BENDING STRENGTH OF BEVEL GEARS

PRODUCT CATEGORY

SPUR GEARS
HELICAL GEARS
INTERNAL GEARS
GEAR RACK
CP RACKS & PINIONS
MITER GEARS
BEVEL GEARS
SCREW GEARS
WORM GEAR

This information is valid for bevel gears which are used for power transmission in general industrial machines. The applicable ranges are:

Transverse module / m / 1.5 – 25mm
Pitch diameter / d0 / 1600mm or less (for straight bevel gears), 1000mm or less (for spiral bevel gears)
Tangential speed / v / 25m/s or less
Rotational speed /n / 3600rpm or less

(1) Conversion Formulas

In calculating strength, transmitted tangential force at the pitch circle, Ftm (kgf), power, P (kW) , and torque, T (kgf・m) , are the design criteria. Their basic relationships are expressed in the following Equations.

$$F_{tm} = \frac{102P}{v_m} = \frac{1.95 \times 10^6 P}{d_m n} = \frac{2000T}{d_m} \quad (10.27)$$

$$P = \frac{F_{tm} v_m}{102} = 5.13 \times 10^{-7} F_{tm} d_m n \quad (10.28)$$

$$T = \frac{F_{tm} d_m}{2000} = \frac{974P}{n} \quad (10.29)$$

Where vm： Tangential speed at the central pitch circle (m/s)
= dmn / 19100

BEVEL GEARBOX

OTHER PRODUCTS

ADVANTAGES OF KHK STOCK GEARS

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KHK GEAR MANUFACTURING PROCESS

View this video to learn about KHK’s advanced gear manufacturing process.

dm： Central pitch diameter (mm)

$$= d_0 - b \sin \delta_0$$

(2) Bending Strength Equations

The tangential force, Ftm, acting at the central pitch circle should be less than the allowable tangential force, Ftmlim, which is based upon the allowable bending stress at the root σFlim.
That is:

$$F_{\mathrm{tm}} \leqq F_{\mathrm{tmlim}} \qquad (10.30)$$

The bending stress at the root, σF, which is derived from Ftm should not exceed the allowable bending stress σFlim.

$$\sigma_{\mathrm{F}} \leqq \sigma_{\mathrm{Flim}} \qquad (10.31)$$

The tangential force at the central pitch circle, Ftmlim(kgf) is obtained from Equation (10.32).

$$\left.\begin{aligned} F_{\mathrm{tmlim}} = 0.85 \cos \beta_{\mathrm{m}} \sigma_{\mathrm{Flim}} m b \, \frac{R_{\mathrm{a}} - 0.5b}{R_{\mathrm{a}}} \\ \frac{1}{Y_{\mathrm{F}} Y_{\varepsilon} Y_{\beta} Y_{\mathrm{C}}} \left(\frac{K_{\mathrm{L}} K_{\mathrm{FX}}}{K_{\mathrm{M}} K_{\mathrm{V}} K_{\mathrm{O}}} \right) \frac{1}{K_{\mathrm{R}}} \end{aligned}\right\} \qquad (10.32)$$

Where βm： Mean spiral angle (degrees)
m： Transverse module (mm)
Ra： Cone distance (mm)

The bending strength at the root, σF (kgf/mm2) , is calculated from Equation (10.33).

$$\left.\begin{aligned} \sigma_{\mathrm{F}} = F_{\mathrm{tm}} \frac{Y_{\mathrm{F}} Y_{\varepsilon} Y_{\beta} Y_{\mathrm{C}}}{0.85 \cos \beta_{\mathrm{m}} m b} \, \frac{R_{\mathrm{a}}}{R_{\mathrm{a}} - 0.5b} \\ \left(\frac{K_{\mathrm{M}} K_{\mathrm{V}} K_{\mathrm{O}}}{K_{\mathrm{L}} K_{\mathrm{FX}}} \right) K_{\mathrm{R}} \end{aligned}\right\} \qquad (10.33)$$

(3) Determination of Various Coefficients

(3)-1 Facewidth b
The term b is defined as the facewidth on the pitch cone. For the meshed pair, the narrower one is used for strength calculations.

