP	

EQUAL ADDENDUM $(x_1 = x_2 = 0)$

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I			0.086													
	J	U	U	0.28	0.28												
17	I			0.091		0.090											
	J	U	U	0.28	0.30	0.30	0.30										
21	I			0.095		0.096		0.092									
	J	U	U	0.28	0.31	0.30	0.31	0.31	0.31								
26	I			0.100		0.101		0.099		0.094							
	J	U	U	0.28	0.33	0.30	0.33	0.31	0.33	0.33	0.33						
35	I			0.106		0.109		0.108		0.104		0.095					
	J	U	U	0.28	0.34	0.30	0.34	0.31	0.34	0.33	0.34	0.34	0.34				
55	I			0.113		0.119		0.121		0.119		0.112		0.095			
	J	U	U	0.28	0.36	0.30	0.36	0.31	0.36	0.33	0.36	0.34	0.36	0.36	0.36		
135	I			0.123		0.132		0.139		0.142		0.141		0.131		0.096	
	J	U	U	0.28	0.38	0.30	0.38	0.31	0.38	0.33	0.38	0.34	0.38	0.36	0.38	0.38	0.38

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS	LOADED AT TIP	

25 PERCENT LONG ADDENDUM PINION $(x_1 = 0.25)$

25 PERCENT SHORT ADDENDUM GEAR $(x_2 = -0.25)$

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I	0.091															
	J	0.32	0.20														
14	I	0.095		0.093													
	J	0.32	0.22	0.33	0.22												
17	I	0.100		0.099		0.094											
	J	0.32	0.25	0.33	0.25	0.34	0.25										
21	I	0.106		0.106		0.102		0.095									
	J	0.32	0.27	0.33	0.27	0.34	0.27	0.36	0.27								
26	I	0.111		0.112		0.109		0.103		0.095							
	J	0.32	0.29	0.33	0.29	0.34	0.29	0.36	0.29	0.36	0.29						
35	I	0.118		0.120		0.119		0.115		0.108		0.096					
	J	0.32	0.31	0.33	0.31	0.34	0.31	0.36	0.31	0.36	0.31	0.37	0.31				
55	I	0.127		0.131		0.133		0.131		0.126		0.116		0.096			
	J	0.32	0.34	0.33	0.34	0.34	0.34	0.36	0.34	0.36	0.34	0.37	0.34	0.38	0.34		
135	I	0.138		0.145		0.151		0.153		0.153		0.148		0.135		0.096	
	J	0.32	0.37	0.33	0.37	0.34	0.37	0.36	0.37	0.36	0.37	0.37	0.37	0.38	0.37	0.39	0.37

I AND *J* FACTORS FOR:[1]

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = – 0.50)

PINION TEETH

GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	T	T														
14	I																
	J	T	T	T	T												
17	I																
	J	T	T	T	T	T	T										
21	I							0.096									
	J	T	T	T	T	T	T	0.40	0.23								
26	I							0.106		0.096							
	J	T	T	T	T	T	T	0.40	0.25	0.40	0.25						
35	I							0.120		0.110		0.096					
	J	T	T	T	T	T	T	0.40	0.28	0.40	0.28	0.40	0.28				
55	I							0.139		0.131		0.118		0.096			
	J	T	T	T	T	T	T	0.40	0.32	0.40	0.32	0.40	0.32	0.40	0.32		
135	I							0.167		0.163		0.155		0.138		0.096	
	J	T	T	T	T	T	T	0.40	0.36	0.40	0.36	0.40	0.36	0.40	0.36	0.40	0.36

1 The letter "T" indicates a gear tooth combination which produces pointed teeth with a top land less than $0.3/P_{nd}$ in one or both components and should be avoided. See Section 7.

I AND *J* FACTORS FOR:[1]

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT HIGHEST POINT OF SINGLE TOOTH CONTACT

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

PINION TEETH

GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I			0.086													
	J	U	U	0.33	0.33												
17	I			0.091		0.090											
	J	U	U	0.33	0.36	0.36	0.36										
21	I			0.095		0.096		0.092									
	J	U	U	0.33	0.39	0.36	0.39	0.39	0.39								
26	I			0.100		0.101		0.099		0.094							
	J	U	U	0.33	0.41	0.37	0.42	0.40	0.42	0.43	0.43						
35	I			0.106		0.109		0.108		0.104		0.095					
	J	U	U	0.34	0.44	0.37	0.45	0.40	0.45	0.43	0.46	0.46	0.46				
55	I			0.113		0.119		0.121		0.119		0.112		0.095			
	J	U	U	0.34	0.47	0.38	0.48	0.41	0.49	0.44	0.49	0.47	0.50	0.51	0.51		
135	I			0.123		0.132		0.139		0.142		0.141		0.131		0.096	
	J	U	U	0.35	0.51	0.38	0.52	0.42	0.53	0.45	0.53	0.48	0.54	0.53	0.56	0.57	0.57

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT HIGHEST POINT OF SINGLE TOOTH CONTACT

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I	0.091															
	J	0.38	0.22														
14	I	0.095		0.093													
	J	0.38	0.25	0.40	0.25												
17	I	0.100		0.099		0.094											
	J	0.38	0.29	0.40	0.29	0.43	0.29										
21	I	0.106		0.106		0.102		0.095									
	J	0.38	0.32	0.41	0.32	0.43	0.33	0.46	0.33								
26	I	0.111		0.112		0.109		0.103		0.095							
	J	0.39	0.35	0.41	0.35	0.44	0.36	0.46	0.36	0.48	0.37						
35	I	0.118		0.120		0.119		0.115		0.108		0.096					
	J	0.39	0.38	0.41	0.39	0.44	0.39	0.47	0.40	0.49	0.41	0.51	0.41				
55	I	0.127		0.131		0.133		0.131		0.126		0.116		0.096			
	J	0.39	0.42	0.42	0.43	0.44	0.44	0.47	0.44	0.49	0.45	0.52	0.46	0.55	0.47		
135	I	0.138		0.145		0.151		0.153		0.153		0.148		0.135		0.096	
	J	0.40	0.47	0.42	0.48	0.45	0.49	0.48	0.49	0.50	0.50	0.53	0.51	0.56	0.53	0.59	0.55

I AND *J* FACTORS FOR:[1]

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
0.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT HIGHEST POINT OF SINGLE TOOTH CONTACT

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	T	T														
14	I																
	J	T	T	T	T												
17	I																
	J	T	T	T	T	T	T										
21	I							0.096									
	J	T	T	T	T	T	T	0.52	0.27								
26	I							0.106		0.096							
	J	T	T	T	T	T	T	0.52	0.30	0.53	0.31						
35	I							0.120		0.110		0.096					
	J	T	T	T	T	T	T	0.52	0.35	0.53	0.35	0.55	0.36				
55	I							0.139		0.131		0.118		0.096			
	J	T	T	T	T	T	T	0.52	0.40	0.54	0.41	0.56	0.42	0.58	0.43		
135	I							0.167		0.163		0.155		0.138		0.096	
	J	T	T	T	T	T	T	0.53	0.46	0.54	0.47	0.56	0.48	0.58	0.50	0.60	0.53

1 The letter "T" indicates a gear tooth combination which produces pointed teeth with a top land less than $0.3/P_{nd}$ in one or both components and should be avoided. See Section 7.

I AND *J* FACTORS FOR:[1]

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
10.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT TIP

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I			0.129													
	J	U	U	0.47	0.47												
17	I			0.144		0.133											
	J	U	U	0.48	0.51	0.52	0.52										
21	I			0.159		0.149		0.136									
	J	U	U	0.48	0.55	0.52	0.55	0.56	0.56								
26	I			0.175		0.165		0.152		0.139							
	J	U	U	0.49	0.58	0.53	0.58	0.57	0.59	0.60	0.60						
35	I			0.195		0.186		0.175		0.162		0.143					
	J	U	U	0.50	0.61	0.54	0.62	0.57	0.63	0.61	0.64	0.64	0.64				
55	I			0.221		0.215		0.206		0.195		0.178		0.148			
	J	U	U	0.51	0.65	0.55	0.66	0.58	0.67	0.62	0.68	0.65	0.69	0.70	0.70		
135	I			0.257		0.255		0.251		0.246		0.236		0.215		0.154	
	J	U	U	0.52	0.70	0.56	0.71	0.60	0.72	0.63	0.73	0.67	0.74	0.71	0.75	0.76	0.76

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
10.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION ($x_1 = 0.25$)

25 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.25$)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I	0.120															
	J	0.53	0.33														
14	I	0.136		0.125													
	J	0.54	0.37	0.56	0.38												
17	I	0.155		0.143		0.129											
	J	0.54	0.41	0.57	0.42	0.60	0.43										
21	I	0.175		0.163		0.149		0.134									
	J	0.55	0.46	0.57	0.46	0.60	0.47	0.63	0.48								
26	I	0.194		0.183		0.168		0.153		0.137							
	J	0.55	0.49	0.58	0.50	0.61	0.51	0.64	0.52	0.66	0.53						
35	I	0.219		0.208		0.194		0.179		0.164		0.142					
	J	0.56	0.54	0.58	0.55	0.61	0.56	0.64	0.57	0.67	0.57	0.69	0.59				
55	I	0.251		0.242		0.229		0.216		0.201		0.180		0.147			
	J	0.56	0.59	0.59	0.60	0.62	0.61	0.65	0.62	0.67	0.63	0.70	0.64	0.73	0.66		
135	I	0.293		0.286		0.278		0.269		0.259		0.244		0.218		0.154	
	J	0.57	0.65	0.60	0.66	0.63	0.67	0.66	0.68	0.68	0.69	0.71	0.71	0.74	0.72	0.78	0.74

I AND *J* FACTORS FOR:[1]

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
10.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	T	T														
14	I																
	J	T	T	T	T												
17	I																
	J	T	T	T	T	T	T										
21	I							0.126									
	J	T	T	T	T	T	T	0.69	0.40								
26	I							0.148		0.132							
	J	T	T	T	T	T	T	0.69	0.44	0.71	0.45						
35	I							0.178		0.161		0.138					
	J	T	T	T	T	T	T	0.70	0.50	0.71	0.51	0.73	0.52				
55	I							0.220		0.203		0.180		0.145			
	J	T	T	T	T	T	T	0.70	0.56	0.72	0.57	0.74	0.59	0.76	0.61		
135	I							0.280		0.267		0.249		0.220		0.153	
	J	T	T	T	T	T	T	0.70	0.64	0.72	0.65	0.74	0.67	0.76	0.69	0.79	0.72

1 The letter "T" indicates a gear tooth combination which produces pointed teeth with a top land less than $0.3/P_{nd}$ in one or both components and should be avoided. See Section 7.

I AND *J* FACTORS FOR:[1]

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
15.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT TIP

EQUAL ADDENDUM ($x_1 = x_2 = 0$)

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	U	U														
14	I			0.130													
	J	U	U	0.49	0.49												
17	I			0.144		0.133											
	J	U	U	0.50	0.53	0.53	0.53										
21	I			0.160		0.149		0.137									
	J	U	U	0.50	0.56	0.54	0.57	0.58	0.58								
26	I			0.175		0.165		0.153		0.140							
	J	U	U	0.51	0.59	0.55	0.60	0.58	0.61	0.61	0.61						
35	I			0.195		0.186		0.175		0.163		0.143					
	J	U	U	0.52	0.63	0.55	0.64	0.59	0.64	0.62	0.65	0.66	0.66				
55	I			0.222		0.215		0.206		0.195		0.178		0.148			
	J	U	U	0.52	0.67	0.56	0.68	0.60	0.68	0.63	0.69	0.67	0.70	0.71	0.71		
135	I			0.257		0.255		0.251		0.246		0.236		0.214		0.154	
	J	U	U	0.53	0.72	0.57	0.72	0.61	0.73	0.64	0.74	0.68	0.75	0.72	0.76	0.78	0.78

1 The letter "U" indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7–1.

I AND *J* FACTORS FOR:

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
15.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.122															
	J	0.55	0.35														
14	I	0.137		0.126													
	J	0.56	0.39	0.58	0.39												
17	I	0.155		0.144		0.130											
	J	0.56	0.43	0.59	0.44	0.62	0.45										
21	I	0.175		0.164		0.149		0.134									
	J	0.57	0.48	0.59	0.48	0.62	0.49	0.65	0.50								
26	I	0.195		0.183		0.169		0.153		0.138							
	J	0.57	0.51	0.60	0.52	0.63	0.53	0.65	0.54	0.68	0.55						
35	I	0.219		0.208		0.195		0.179		0.164		0.142					
	J	0.57	0.55	0.60	0.56	0.63	0.57	0.66	0.58	0.68	0.59	0.71	0.60				
55	I	0.251		0.241		0.229		0.215		0.201		0.180		0.147			
	J	0.58	0.61	0.61	0.61	0.64	0.62	0.66	0.63	0.69	0.64	0.71	0.66	0.75	0.67		
135	I	0.292		0.285		0.277		0.268		0.258		0.244		0.218		0.153	
	J	0.59	0.66	0.62	0.67	0.64	0.68	0.67	0.70	0.70	0.71	0.72	0.72	0.75	0.74	0.79	0.76

I AND *J* FACTORS FOR:[1]

25.0 DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
15.0 DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270 TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	T	T														
14	I																
	J	T	T	T	T												
17	I					0.121											
	J	T	T	T	T	0.69	0.36										
21	I					0.144		0.127									
	J	T	T	T	T	0.69	0.41	0.71	0.42								
26	I					0.166		0.149		0.133							
	J	T	T	T	T	0.69	0.45	0.71	0.46	0.73	0.47						
35	I					0.196		0.179		0.162		0.138					
	J	T	T	T	T	0.69	0.50	0.71	0.52	0.73	0.53	0.75	0.54				
55	I					0.236		0.220		0.203		0.180		0.145			
	J	T	T	T	T	0.70	0.57	0.72	0.58	0.73	0.59	0.75	0.60	0.77	0.62		
135	I					0.292		0.279		0.266		0.249		0.219		0.152	
	J	T	T	T	T	0.70	0.64	0.72	0.65	0.74	0.67	0.75	0.68	0.78	0.70	0.80	0.73

1 The letter “T” indicates a gear tooth combination which produces pointed teeth with a top land less than $0.3/P_{nd}$ in one or both components and should be avoided. See Section 7.

I AND *J* FACTORS FOR:

25.0 DEG. PRESSURE ANGLE
20.0 DEG. HELIX ANGLE
0.270 TOOL EDGE RADIUS
EQUAL ADDENDUM ($x_1 = x_2 = 0$)

2.350 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I	0.128															
	J	0.47	0.47														
14	I	0.140		0.131													
	J	0.47	0.50	0.50	0.50												
17	I	0.154		0.145		0.134											
	J	0.48	0.53	0.51	0.54	0.54	0.54										
21	I	0.169		0.161		0.150		0.137									
	J	0.48	0.56	0.51	0.57	0.55	0.58	0.58	0.58								
26	I	0.184		0.176		0.166		0.153		0.140							
	J	0.49	0.59	0.52	0.60	0.55	0.60	0.59	0.61	0.62	0.62						
35	I	0.202		0.196		0.187		0.176		0.163		0.144					
	J	0.49	0.62	0.53	0.63	0.56	0.64	0.60	0.64	0.62	0.65	0.66	0.66				
55	I	0.227		0.222		0.215		0.206		0.196		0.178		0.148			
	J	0.50	0.66	0.53	0.67	0.57	0.67	0.60	0.68	0.63	0.69	0.67	0.70	0.71	0.71		
135	I	0.258		0.257		0.255		0.251		0.246		0.236		0.214		0.153	
	J	0.51	0.70	0.54	0.71	0.58	0.72	0.62	0.72	0.65	0.73	0.68	0.74	0.72	0.75	0.76	0.76

I AND *J* FACTORS FOR:

25.0 DEG. PRESSURE ANGLE
20.0 DEG. HELIX ANGLE
0.270 TOOL EDGE RADIUS
25 PERCENT LONG ADDENDUM PINION ($x_1 = 0.25$)
25 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.25$)

2.350 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

GEAR TEETH		PINION TEETH 12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I	0.123															
	J	0.56	0.37														
14	I	0.138		0.127													
	J	0.56	0.40	0.59	0.41												
17	I	0.156		0.145		0.131											
	J	0.57	0.45	0.59	0.45	0.62	0.46										
21	I	0.176		0.164		0.150		0.135									
	J	0.57	0.49	0.60	0.49	0.62	0.50	0.65	0.51								
26	I	0.195		0.184		0.169		0.154		0.138							
	J	0.58	0.52	0.60	0.53	0.63	0.54	0.65	0.54	0.67	0.55						
35	I	0.219		0.208		0.195		0.180		0.164		0.143					
	J	0.58	0.56	0.61	0.57	0.63	0.58	0.66	0.59	0.68	0.59	0.70	0.60				
55	I	0.250		0.241		0.229		0.215		0.201		0.180		0.147			
	J	0.59	0.61	0.61	0.61	0.64	0.62	0.66	0.63	0.69	0.64	0.71	0.65	0.74	0.67		
135	I	0.290		0.284		0.276		0.267		0.257		0.243		0.217		0.153	
	J	0.59	0.66	0.62	0.67	0.65	0.68	0.67	0.69	0.69	0.70	0.72	0.71	0.75	0.73	0.78	0.75

I AND *J* FACTORS FOR:[1]

25.0 DEG. PRESSURE ANGLE
20.0 DEG. HELIX ANGLE
0.270 TOOL EDGE RADIUS
2.350 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	T	T														
14	I																
	J	T	T	T	T												
17	I					0.123											
	J	T	T	T	T	0.68	0.37										
21	I					0.145		0.129									
	J	T	T	T	T	0.69	0.42	0.70	0.43								
26	I					0.167		0.150		0.134							
	J	T	T	T	T	0.69	0.46	0.71	0.47	0.72	0.48						
35	I					0.197		0.179		0.162		0.139					
	J	T	T	T	T	0.69	0.51	0.71	0.52	0.72	0.53	0.74	0.54				
55	I					0.236		0.219		0.203		0.180		0.145			
	J	T	T	T	T	0.70	0.57	0.71	0.58	0.73	0.59	0.74	0.61	0.76	0.62		
135	I					0.290		0.277		0.265		0.248		0.219		0.152	
	J	T	T	T	T	0.70	0.64	0.72	0.65	0.73	0.66	0.75	0.68	0.77	0.70	0.79	0.72

1 The letter "T" indicates a gear tooth combination which produces pointed teeth with a top land less than $0.3/P_{nd}$ in one or both components and should be avoided. See Section 7.

I AND *J* FACTORS FOR:

25.0 DEG. PRESSURE ANGLE
25.0 DEG. HELIX ANGLE
0.270 TOOL EDGE RADIUS
EQUAL ADDENDUM ($x_1 = x_2 = 0$)
2.350 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

GEAR		PINION TEETH 12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.129															
	J	0.47	0.47														
14	I	0.141		0.132													
	J	0.47	0.50	0.50	0.50												
17	I	0.155		0.146		0.135											
	J	0.48	0.53	0.51	0.53	0.54	0.54										
21	I	0.170		0.162		0.151		0.138									
	J	0.48	0.55	0.51	0.56	0.54	0.57	0.57	0.57								
26	I	0.185		0.177		0.166		0.154		0.141							
	J	0.49	0.58	0.52	0.58	0.55	0.59	0.58	0.60	0.60	0.60						
35	I	0.203		0.197		0.188		0.176		0.163		0.144					
	J	0.49	0.61	0.52	0.61	0.56	0.62	0.58	0.63	0.61	0.63	0.64	0.64				
55	I	0.227		0.223		0.216		0.207		0.196		0.178		0.148			
	J	0.50	0.64	0.53	0.65	0.56	0.65	0.59	0.66	0.62	0.67	0.65	0.67	0.68	0.68		
135	I	0.259		0.258		0.255		0.251		0.246		0.235		0.213		0.152	
	J	0.51	0.68	0.54	0.68	0.57	0.69	0.60	0.70	0.63	0.70	0.66	0.71	0.69	0.72	0.73	0.73

I AND *J* FACTORS FOR:

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
25.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT TIP

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I	0.125															
	J	0.55	0.38														
14	I	0.139		0.128													
	J	0.56	0.41	0.58	0.42												
17	I	0.157		0.146		0.132											
	J	0.56	0.45	0.58	0.45	0.61	0.46										
21	I	0.177		0.165		0.151		0.136									
	J	0.57	0.48	0.59	0.49	0.61	0.50	0.63	0.51								
26	I	0.195		0.184		0.170		0.154		0.139							
	J	0.57	0.52	0.59	0.52	0.61	0.53	0.64	0.54	0.65	0.54						
35	I	0.219		0.208		0.195		0.180		0.164		0.143					
	J	0.57	0.55	0.60	0.56	0.62	0.57	0.64	0.57	0.66	0.58	0.68	0.59				
55	I	0.249		0.240		0.228		0.215		0.201		0.180		0.147			
	J	0.58	0.59	0.60	0.60	0.62	0.61	0.65	0.62	0.66	0.63	0.69	0.64	0.71	0.65		
135	I	0.288		0.281		0.274		0.265		0.256		0.242		0.216		0.152	
	J	0.59	0.64	0.61	0.65	0.63	0.66	0.65	0.67	0.67	0.68	0.69	0.69	0.72	0.70	0.74	0.72

I AND *J* FACTORS FOR:[1]

25.0	DEG. PRESSURE ANGLE	2.350	WHOLE DEPTH FACTOR
25.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.270	TOOL EDGE RADIUS		LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

GEAR TEETH		12 P	12 G	14 P	14 G	17 P	17 G	21 P	21 G	26 P	26 G	35 P	35 G	55 P	55 G	135 P	135 G
12	I																
	J	T	T														
14	I			0.119													
	J	T	T	0.65	0.33												
17	I			0.140		0.125											
	J	T	T	0.65	0.38	0.66	0.38										
21	I			0.163		0.147		0.130									
	J	T	T	0.65	0.42	0.67	0.43	0.68	0.43								
26	I			0.184		0.168		0.151		0.135							
	J	T	T	0.65	0.46	0.67	0.46	0.68	0.47	0.70	0.48						
35	I			0.213		0.197		0.180		0.163		0.140					
	J	T	T	0.66	0.50	0.67	0.51	0.69	0.52	0.70	0.53	0.71	0.54				
55	I			0.249		0.235		0.219		0.203		0.180		0.145			
	J	T	T	0.66	0.55	0.67	0.56	0.69	0.57	0.70	0.58	0.72	0.59	0.73	0.61		
135	I			0.298		0.287		0.275		0.263		0.246		0.218		0.151	
	J	T	T	0.66	0.61	0.68	0.62	0.69	0.63	0.70	0.64	0.72	0.66	0.73	0.67	0.75	0.70

1 The letter “T” indicates a gear tooth combination which produces pointed teeth with a top land less than $0.3/P_{nd}$ in one or both components and should be avoided. See Section 7.