(3)-2 Tooth Profile Factor, YF
The tooth profile factor, YF, can be obtained in the following manner: Using Figures 10.8 and 10.9, determine the value of the radial tooth profile factor, YF0. And then, from Figure 10.7 obtain the correction factor, C, for axial shift. Finally, calculate YF by Equation 10.34.

$$Y_F = CY_{F0} \tag{10.34}$$

Should the bevel gear pair not have any axial shift, the tooth profile factor, YF, is simply YF0.
The equivalent number of teeth, zv, and the profile shift coefficient, x, when using Figures 10.8 and 10.9 is obtainable from Equation (10.35).

$$\left.\begin{aligned} z_v &= \frac{z}{\cos\delta_0 \cos^3\beta_m} \\ x &= \frac{h_k - h_{k0}}{m} \end{aligned}\right\} \tag{10.35}$$

Where
hk： Addendum at outer end(mm)
hk0： Addendum of standard form(mm)
m： Transverse module(mm)
s： Outer transverse circular tooth thickness(mm)

The axial shift factor, K, is computed from the formula:

$$K = \frac{1}{m}\left\{ s - 0.5\pi m - \frac{2(h_k - h_{k0})\tan\alpha_n}{\cos\beta_m} \right\} \tag{10.36}$$

Fig.10.7 Correction factor for axial shift, C

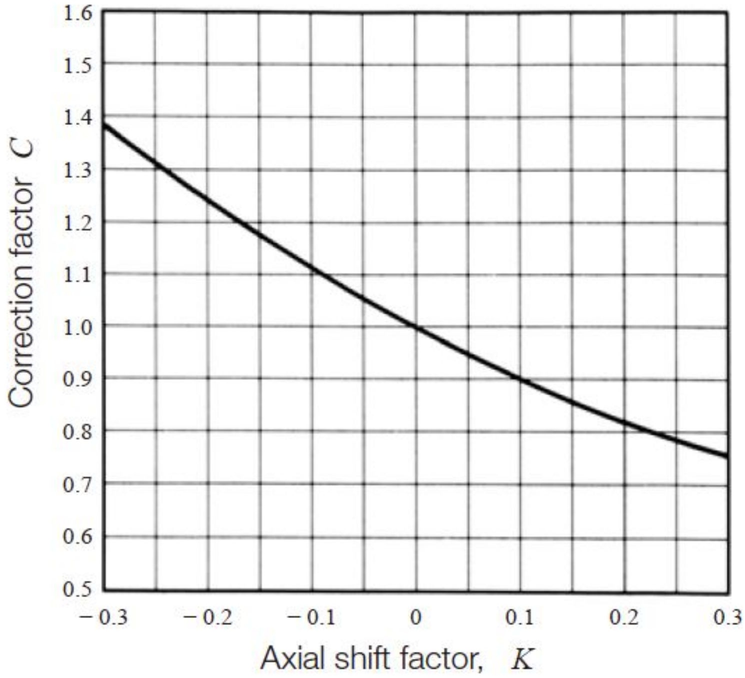


Fig.10.8 Tooth profile factor, YF0 (Straight bevel gear)