I AND *J* FACTORS FOR:

25.0 DEG. PRESSURE ANGLE
30.0 DEG. HELIX ANGLE
0.270 TOOL EDGE RADIUS
EQUAL ADDENDUM ($x_1 = x_2 = 0$)

2.350 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.130															
	J	0.46	0.46														
14	I	0.142		0.133													
	J	0.47	0.49	0.49	0.49												
17	I	0.156		0.147		0.136											
	J	0.47	0.51	0.50	0.52	0.52	0.52										
21	I	0.171		0.163		0.151		0.138									
	J	0.48	0.54	0.50	0.54	0.53	0.55	0.55	0.55								
26	I	0.186		0.178		0.167		0.154		0.141							
	J	0.48	0.56	0.51	0.56	0.53	0.57	0.56	0.57	0.58	0.58						
35	I	0.204		0.198		0.188		0.176		0.163		0.144					
	J	0.49	0.58	0.51	0.59	0.54	0.59	0.56	0.60	0.58	0.60	0.61	0.61				
55	I	0.228		0.223		0.216		0.207		0.196		0.178		0.147			
	J	0.49	0.61	0.52	0.61	0.54	0.62	0.57	0.62	0.59	0.63	0.62	0.64	0.64	0.64		
135	I	0.259		0.257		0.255		0.251		0.245		0.234		0.212		0.151	
	J	0.50	0.64	0.53	0.64	0.55	0.65	0.58	0.66	0.60	0.66	0.62	0.67	0.65	0.68	0.68	0.68

I AND *J* FACTORS FOR:

25.0 DEG. PRESSURE ANGLE
30.0 DEG. HELIX ANGLE
0.270 TOOL EDGE RADIUS
25 PERCENT LONG ADDENDUM PINION ($x_1 = 0.25$)
25 PERCENT SHORT ADDENDUM GEAR ($x_2 = -0.25$)

2.350 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.127															
	J	0.54	0.38														
14	I	0.141		0.130													
	J	0.54	0.41	0.56	0.42												
17	I	0.159		0.147		0.133											
	J	0.54	0.44	0.56	0.45	0.58	0.46										
21	I	0.177		0.166		0.152		0.137									
	J	0.55	0.47	0.57	0.48	0.58	0.49	0.60	0.49								
26	I	0.195		0.184		0.170		0.155		0.140							
	J	0.55	0.50	0.57	0.51	0.59	0.51	0.61	0.52	0.62	0.53						
35	I	0.218		0.208		0.194		0.180		0.164		0.143					
	J	0.56	0.53	0.57	0.54	0.59	0.54	0.61	0.55	0.63	0.56	0.64	0.57				
55	I	0.247		0.238		0.227		0.214		0.200		0.180		0.147			
	J	0.56	0.57	0.58	0.57	0.60	0.58	0.61	0.59	0.63	0.59	0.65	0.60	0.67	0.61		
135	I	0.285		0.279		0.272		0.263		0.254		0.240		0.215		0.151	
	J	0.56	0.61	0.58	0.61	0.60	0.62	0.62	0.63	0.64	0.64	0.65	0.65	0.67	0.66	0.70	0.67

I AND *J* FACTORS FOR:

25.0 DEG. PRESSURE ANGLE
30.0 DEG. HELIX ANGLE
0.270 TOOL EDGE RADIUS
2.350 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.117															
	J	0.60	0.30														
14	I	0.134		0.122													
	J	0.61	0.34	0.62	0.34												
17	I	0.155		0.142		0.127											
	J	0.61	0.37	0.62	0.38	0.63	0.39										
21	I	0.177		0.164		0.148		0.132									
	J	0.61	0.41	0.62	0.42	0.63	0.42	0.64	0.43								
26	I	0.198		0.185		0.169		0.152		0.136							
	J	0.61	0.44	0.62	0.45	0.63	0.46	0.64	0.46	0.65	0.47						
35	I	0.225		0.212		0.196		0.180		0.163		0.140					
	J	0.61	0.48	0.62	0.48	0.64	0.49	0.65	0.50	0.66	0.51	0.67	0.52				
55	I	0.259		0.247		0.233		0.218		0.202		0.179		0.145			
	J	0.62	0.52	0.63	0.53	0.64	0.54	0.65	0.55	0.66	0.56	0.67	0.57	0.68	0.58		
135	I	0.303		0.294		0.283		0.272		0.261		0.244		0.216		0.151	
	J	0.62	0.57	0.63	0.58	0.64	0.59	0.65	0.60	0.66	0.61	0.67	0.62	0.69	0.64	0.70	0.65

I AND *J* FACTORS FOR:[1]

STUB TOOTH (SYKES) FORM
20.0 DEG. PRESSURE ANGLE TRANSVERSE
30. DEG. HELIX ANGLE
0.157 TOOL EDGE RADIUS
EQUAL ADDENDUM ($x_1 = x_2 = 0$)
0.8 ADDENDUM FACTOR
1.900 WHOLE DEPTH FACTOR
0.024 TOOTH THINNING FOR BACKLASH
LOADED AT TIP

		PINION TEETH															
GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I																
	J	U	U														
14	I																
	J	U	U	U	U												
17	I					0.115											
	J	U	U	U	U	0.37	0.37										
21	I					0.129		0.119									
	J	U	U	U	U	0.38	0.39	0.39	0.39								
26	I					0.143		0.133		0.122							
	J	U	U	U	U	0.38	0.40	0.40	0.41	0.41	0.41						
35	I					0.163		0.153		0.143		0.127					
	J	U	U	U	U	0.39	0.41	0.40	0.42	0.42	0.43	0.43	0.43				
55	I					0.189		0.181		0.173		0.158		0.132			
	J	U	U	U	U	0.40	0.43	0.41	0.44	0.43	0.44	0.44	0.45	0.46	0.46		
135	I					0.226		0.223		0.219		0.211		0.193		0.139	
	J	U	U	U	U	0.41	0.45	0.43	0.46	0.44	0.47	0.46	0.47	0.47	0.48	0.50	0.50

1 The letter “U” indicates a gear tooth combination which produces an undercut tooth form in one or both components and should be avoided. See Section 7 and Fig 7−1.

I AND *J* FACTORS FOR:

	STUB TOOTH (SYKES) FORM	0.8	ADDENDUM FACTOR
20.0	DEG. PRESSURE ANGLE TRANSVERSE	1.900	WHOLE DEPTH FACTOR
30.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS	LOADED AT TIP	

25 PERCENT LONG ADDENDUM PINION (x_1 = 0.25)

25 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.25)

PINION TEETH

GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.097															
	J	0.38	0.27														
14	I	0.112		0.102													
	J	0.38	0.29	0.39	0.30												
17	I	0.131		0.120		0.108											
	J	0.38	0.31	0.39	0.32	0.41	0.32										
21	I	0.151		0.140		0.127		0.113									
	J	0.39	0.33	0.40	0.33	0.41	0.34	0.42	0.35								
26	I	0.171		0.160		0.147		0.132		0.118							
	J	0.39	0.34	0.40	0.35	0.41	0.36	0.43	0.37	0.44	0.37						
35	I	0.197		0.186		0.172		0.158		0.143		0.124					
	J	0.40	0.36	0.41	0.37	0.42	0.38	0.43	0.39	0.44	0.39	0.46	0.40				
55	I	0.229		0.219		0.207		0.194		0.180		0.160		0.130			
	J	0.40	0.38	0.41	0.39	0.42	0.40	0.44	0.41	0.45	0.42	0.46	0.43	0.48	0.44		
135	I	0.272		0.264		0.255		0.246		0.236		0.221		0.197		0.138	
	J	0.41	0.41	0.42	0.41	0.43	0.42	0.44	0.43	0.45	0.44	0.47	0.45	0.48	0.47	0.50	0.49

I AND *J* FACTORS FOR:

	STUB TOOTH (SYKES) FORM	0.8	ADDENDUM FACTOR
20.0	DEG. PRESSURE ANGLE TRANSVERSE	1.900	WHOLE DEPTH FACTOR
30.0	DEG. HELIX ANGLE	0.024	TOOTH THINNING FOR BACKLASH
0.157	TOOL EDGE RADIUS	LOADED AT TIP	

50 PERCENT LONG ADDENDUM PINION (x_1 = 0.50)

50 PERCENT SHORT ADDENDUM GEAR (x_2 = − 0.50)

PINION TEETH

GEAR		12		14		17		21		26		35		55		135	
TEETH		P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G
12	I	0.069															
	J	0.41	0.21														
14	I	0.089		0.079													
	J	0.41	0.23	0.42	0.24												
17	I	0.114		0.103		0.090											
	J	0.41	0.25	0.42	0.26	0.43	0.27										
21	I	0.141		0.129		0.114		0.100									
	J	0.41	0.28	0.42	0.28	0.43	0.29	0.44	0.30								
26	I	0.167		0.154		0.138		0.122		0.108							
	J	0.41	0.29	0.42	0.30	0.43	0.31	0.44	0.32	0.45	0.33						
35	I	0.199		0.186		0.170		0.153		0.137		0.116					
	J	0.42	0.32	0.43	0.32	0.43	0.33	0.44	0.34	0.45	0.35	0.47	0.37				
55	I	0.240		0.227		0.212		0.195		0.179		0.158		0.126			
	J	0.42	0.34	0.43	0.35	0.44	0.36	0.45	0.37	0.46	0.38	0.47	0.39	0.48	0.41		
135	I	0.293		0.283		0.270		0.257		0.244		0.226		0.198		0.137	
	J	0.42	0.37	0.43	0.38	0.44	0.39	0.45	0.40	0.46	0.41	0.47	0.43	0.48	0.44	0.50	0.47

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Appendix A
Original Derivation of AGMA Geometry Factor for Pitting Resistance, *I*

This Appendix is not part of AGMA 908-B89, *INFORMATION SHEET - Geometry Factors for Determining the Pitting Resistance and Bending Strength for Spur, Helical and Herringbone Gear Teeth,* but is included for informational purposes only.