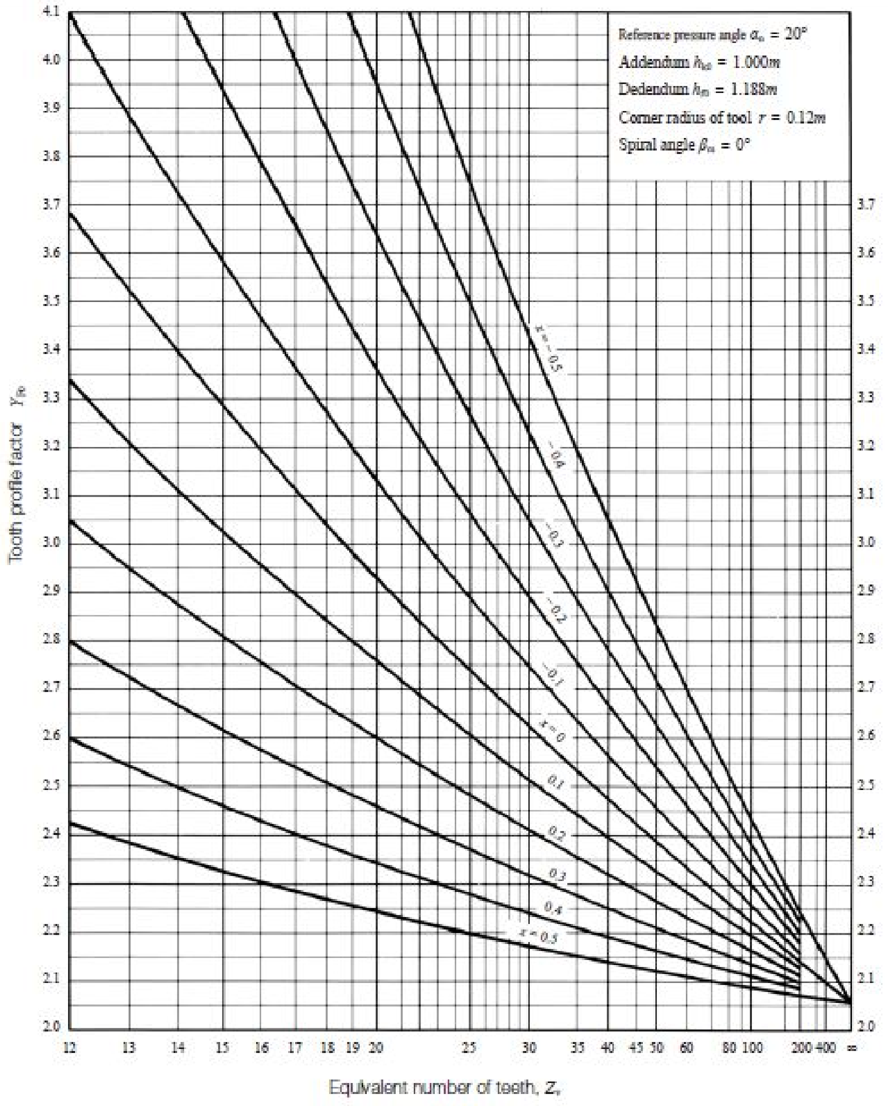
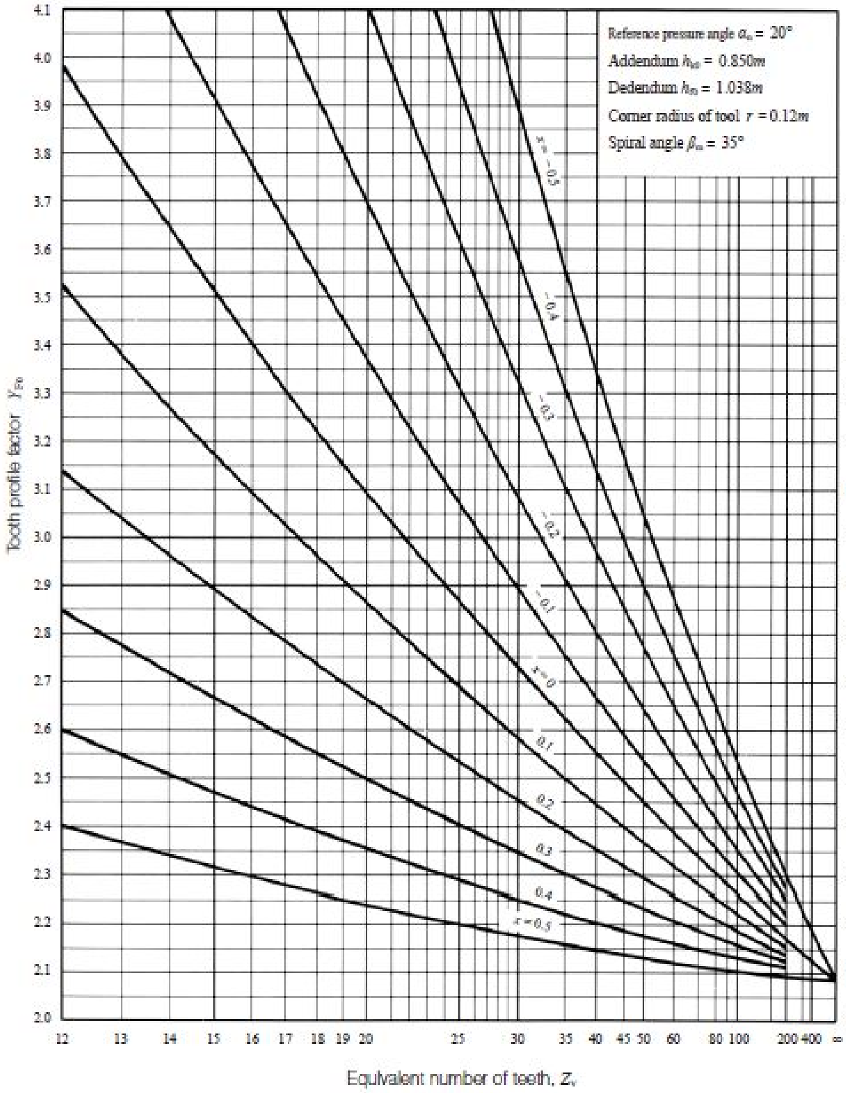


Fig.10.9 Tooth profile factor, YF0 (Spiral bevel gear)



(3)-3 Load Sharing Factor, Yε

Load sharing factor, Yε, is the reciprocal of transverse contact ratio, εα.

$$Y_\varepsilon = \frac{1}{\varepsilon_\alpha} \qquad (10.37)$$

The transverse contact ratio, εα, for a straight bevel gear mesh is:

$$\varepsilon_\alpha = \frac{\sqrt{R_{vk1}{}^2 - R_{vg1}{}^2} + \sqrt{R_{vk2}{}^2 - R_{vg2}{}^2} - (R_{v1} + R_{v2}) \sin \alpha_0}{\pi m \cos \alpha_0}$$

And the transverse contact ratio for spiral bevel gear is:

$$\varepsilon_\alpha = \frac{\sqrt{R_{vk1}{}^2 - R_{vg1}{}^2} + \sqrt{R_{vk2}{}^2 - R_{vg2}{}^2} - (R_{v1} + R_{v2}) \sin \alpha_s}{\pi m \cos \alpha_s} \qquad (10.38)$$

See Tables 10.17 – 10.19 for some calculating examples of transverse contact ratio for various bevel gear pairs.

Where:

Rvk :Tip diameter on back cone for equivalent spur gear (mm)

Rvk = Rv + hk = r0secδ0 + hk
Rvg :Reference radius on back cone for equivalent spur gear(mm)
Helical gears = Rv cosα0 = r0secδ0 cosα0
Spiral bevel gears ＝ Rv cosαs = r0secδ0 cosαs
Rv :Back cone distance(mm) = r0secδ0
r0 :Pitch radius(mm) = 0.5z m
hk :Addendum at outer end(mm)
α0 :Reference pressure angle (degree)
αs :Mean transverse pressure angle (degree) = tan–1(tanαn/cosβm)
αn :Reference normal pressure angle (degree)