A1. Purpose. This Appendix provides an historical record for the original derivation of the pitting resistance geometry factor, *I*, based on the Hertzian theory for contact compressive stress between two contacting cylinders as first introduced in AGMA 229.06, June 1962.

A2. Derivation. The surface contact compressive stress between two contacting cylinders is:

$$S_c = \frac{4P}{\pi b} \qquad \text{(Eq A.1)}$$

where

S_c = surface contact compressive stress

P = load per linear unit of contact length

b = total width of contact band

$$b = \sqrt{16\,P\,(K_1+K_2)\left(\frac{R_1\,R_2}{R_1+R_2}\right)} \qquad \text{(Eq A.2)}$$

where

R_1 = radius of curvature of body 1

R_2 = radius of curvature of body 2

$$K_1 = \frac{1-\mu_1^2}{\pi\,E_1} \qquad \text{(Eq A.3)}$$

$$K_2 = \frac{1-\mu_2^2}{\pi\,E_2} \qquad \text{(Eq A.4)}$$

where

E_1, E_2 = modulus of elasticity for material of cylinders 1 and 2

μ_1, μ_2 = Poisson's ratio for material of cylinders 1 and 2

Combining Eqs A.1 and A.2.

$$S_c = C_p\sqrt{\frac{P\,(R_1+R_2)}{R_1\,R_2}} \qquad \text{(Eq A.5)}$$

where

$$C_p = \sqrt{\frac{1}{\pi^2(K_1+K_2)}} = \sqrt{\frac{1}{\pi\left(\frac{1-\mu_1^2}{E_1}+\frac{1-\mu_2^2}{E_2}\right)}} \qquad \text{(Eq A.6)}$$

For helical gear teeth, at the operating pitch diameter:

$$P = \frac{W_N}{L_{min}} = \frac{W_t}{(\cos\phi_t\,\cos\psi_b)\,L_{min}} \qquad \text{(Eq A.7)}$$

where

W_N = normal load in transverse plane

W_t = tangential load in transverse plane

ϕ_t = operating transverse pressure angle

ψ_b = base helix angle

L_{min} = minimum total length of lines of contact

$$R_1 = \frac{d\,\sin\phi_t}{2\,\cos\psi_b} \qquad \text{(Eq A.8)}$$

$$R_2 = \frac{D\,\sin\phi_t}{2\,\cos\psi_b} \qquad \text{(Eq A.9)}$$

d = operating pitch diameter of pinion

D = operating pitch diameter of gear

Making proper substitutions and multiplying by $\sqrt{\frac{F}{F}}$

$$S_c = C_p\sqrt{\frac{W_t}{\cos\phi_t\,\sin\phi_t}\,\frac{F}{L_{min}}\,\frac{d+D}{d\,D}\,\frac{2}{F}} \qquad \text{(Eq A.10)}$$

Regrouping terms

$$S_c = C_p\sqrt{\frac{W_t}{F}\,\frac{1}{d}\,\frac{1}{\left(\dfrac{\dfrac{\cos\phi_t\,\sin\phi_t}{2}\;\dfrac{D}{d+D}}{\left(\dfrac{F}{L_{min}}\right)}\right)}} \qquad \text{(Eq A.11)}$$

but

$$\frac{\cos\phi_t\,\sin\phi_t}{2}\,\frac{D}{d+D} = \frac{\cos\phi_t\,\sin\phi_t}{2}\,\frac{m_G}{m_G+1} \qquad \text{(Eq A.12)}$$

letting

$$C_c = \frac{\cos\phi_t \sin\phi_t}{2} \frac{m_G}{m_G + 1} \qquad \text{(Eq A.13)}$$

$$m_N = \frac{F}{L_{min}} \qquad \text{(Eq A.14)}$$

$$I = \frac{C_c}{m_N} \qquad \text{(Eq A.15)}$$

then

$$S_c = C_p \sqrt{\frac{W_t}{F} \frac{1}{d} \frac{1}{I}} \qquad \text{(Eq A.16)}$$

To adapt Eq A.16 to actual gears, AGMA added additional factors to the equation. These factors are:

- C_a = application factor for pitting resistance
- C_v = dynamic factor for pitting resistance
- C_s = size factor for pitting resistance
- C_m = load distribution factor for pitting resistance
- C_f = surface condition factor for pitting resistance

Putting these factors in Eq A.16 gives:

$$S_c = C_p \sqrt{\frac{W_t C_a}{C_v} \frac{C_s}{d F} \frac{C_m C_f}{I}} \qquad \text{(Eq A.17)}$$

Equation A.17 is the fundamental formula for pitting resistance and is identical to Eq 5.1 in AGMA 2001-B88 and Eq 5.1 in AGMA 218.01.

In rating standard 218.01, Dec., 1982, the I factor was expanded to include two new terms:

$$I = \frac{C_c}{m_N} \text{ expanded to } I = \frac{C_c}{m_N}\left[C_x\, C_\psi^2\right] \qquad \text{(Eq A.18)}$$

The C_x multiplier was added to consider the criterion rating stress at the mean diameters, d_m and D_m, of the meshing elements rather than at the operating diameters d and D. Its derivation follows:

From Eq A.5

$$S_c = C_p \sqrt{\frac{P\;(R_1 + R_2)}{R_1\; R_2}} \qquad \text{(Eq A.19)}$$

dividing by C_p and squaring:

$$\left(\frac{S_c}{C_p}\right)^2 = P\left(\frac{R_1 + R_2}{R_1\; R_2}\right) \qquad \text{(Eq A.20)}$$

solving for P at operating diameters:

$$P = \left(\frac{S_c}{C_p}\right)^2 \frac{R_1\; R_2}{R_1 + R_2} \qquad \text{(Eq A.21)}$$

solving for P at mean tooth diameters:

$$P = \left(\frac{S_c}{C_p}\right)^2 \frac{R_{1m}\; R_{2m}}{R_{1m} + R_{2m}} \qquad \text{(Eq A.22)}$$

where

$$R_{1m} = \frac{d_m \sin\phi_t}{2\cos\psi_b} \qquad \text{(Eq A.23)}$$

$$R_{2m} = \frac{D_m \sin\phi_t}{2\cos\psi_b} \qquad \text{(Eq A.24)}$$

then

$$C_x = \frac{\left(\frac{S_c}{C_p}\right)^2 \left(\frac{R_{1m}\; R_{2m}}{R_{1m} + R_{2m}}\right)}{\left(\frac{S_c}{C_p}\right)^2 \left(\frac{R_1\; R_2}{R_1 + R_2}\right)} = \frac{R_{1m}\, R_{2m}}{R_1\; R_2} \qquad \text{(Eq A.25)}$$

noting that $R_{1m} + R_{2m}$ is always equal to $R_1 + R_2$

The C_ψ^2 factor modifies C_x for the three face contact ratio conditions, see Fig A-1:

- m_F = 0.0 for spur gears
- $0 < m_F \leq 1.0$ for LACR gears
- $m_F > 1.0$ for conventional helical gears

For spur gears and conventional helical gears: $C_\psi^2 = 1.0$.

For low axial contact ratio gears, LACR, the C_ψ^2 factor provides a linear interpolation of I between spur and conventional helical gears, see Fig A-2.

Premise:

$$I_{LACR} = I_s + m_F\,(I_H - I_s) \qquad \text{(Eq A.26)}$$

where

- I_{LACR} = geometry factor for the low axial contact ratio helical gear
- I_s = geometry factor for the spur gear
- I_H = geometry factor for the conventional helical gear

for spur gears

$$I_s = \frac{C_c \; C_{xs} \, C_\psi^2}{m_N} = C_c \, C_{xs} \qquad \text{(Eq A.27)}$$

where

m_N = 1.0
C_{xs} = C_x as determined for LPSTC
C_ψ^2 = 1.0

for conventional helicals

$$I_H = \frac{C_c \, C_{xh} \; C_\psi^2}{m_N} = \frac{C_c \; C_{xh}}{m_N} \qquad \text{(Eq A.28)}$$