Table 10.17 The transverse contact ratio for Gleason’s straight bevel gear, εα (Σ = 90°、α0 = 20°)

z_2 \ z_1	12	15	16	18	20	25	30	36	40	45	60
12	1.514										
15	1.529	1.572									
16	1.529	1.578	1.588								
18	1.528	1.584	1.597	1.616							
20	1.525	1.584	1.599	1.624	1.640						
25	1.518	1.577	1.595	1.625	1.650	1.689					
30	1.512	1.570	1.587	1.618	1.645	1.697	1.725				
36	1.508	1.563	1.579	1.609	1.637	1.692	1.732	1.758			
40	1.506	1.559	1.575	1.605	1.632	1.688	1.730	1.763	1.775		
45	1.503	1.556	1.571	1.600	1.626	1.681	1.725	1.763	1.781	1.794	
60	1.500	1.549	1.564	1.591	1.615	1.668	1.710	1.751	1.773	1.796	1.833

Table 10.18 The transverse contact ratio for standard straight bevel gear, εα(Σ = 90°、α0 = 20°)

z_2 \ z_1	12	15	16	18	20	25	30	36	40	45	60
12	1.514										
15	1.545	1.572									
16	1.554	1.580	1.588								
18	1.571	1.595	1.602	1.616							
20	1.585	1.608	1.615	1.628	1.640						
25	1.614	1.636	1.643	1.655	1.666	1.689					
30	1.634	1.656	1.663	1.675	1.685	1.707	1.725				
36	1.651	1.674	1.681	1.692	1.703	1.725	1.742	1.758			
40	1.659	1.683	1.689	1.702	1.712	1.734	1.751	1.767	1.775		
45	1.666	1.691	1.698	1.711	1.721	1.743	1.760	1.776	1.785	1.794	
60	1.680	1.707	1.714	1.728	1.739	1.762	1.780	1.796	1.804	1.813	1.833

Table 10.19 The transverse contact ratio for Gleason’s spiral bevel gear, εα(Σ = 90°、α0 = 20°、βm = 35 deg)

(3)-4 Spiral Angle Factor, Yß
The spiral angle factor, Yß, is obtainable from Equation (10.39).

(3)-5 Cutter Diameter Effect Factor, YC
The cutter diameter effect factor, YC, can be obtained from Table 10.20 by the value of tooth flank length, b/cos βm (mm),

over cutter diameter.
If cutter diameter is not known, assume YC = 1.0.

Table 10.20 Cutter diameter effect factor, YC

(3)-6 Life Factor, KL
The life factor, KL, is obtainable from Table 10.2.

(3)-7 Size Factor of Bending Stress at Root, KFX
The size factor of bending stress at root, KFX, can be obtained from Table 10.21 based on the transverse module, m.

Table 10.21 Size factor for bending strength, KFX

(3)-8 Longitudinal Load Distribution Factor, KM
The longitudinal load distribution factor, KM, is obtained from Table 10.22 or Table 10.23.

Table 10.22 Longitudinal load distribution factor, KM for spiral bevel gears, zerol bevel gears and straight bevel gears with crowning

Table 10.23 Tooth Flank Load Distribution Factor KM for Straight Bevel Gears without Crowning

(3)-9 Dynamic Load Factor, KV

Dynamic load factor, KV, is a function of the precision grade of the gear and the tangential speed at the outer pitch circle, as shown in Table 10.24.

(3)-10 Overload Factor, KO
The overload factor, KO, can be computed from Equation (10.12) or obtained from Table 10.4, identical to the case of spur and helical gears.

(3)-11 Reliability Factor, KR
The reliability factor, KR, should be assumed to be as follows:
1. General case KR = 1.2
2. When all other factors can be determined accurately: KR = 1.0
3. When all or some of the factors cannot be known with certainty: KR = 1.4

(3)-12 Allowable Bending Stress at Root, σFlim
The allowable bending stress at the root is obtained by a bending strength calculation for spur and helical gears as shown at < (3)-10 >.

(4) Example of Calculation

Gleason straight bevel gear design details

Bending strength factors for Gleason straight bevel gear

Related links:
Strength and Durability of Gears – A page of The ABC's of Gears / Basic Guide – B

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