where

m_N = F/L_{min}
C_{xh} = C_x as determined at d_m diameter
C_ψ^2 = 1.0

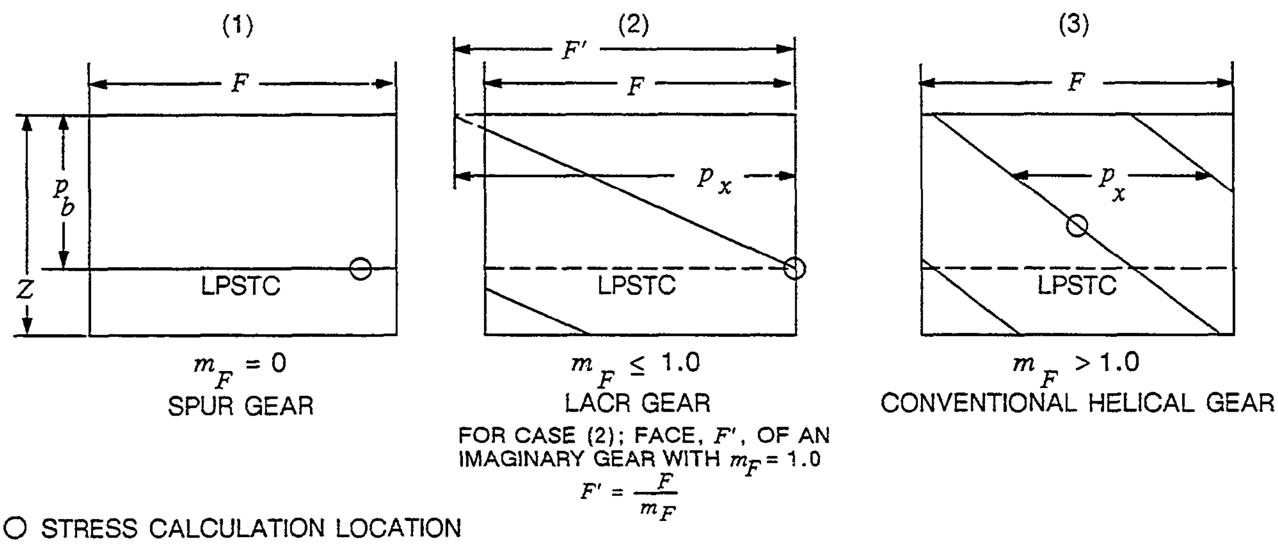

Fig A-1 C_x Determination in Plane of Action

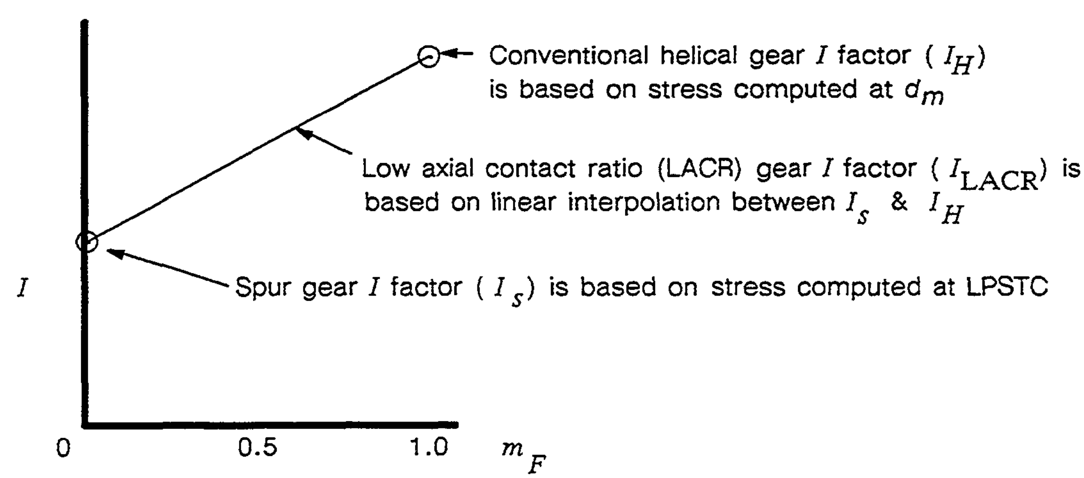

Fig A-2 Variation of I for LACR Gear

for LACR gears

$$I_{LACR} = \frac{C_c C_{xs} C_\psi^2}{m_N} = C_c C_{xs} C_\psi^2 \qquad \text{(Eq A.29)}$$

Substituting in Eq A.26 using Eq A.27, Eq A.28 and Eq A.29:

where

m_N = 1.0
C_{xs} = C_x as determined for LPSTC
C_ψ^2 = a transition factor for spurs to conventional helicals, for LACR gears

$$I_{LACR} = C_c C_{xs} C_\psi^2$$
$$= (C_c C_{xs}) + m_F \left(\frac{C_c C_{xh}}{m_N} - C_c C_{xs} \right) \qquad \text{(Eq A.30)}$$

Dividing by C_c and C_{xs}

$$C_\psi^2 = 1 + m_F \left(\frac{C_{xh}}{C_{xs} m_N} - 1 \right) \qquad \text{(Eq A.31)}$$

where

The m_N represents an imaginary conventional helical gear having a face contact ratio of 1.0

The equivalent face, F′, of such a gear is:

$$F' = \frac{F}{m_F} \qquad \text{(Eq A.32)}$$

and the associated load sharing ratio

$$m_N = \frac{F'}{L_{min}} \qquad \text{(Eq A.33)}$$

For the case of $m_F = 1.0$

$$L_{min} = \frac{Z}{\sin \psi_b} \qquad \text{(Eq A.34)}$$

$$m_N = \frac{F'}{L_{min}} = \frac{\frac{F}{m_F}}{\frac{Z}{\sin \psi_b}} = \frac{F \sin \psi_b}{m_F Z} \qquad \text{(Eq A.35)}$$

Substituting in Eq A.31

$$C_\psi^2 = 1 + m_F \left(\frac{C_{xh} \; m_F Z}{C_{xs} F \sin \psi_b} - 1 \right)$$
$$= 1 + \left(\frac{C_{xh} m_F^2 Z}{C_{xs} F \sin \psi_b} \right) - m_F \qquad \text{(Eq A.36)}$$

Rearranging

$$C_\psi^2 = 1 - m_F + \left(\frac{C_{xh} m_F^2 Z}{C_{xs} F \sin \psi_b} \right) \qquad \text{(Eq A.37)}$$

Taking the square root results in the expressiom found in 218.01.

$$C_\psi = \sqrt{1 - m_F + \frac{C_{xh} \; m_F^2 Z}{C_{xs} \; F \sin \psi_b}} \qquad \text{(Eq A.38)}$$

NOTE: C_{xh} is C_x for the imaginary helical having $m_F = 1.0$ and face = F′, C_{xs} is C_x for equivalent spur gear with contact stress computed at LPSTC.

A3. Proof for Equivalency of *I*. The remainder of this appendix is a proof that the formulation for *I* factor given in AGMA 2001–B88 is identical to the *I* factor in AGMA 908–B89.

From AGMA 2001–B88, Eq 6.1 is:

$$I = \frac{C_c C_x C_\psi^2}{m_N} \qquad \text{(Eq. A.39)}$$

From AGMA 908–B89, Eq 4.1 is:

$$I = \frac{\cos \phi_r \; C_\psi^2}{m_N d \left(\frac{1}{\rho_1} + \frac{1}{\rho_2} \right)} \qquad \text{(Eq. A.40)}$$

Letting $\phi_r = \phi_t$, $\rho_1 = R_1$ & $\rho_2 = R_2$ in Eq A.40, it can now be shown that:

$$I = \frac{\cos \phi_t}{d \left(\frac{1}{R_1} + \frac{1}{R_2} \right)} \frac{C_\psi^2}{m_N} = C_c C_x \frac{C_\psi^2}{m_N} \qquad \text{(Eq A.41)}$$

cancelling $\frac{C_\psi^2}{m_N}$

$$\frac{\cos\phi_t}{d\left(\frac{1}{R_1}+\frac{1}{R_2}\right)} = C_c C_x \quad \text{(Eq A.42)}$$

$$= \left(\frac{\cos\phi_t \ \sin\phi_t}{2}\right)\left(\frac{m_G}{m_G+1}\right)\left(\frac{R_1 R_2}{R_P R_G}\right)$$

$$= \left(\frac{\cos\phi_t \ \sin\phi_t}{2}\right)\left(\frac{m_G}{m_G+1}\right)\left(\frac{R_1 \quad R_2}{\frac{d}{2}\sin\phi_t \ \frac{D}{2}\sin\phi_t}\right)$$

$$= \left(\frac{\cos\phi_t \ \sin\phi_t}{2}\right)\left(\frac{m_G}{m_G+1}\right)\left(\frac{R_1 \quad R_2}{\frac{d\,D}{4} \ \sin^2\phi_t}\right)$$

cancelling and letting $D = m_G\, d$

$$\frac{\cos\phi_t}{d\left(\frac{1}{R_1}+\frac{1}{R_2}\right)} = \cos\phi_t \frac{m_G}{m_G+1}\ \frac{2\ R_1\, R_2}{d^2\, m_G \sin\phi_t} \quad \text{(Eq A.43)}$$

solve for d

$$d = \left(\frac{2\ R_1\, R_2}{\sin\phi_t\ (m_G+1)}\right)\left(\frac{1}{R_1}+\frac{1}{R_2}\right) \quad \text{(Eq A.44)}$$

note that

$$\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = \left(\frac{R_1+R_2}{R_1 \quad R_2}\right)$$

then

$$d = \frac{2\ R_1\, R_2}{\sin\phi_t\,(m_G+1)}\ \frac{R_1+R_2}{R_1 \quad R_2} \quad \text{(Eq A.45)}$$

so

$$d = \frac{2\ (R_1+R_2)}{(m_G+1)\sin\phi_t} \quad \text{(Eq A.46)}$$

rearranging

$$\frac{d\ (m_G+1)}{2} = \frac{R_1+R_2}{\sin\phi_t} \quad \text{(Eq A.47)}$$

but

$$2C = d\ (m_G+1) \quad \text{(Eq A.48)}$$

so

$$\frac{2C}{2} = C = \frac{R_1+R_2}{\sin\phi_t} \quad \text{(Eq A.49)}$$

see Fig A-3

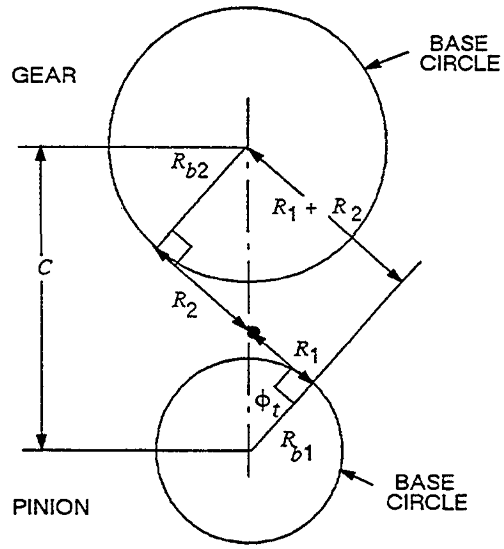

Fig A-3

Therefore, Eq A.41 holds and it is shown that the I factor given in ANSI/AGMA 2001-B88 is numerically identical to that in AGMA 908-B89.

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Appendix B
ANSI/AGMA 2001–B88 Pitting Resistance Formula Derivation

This Appendix is not part of AGMA 908–B89, *INFORMATION SHEET – Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth,* but is included for informational purposes only.

B1. Purpose. This Appendix presents the derivation of the pitting resistance formula and the I factor as used in this Information Sheet. The I factor given here is a simplified version of that derived in Appendix A. This simplification results in the same numerical value of I.

B2. Derivation. The AGMA pitting resistance formula is based on the *Hertz* contact stress equation for cylinders with parallel axes. See Fig B–1. The load applied to the cylinder is the load normal to the tooth flank, and the length of contact is the *minimum total length of lines of contact in the contact zone* of the gear set. The radii of the cylinders are the radii of curvature of the teeth at the point of contact for the mating pair of gears. Depending on the face contact ratio of the gearset, this point can be the mean diameter of the pinion or the lowest point of single tooth contact on the pinion. Additional rating factors are also added to the basic equation to adjust the stress due to factors peculiar to gearing. Starting with the general *Hertz* equation:

$$s_c = \frac{2\,W}{\pi\,b\,L} \qquad \text{(Eq B.1)}$$

$$b = \sqrt{\frac{2\,W}{\pi\,L}\,\frac{\left(\dfrac{1-\mu_1^2}{E_1}+\dfrac{1-\mu_2^2}{E_2}\right)}{\left(\dfrac{1}{d_1}+\dfrac{1}{d_2}\right)}} \qquad \text{(Eq B.2)}$$

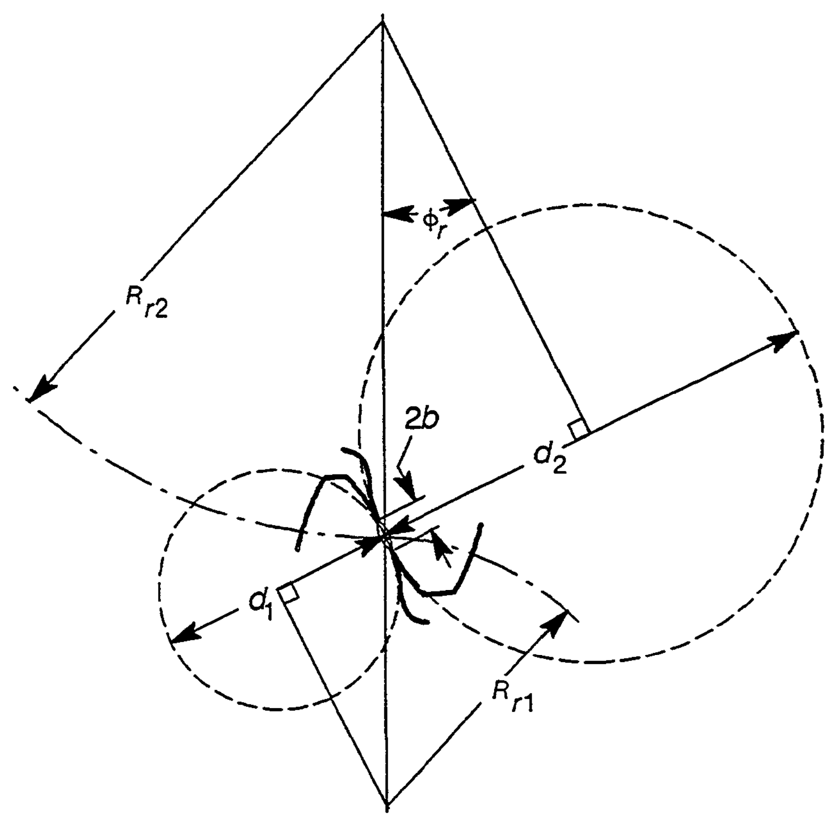


Fig B–1 Tooth Contact Stress Area

where

s_c = maximum contact stress of parallel axis cylinders, lb/in²

W = contact load normal to the cylinders, lb

b = semi-width of contact between cylinders, in

L = length of contact between cylinders, in

μ_1, μ_2 = Poisson's ratio of material in cylinders 1 and 2

E_1, E_2 = modulus of elasticity of material in cylinders 1 and 2

d_1, d_2 = contact diameter of cylinders 1 and 2

Figure B-2 shows the oblique contact line between helical gear tooth profiles. It can be represented as the line of two contacting cones. The radii of curvature, ρ_{n1}, ρ_{n2}, of the pinion and gear teeth at any point along the contact line are perpendicular to the line of contact and the involute profiles at the point of contact. They are contained in the plane of action and are inclined at the base helix angle, ψ_b, relative to the transverse plane.

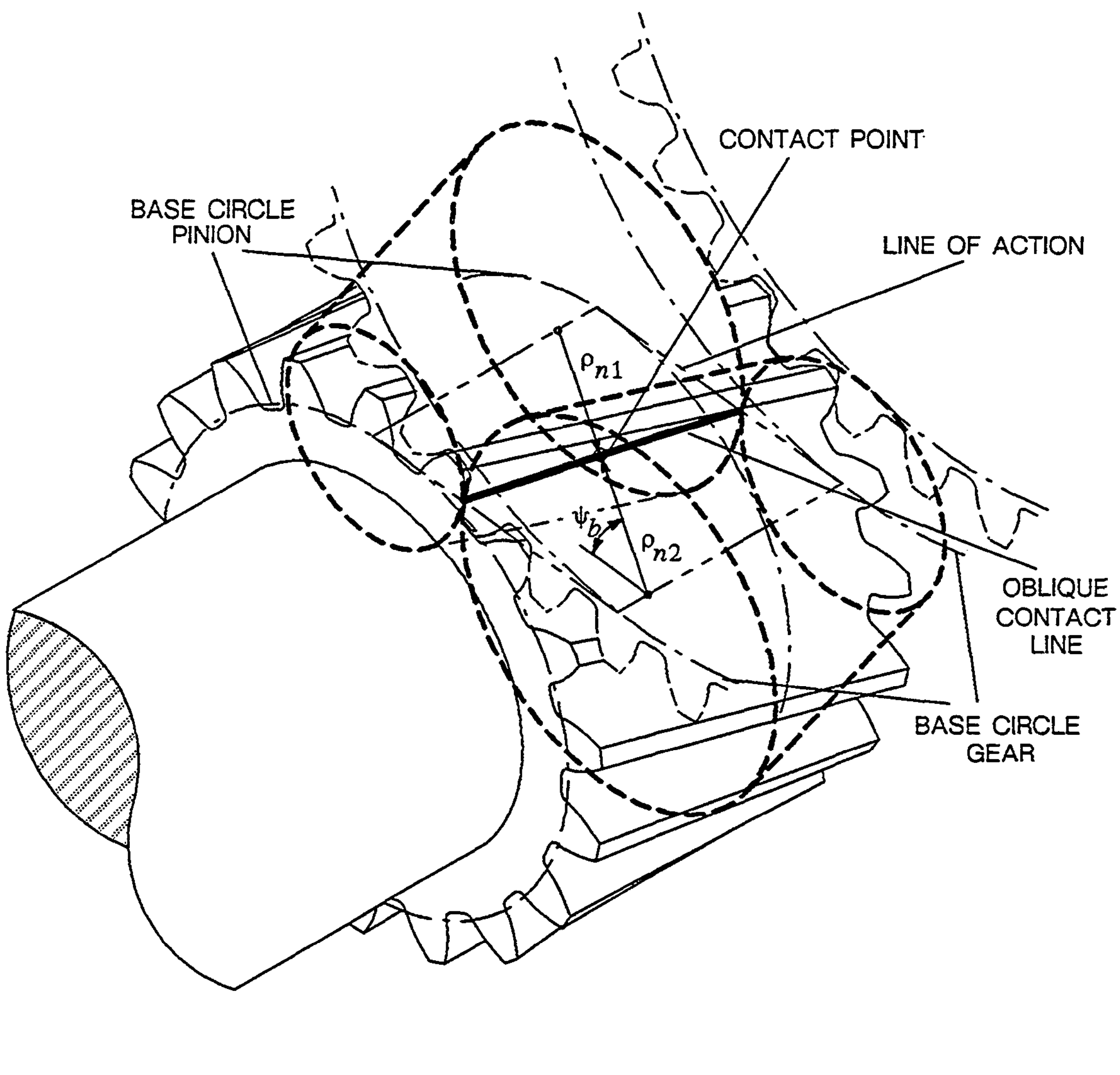


Fig B-2 Contacting Cones of Helical Gears
(Extracted from AGMA 229.06)

Converting the general nomenclature in Eqs B.1 and B.2 to those used in AGMA 908–B89:

$$W_N = W$$
$$L_{min} = L$$
$$2\,\rho_{n1} = d_1$$
$$2\,\rho_{n2} = d_2$$
$$\mu_P = \mu_1$$
$$\mu_G = \mu_2$$
$$E_P = E_1$$
$$E_G = E_2$$

where

W_N = transmitted load in the plane of action (normal to the tooth flank)

L_{min} = minimum total length of lines of contact in contact zone

ρ_{n1}, ρ_{n2} = radius of curvature normal to the profile at point of stress calculation for pinion and gear, respectively

μ_P, μ_G = Poisson's ratio for pinion and gear material, respectively

E_P, E_G = modulus of elasticity for pinion and gear material, respectively

Rearranging Eqs B–1 and B–2, then using AGMA 908–B89 terms:

$$s_c = \sqrt{\frac{W_N}{L_{min}} \, \frac{\left(\frac{1}{\rho_{n1}} \pm \frac{1}{\rho_{n2}}\right)}{\pi\left(\frac{1-\mu_P^2}{E_P} + \frac{1-\mu_G^2}{E_G}\right)}} \qquad \text{(Eq B.3)}$$

NOTE: Double signs are used in Eq B.3; i.e., $\pm$, to generalize the equation for both external and internal gears. The upper sign applies to external gear sets and the lower sign applies to internal gear sets.

by defining C_p as:

$$C_p = \sqrt{\frac{1}{\pi\left(\frac{1-\mu_P^2}{E_P} + \frac{1-\mu_G^2}{E_G}\right)}} \qquad \text{(Eq B.4)}$$

Also transferring the load and radii of curvature from the normal to the transverse plane where the geometry is more readily defined:

$$W_N = \frac{W_t}{\cos\phi_t \ \cos\psi_b} \qquad \text{(Eq B.5)}$$

$$\rho_{n1} = \frac{\rho_1}{\cos\psi_b} \qquad \text{(Eq B.6)}$$

$$\rho_{n2} = \frac{\rho_2}{\cos\psi_b} \qquad \text{(Eq B.7)}$$

where

W_t = transmitted tangential load at the operating pitch diameter of the pinion

ϕ_t = operating transverse pressure angle

ψ_b = base helix angle

ρ_1, ρ_2 = radii of curvature of profile in transverse plane at the point of stress calculation

Eq B.3 can now be shown as:

$$s_c = C_p \sqrt{\frac{W_t}{\cos\phi_t \ L_{min}} \left(\frac{1}{\rho_1} \pm \frac{1}{\rho_2}\right)} \qquad \text{(Eq B.8)}$$

Eq B.12 was originally developed before calculators and computers, and it has some terms that made calculation simpler. These terms are not necessarily needed today, but data and values have been developed over the years, and changing terms could cause a great deal of confusion. The load sharing ratio, m_N, and the pitting resistance geometry factor, I, are these terms.

They are developed by multiplying Eq B.8 by

$$\sqrt{\frac{F}{F}} \quad \text{and} \quad \sqrt{\frac{d}{d}}$$

and then recombining terms so that m_N and I can be defined as follows:

$$m_N = \frac{F}{L_{\min}} \qquad \text{(Eq B.9)}$$

$$I = \frac{\cos \phi_t \; C_\psi^2}{\left(\frac{1}{\rho_1} \pm \frac{1}{\rho_2}\right) d \; m_N} \qquad \text{(Eq B.10)}$$

where

F = effective face width of gear set

d = operating pitch diameter of pinion

C_ψ = helical overlap factor

The helical overlap factor, C_ψ, is added to the equation for I to give a smooth transition between the I factors of spurs and low axial contact ratio (LACR) helicals. See Appendix E for its definition and derivation.

Now Eq B.8 can be rewritten as:

$$s_c = C_p \sqrt{\frac{W_t}{d \; F \; I}} \qquad \text{(Eq B.11)}$$

To adapt Eq B.11 to actual gears, AGMA has added additional factors to the equation. These factors are:

C_a = application factor for pitting resistance

C_v = dynamic factor for pitting resistance

C_s = size factor for pitting resistance

C_m = load distribution factor for pitting resistance

C_f = surface condition factor for pitting resistance

Putting these factors in Eq B.11 gives:

$$s_c = C_p \sqrt{\frac{W_t \; C_a}{C_v} \; \frac{C_s}{d \; F} \; \frac{C_m \; C_f}{I}} \qquad \text{(Eq B.12)}$$

Equation B.12 is the fundamental formula for pitting resistance and is identical to Eq 5.1 in ANSI/AGMA 2001-B88 and Eq 5.1 in AGMA 218.01.

Appendix C
Explanation of the AGMA Gear Tooth Strength Rating Derivation For External Gears

This Appendix is not part of AGMA 908-B89, *INFORMATION SHEET – Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth,* but is included for informational purposes only.

C1. Purpose. This Appendix explains the derivation of the AGMA strength rating formula for external gears. The formula is derived from a simplified cantilever beam theory for stress. It is based on the method of Lewis [1] where the beam is assumed to be parabolic in shape and inscribed within the gear tooth. References are sometimes made to the *stress parabola* which refers to the beam assumption.

The formulas given are for helical gears; however, spur gears may be calculated by setting the helix angle at zero degrees so that the transverse plane equals the normal plane. Many of the variables used in this appendix are not fully derived as they are more fully explained in other sections of this information sheet.

C2. Tooth load. To simplify the geometry of helical gear teeth in the normal plane, the concept of the virtual spur gear is used. The concept incorporated is a spur gear whose shape in the transverse plane is similar to that of a helical gear in the normal plane. The calculation of this virtual spur gear is explained in other sections. The load normal to the tooth is calculated at the working pitch diameter of the tooth. This load is then applied along the line of action (tangent to the base circle) and passing through the tip of the tooth. Figure C-1 shows a tooth with the load applied and the inscribed parabola. Certain spur gears may have this load applied at the highest point of single tooth contact.

C3. Derivation of the stress equation. The following procedure is used to derive the equations necessary for calculating the tooth form factor, Y, geometry factor, J, and corrected tensile stress, S_t.

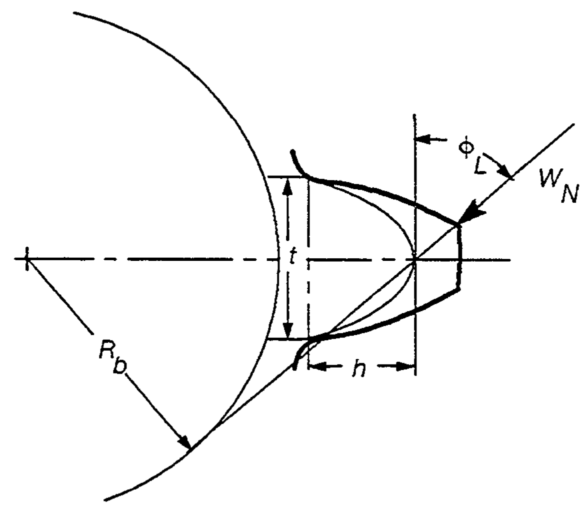


Fig C-1 Tooth Load Acting at Inscribed Parabola

The basic bending stress equation (see Fig C-2) for a cantilever parabolic shaped beam is:

$$s_b = \frac{6\ h\ P_l}{L\ t^2} \quad \text{(Eq C.1)}$$

The basic compressive stress equation for this beam is:

$$s_c = \frac{P_c}{L\ t} \quad \text{(Eq C.2)}$$

where

s_b = bending stress, lb/in²

s_c = compressive stress, lb/in²

P_l = bending load on beam, lb

P_c = compressive load on beam, lb

h = height of beam, in

L = length of beam, in

t = tooth thickness at the critical section (tangent point of the stress parabola and the tooth root), in

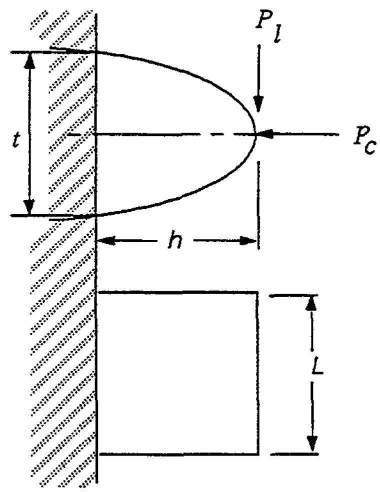


Fig C-2 Gear Tooth as a Simple Beam

The actual load applied normal to the tooth at the pitch circle is:

$$W_N = \frac{W_t}{\cos\phi_n \cos\psi} \quad \text{(Eq C.3)}$$

$$W_t = \frac{2\,T}{d} \quad \text{(Eq C.4)}$$

$$T = \frac{63\,000\ P}{n_p} \quad \text{(Eq C.5)}$$

where

- W_N = load normal to the tooth, lb
- W_t = load tangential to the tooth, lb
- T = torque on the pinion, lb in
- d = operating pitch diameter of the pinion, in
- P = transmitted horsepower, hp
- n_p = pinion speed, rpm
- ϕ_n = operating normal pressure angle
- ψ = operating helix angle

The load, W_N, is applied at the load angle, ϕ_L. Calculation of angle ϕ_L appears in other sections (see Fig C–1). The radial component of this load causing compressive stress is:

$$P_c = W_N \sin\phi_L \quad \text{(Eq C.6)}$$

The compressive stress is

$$s_c = \frac{W_N \sin\phi_L}{L_{min}\ t} \quad \text{(Eq C.7)}$$

where

- ϕ_L = load angle
- L_{min} = minimum length of lines of contact

The tangential component of this load causing bending stress is

$$P_l = \frac{W_N \cos\phi_L}{C_h} \quad \text{(Eq C.8)}$$

where

- C_h = helical factor: A helical factor must be added to account for the oblique lines of contact in helical gears, see 5.10 and Eq 5.70, based on work of Wellauer and Seireg [2]

This gives a bending stress of:

$$s_b = \frac{6\ h\ W_N \cos\phi_L}{L_{min}\ t^2\ C_h} \quad \text{(Eq C.9)}$$

Bending and compressive stresses are combined to find the maximum tensile stress.

$$s_t' = s_b - s_c \quad \text{(Eq C.10)}$$

$$s_t' = \frac{W_N \cos\phi_L}{L_{min}} \left(\frac{6\ h}{t^2\ C_h} - \frac{\tan\phi_L}{t} \right) \quad \text{(Eq C.11)}$$

where

- s_t' = maximum uncorrected tensile stress

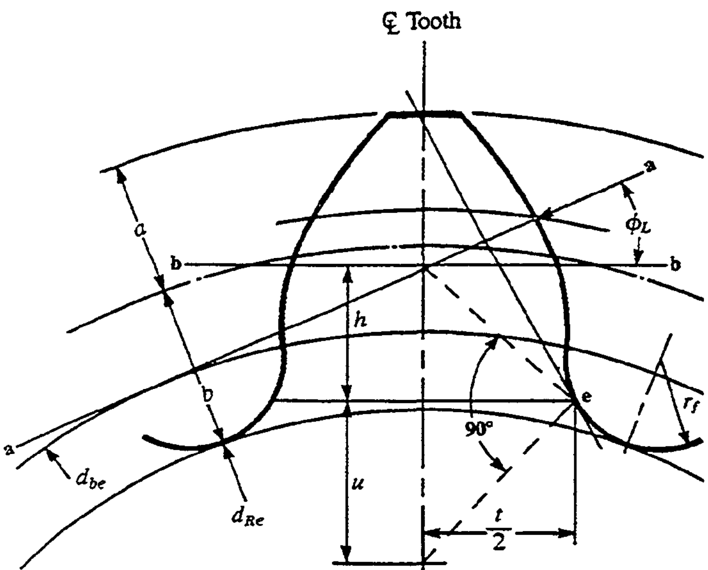
When the orginal derivations were made, calculations were done using tooth layouts and not computer calculations. The equation was therefore modified to make this task easier. Layouts were done to a scale of 1 Normal Diametral Pitch (NDP) so they would be large enough to measure. Therefore, the stress equation had to be multiplied by the Normal Diametral Pitch, P_d , to convert these 1 NDP dimensions to actual dimensions. A load sharing ratio, m_N, was defined to relate face width of the tooth to L_{min}. A stress correction factor, K_f, based on photoelastic experiments of Dolan and Broghamer [3], was introduced to account for the radius of the tooth root.

Note the following right triangle relationships in Fig C-3.

$$h = \frac{t^2}{4u} \quad \text{(Eq C.12)}$$

therefore

$$\frac{6h}{t^2} = \frac{1.5}{u} \quad \text{(Eq C.13)}$$



NOTE: Shown in the Normal Plane Through the Pitch Point

Fig C-3 Tooth Form Factor Layout With Load Sharing

Rearranging equation C.11, adding these factors and substituting, gives the following:

$$s_t' = \frac{W_t \cos\phi_L \, m_N}{F \cos\phi_n \cos\psi}\left(\frac{1.5}{u\,C_h} - \frac{\tan\phi_L}{t}\right) K_f \frac{P_d}{\cos\psi_s} \quad \text{(Eq C.14)}$$

where

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

$$m_N = \frac{F}{L_{min}} \quad \text{(Eq C.15)}$$

K_f = stress correction factor (see 5.11)

P_d = nominal pitch in the plane of rotation (introduced to convert J to a dimensionless value).

ψ_s = standard helix angle

F = face width

Eq C.14 can be subdivided into two variables; tooth form factor, Y, and geometry factor, J, where

$$Y = \frac{\cos\psi \cos\psi_s \, P_s}{\frac{\cos\phi_L}{\cos\phi_n}\left(\frac{1.5}{u\,C_h} - \frac{\tan\phi_L}{t}\right)} \quad \text{(Eq C.16)}$$

where

P_s = normal diametral pitch of layout (scale pitch), usually 1.0 in^{-1}

The Form Factor includes a term P_s which is the diametral pitch to which the layout is drawn. This term converts the values of u and t to actual values and was added to account for layouts or calculations that are done to a scale other than one NDP.

Substituting Eq C.13 and letting:

$S_F = t$, $h_F = h$ (see AGMA 908-B89 Fig 5-7)

Scale pitch P_s = 1.0 in^{-1}

$$K_\psi = \cos\psi \cos\psi_s \quad \text{(Eq C.17)}$$

where

K_ψ = a factor which converts the pitch and load from the normal plane to the transverse plane. (see Eq C.17)

$$Y = \frac{K_\psi}{\frac{\cos\phi_L}{\cos\phi_n}\left(\frac{6\,h_F}{S_F^2\,C_h} - \frac{\tan\phi_L}{S_F}\right)} \quad \text{(Eq C.18)}$$

which is identical to AGMA 908-B89, Eq 5.78

$$J = \frac{Y\,C_\psi}{K_f\,m_N} \quad \text{(Eq C.19)}$$

where

J = geometry factor for bending strength

Y = tooth form factor

C_ψ = helical overlap factor

m_N = load sharing ratio

The Geometry Factor, J, includes a helical overlap factor, C_ψ. C_ψ is a factor used to interpolate the values for LACR gears for J, from that for spurs to conventional helicals. This factor accounts for low axial contact ratio gearing which has a face contact ratio, m_F, less than or equal to 1.0. For normal helical gears and spur gears, this factor is 1.0, see 4.4.

The stress equation now can be written as:

$$s_t' = \frac{W_t \; P_d}{F \; J} \qquad \text{(Eq C.20)}$$

Rating factors are added to the equation to account for increased loads that occur in gearing:

K_s = size factor for bending strength

K_a = application factor for bending strength

K_m = load distribution factor for bending strength

K_v = dynamic factor for bending strength

resulting in the final stress equation:

$$s_t = \frac{W_t \; K_a}{K_v} \frac{P_d}{F} \frac{K_s \; K_m}{J} \qquad \text{(Eq C. 21)}$$

where

s_t = corrected tensile stress

Eq C.21 is the fundamental formula for bending strength and is identical to Eq 5.10 in AGMA 218.01. Eq 5.10 in ANSI/AGMA 2001–B88 is similar, but a rim thickness factor, K_B, has been added.

Bibliography

1 Lewis, W., *Investigation of the Strength of Gear Teeth*, Proc. of the Engineers Club, Philadelphia, PA, 1893, pp.16–23.

2 Wellauer, E. J., and Seireg, A., *Bending Strength of Gear Teeth by Cantilever Plate Theory*, Journal of Engineering for Industry, Trans. ASME, Series B, Vol. 82, 1960, pp. 213–222.

3 Dolan, T. J. and Broghamer, E. L., *A Photoelastic Study of the Stresses in Gear Tooth Fillets*, University of Illinois, Engineering Experiment Station, Bulletin No. 335, 1942.

Appendix D
Selection Of Shaper Cutter Geometry

This Appendix is not part of AGMA 908–B89, *INFORMATION SHEET – Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth,* but is included for informational purposes only.

D1. Purpose. This Appendix provides default shaper cutter data for use in calculating the bending strength geometry factor, J, when the original cutter data at the time of gear manufacture is unavailable.

D2. General. This method allows a wide choice of cutter geometries to be used in generating the root trochoid form of the virtual spur gear and the J factor. For very accurate work, the exact cutter form should be used, but for most cases, the cutter form can be approximated. The method assumes that generation takes place in the normal plane. Cutters which act in the transverse plane, such as helical disc shaper cutters and some rack shaper cutters will generate root trochoid forms which are slightly different from those assumed by this method. This has a minor effect on the accuracy of the J factor.

D3. Rack Shaped Cutters and Hobs. Rack cutters and hobs are represented as disk cutters with large numbers of teeth, such as 9999. The actual form of the cutter, in the normal plane, should be used, with all dimensions made dimensionless. To make actual measurements dimensionless, they are scaled by multiplying them by diametral pitch, dividing them by module or comparing them to a π (3.1416) circular pitch at the standard pitch diameter. Any consistent system of units can be used for this conversion. See Section 3 of AGMA 908–B89 for examples.

D4. Disk Shaped Cutters. Disk shaped cutters are not as standardized as hobs or other rack shaped cutters. The geometry of disk shaped cutters changes with each sharpening. Generally, the radius of the root fillet generated by these cutters decreases as they are sharpened.

> **CAUTION:** The tip radii and cutting depths which are commonly assumed for hobs must not be used for disk (pinion) shaped cutters without verification of the actual tool design. For example, many disk cutters have a small chamfer at the tooth tip, rather than a radius. If this is the case, the cutter should be considered sharp cornered at the inner edge of the chamfer.
>
> The knowledge required to convert the actual dimensions of a disk type cutter to the values necessary to determine the J factor of a specific gear is beyond the scope of this Information Sheet. Cutter manufacturers have different designs and production techniques, which affect the final tooth form and the resulting J factor. The simplified information given here is intended to provide typical values which may be used as a guide to usual practice.

If the exact geometry at its worst condition is known, that geometry should be used to calculate the J factor. If the dimensions are not known, the geometry of a minimum cutter may be estimated from the following information:

D4.1 Number of Teeth. The maximum pitch diameter of the cutter is limited by the size of the gear shaper to 3, 4, 5, 6 or 8 inch. This limits the number of cutter teeth as a function of the pitch. The following table is typical.

Table D–1
Number of Cutter Teeth Default Values

Diametral Pitch	Number of Teeth
to 20	40
16	32
12	32
10	30
8	24
6	18
4	16
3	15

Coarser pitches require consultation with the manufacturer.

Table D-2
Typical 20° NPA Spur Disk Cutter Proportions* – Inches

Diametral Pitch, P_{nd}	% Life	Number of Teeth	Tooth Thickness s_{no}	Addendum Modification x_o	Outside Diameter	Tool Addendum h_{ao}	Tip Radius (chamfer)
3	90	15	0.523	0.00	5.918	0.410	0.030 chamfer
3	50	15	0.505	−0.08	5.804	0.427	0.020 chamfer
3	25	15	0.495	−0.11	5.756	0.416	0.030 chamfer
6	90	24	0.266	0.04	4.430	0.209	0.020 radius
6	50	24	0.245	−0.14	4.365	0.202	0.010 chamfer
6	10	24	0.221	−0.34	4.297	0.204	0.000 sharp
10	90	30	0.158	0.01	3.256	0.128	0.010 chamfer
10	40	30	0.140	−0.23	3.201	0.123	0.010 chamfer
10	10	30	0.124	−0.45	3.167	0.128	0.010 radius

* The table values are actual measurements of cutters in the field and are included to illustrate the difference between different cutter manufacturers' standards and different sharpening conditions.

D4.2 Tooth Proportions. Table D–2, comprised of actual cutter measurements, is typical.

D4.3 Tip Radius. For cutters with less than 24 teeth, assume a sharp corner. Over 24 teeth, assume a $0.1 / P_{nd}$ radius.

D4.4 Tooth Thickness. See D5.

D4.5 Cutter Addendum and Clearance. Assume that cutter addendum is $1.25 / P_{nd}$ for full depth cutters, and $1.0 / P_{nd}$ for stub depth cutters. Clearances are $0.25/P_{nd}$ and $0.20/P_{nd}$, respectively.

D4.6 Protuberance Disk Cutters. Protuberance (pregrind and preshave) disk cutters are usually specially designed for a specific part. No default values are given here for these special cutters.

D5. Spur Gear Disc Shaper Cutters. If the actual cutter is at hand, the tooth thickness can be measured by the span method (see ANSI/AGMA 2002–B88 *Tooth Thickness Specifications and Measurement*) and the outside diameter can be measured. The tooth thickness at the standard pitch diameter, the addendum modification coefficient and the tool addendum can be calculated from involute geometry and the information in Section 5 of AGMA 908–B89.

D6. Helical Gear Disc Shaper Cutters. Helical disk shaper cutters cannot be measured as described above, so they must be described from the cutter design data. To furnish a starting point when the cutter design data is not available, approximate cutter geometry values are provided.

The dimensions used are those of the spur gear equivalent to the actual cutter, in the transverse plane. These dimensions are made dimensionless and are converted to virtual spur gear dimensions in the normal plane.

The approximate geometry is based on the assumption that the cutter has 18 teeth, a sharp tip radius and will reach the end of its useful life when it is sharpened to the condition where the outside diameter is equal to the standard pitch diameter plus 1.8 cutter addendums. Cutters with outside diameters larger than these will generate gears with J factors larger than or equal to the approximate cutter.

Approximate minimum cutter geometry – dimensionless

Number of teeth	18
Std. tooth thickness, transverse	1.5708
Tool Addendum	1.25
Addendum modification	−0.35
Tip radius	0.0 (sharp)

Depending on pressure angle, actual cutters with this geometry may not be feasible due to involute interference with the work gear. If it is possible, or if cutters with less than 18 teeth must be used, consult a cutter manufacturer for more information.

Appendix E
Derivation of Helical Overlap Factor, C_ψ

This Appendix is not part of AGMA 908–B89, *INFORMATION SHEET – Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth,* but is included for informational purposes only.

E1. Purpose. This Appendix provides the derivation for a simplified method for calculating C_ψ as used in AGMA 908–B89. The results are identical to AGMA 218.01, but the procedure eliminates the need for C_x and C_{xh} for LACR gears.

E2. Derivation. In AGMA 218.01, the helical overlap factor for LACR helical gears is:

$$C_\psi = \left[1 - m_F + \frac{C_{xh}\ Z\ m_F^2}{C_x\ F\ \sin\psi_b}\right]^{0.5} \quad \text{(Eq E.1)}$$

The term, C_{xh} / C_x, is the ratio of the radii of curvature at the mean diameter of the pinion to the radii of curvature at the LPSTC, i.e.;

$$\frac{C_{xh}}{C_x} = \frac{\rho_{m1}\ \rho_{m2}}{\rho_1\ \rho_2} \quad \text{(Eq E.2)}$$

where

$$\rho_{m1} = (R_{m1}^2 - R_{b1}^2)^{0.5} \quad \text{(Eq E.3)}$$

$$\rho_{m2} = C_6 \mp \rho_{m1} \quad \text{(Eq E.4)}$$

$$\rho_1 = C_2 \quad \text{(Eq E.5)}$$

$$\rho_2 = C_6 \mp \rho_1 \quad \text{(Eq E.6)}$$

Substituting Eq E.2 into Eq E.1 together with Eq E.7 and Eq E.8 gives the new expression for C_ψ.

$$m_F = \frac{F}{p_x} \quad \text{(Eq E.7)}$$

$$p_N = p_x\ \sin\psi_b \quad \text{(Eq E.8)}$$

$$C_\psi = \left[1 - m_F\left(1 - \frac{\rho_{m1}\ \rho_{m2}\ Z}{\rho_1\ \rho_2\ p_N}\right)\right]^{0.5} \quad \text{(Eq E.9)}$$

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Appendix F
High Transverse Contact Ratio Gears

This Appendix is not part of AGMA 908–B89, *INFORMATION SHEET – Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth,* but is included for informational purposes only.

F1. Purpose. This Appendix provides a reference for accommodating load distribution in a pair of high contact ratio gears.

F2. High transverse contact ratio gears. When the transverse contact ratio is greater than or equal to 2.0, the load distribution between the two pairs of teeth in contact at the highest point of double tooth contact becomes indeterminate, depending on tooth accuracy and stiffness.

Studies have been done on the subject of high transverse contact ratio, HTCR gears. See, for instance, the reference paper of Elkholy [1].

Bibliography

1. Elkholy, A. H., *Tooth Load Sharing in High–Contact Ratio Spur Gears*, ASME paper 84–DET–65.