1.6 Features of common gears

Chapter 1.2 covered briefly on types of gear. The main gear features are explained here.

Helical gear

Helical gear has characteristics of transferability of larger load, less vibration and lower noise compared with Spur gear.
However, thrust load (axial direction) occurs due to helix angle. It is therefore necessary to design thrust bearings. (Refer to chapter 2 for thrust load)
When using parallel axis, engage with right and left hand of Helical gears at the same angle.
Using Screw gear for Non-parallel and Non-intersecting axis is called Crossed helical gear.
Roll up a piece of right-angled triangle paper as seen in Fig. 8. The straight lines of slope of the right-angled triangle become a thread curve (helix). Helical gear adopts this curved line as Tooth trace curve.
This right angled triangle unrolls to draw layers of Helical gear to become Fig. 9.

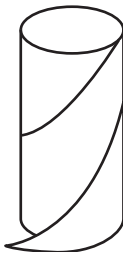


Fig. 8 Helix

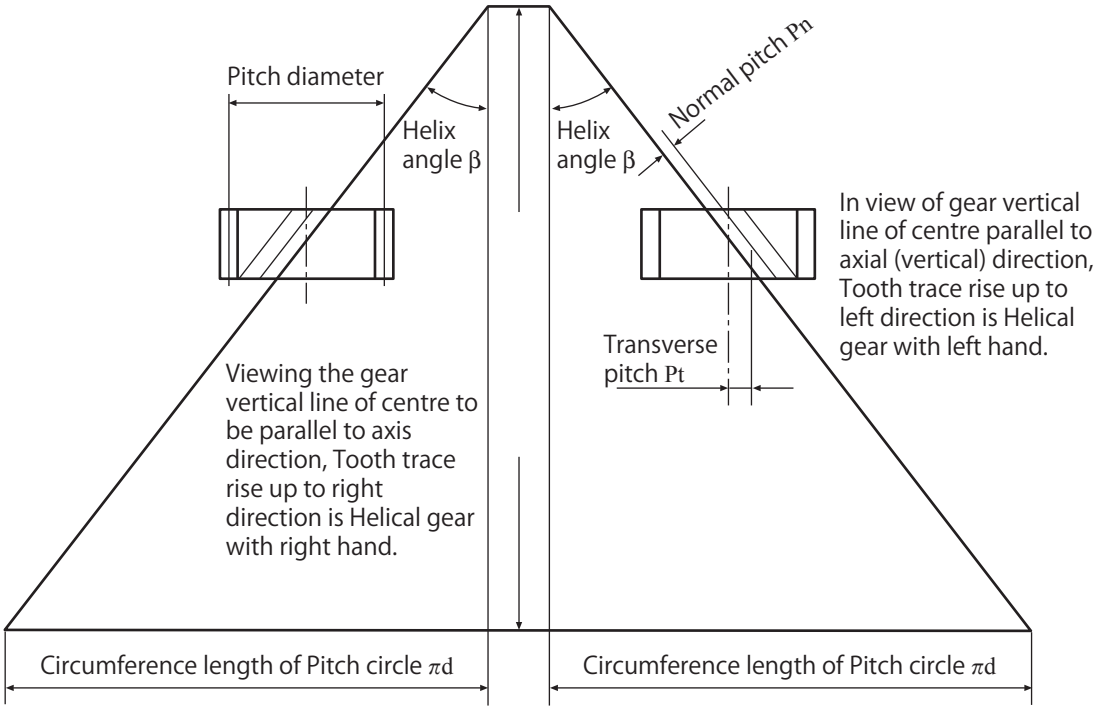


Fig. 9 Helical gear (right and left hands)

There are types of Normal and Axial for Helical gear.
Standard tooth profile for Normal type of Helical gear is a section of the Tooth profile perpendicular to Tooth trace of Helical rack which is obtained by setting the Reference pitch radius to infinity.
Standard tooth profile for Axis type of Helical gear is perpendicular to gear axis.
Fig. 10 shows both of the Reference sections.

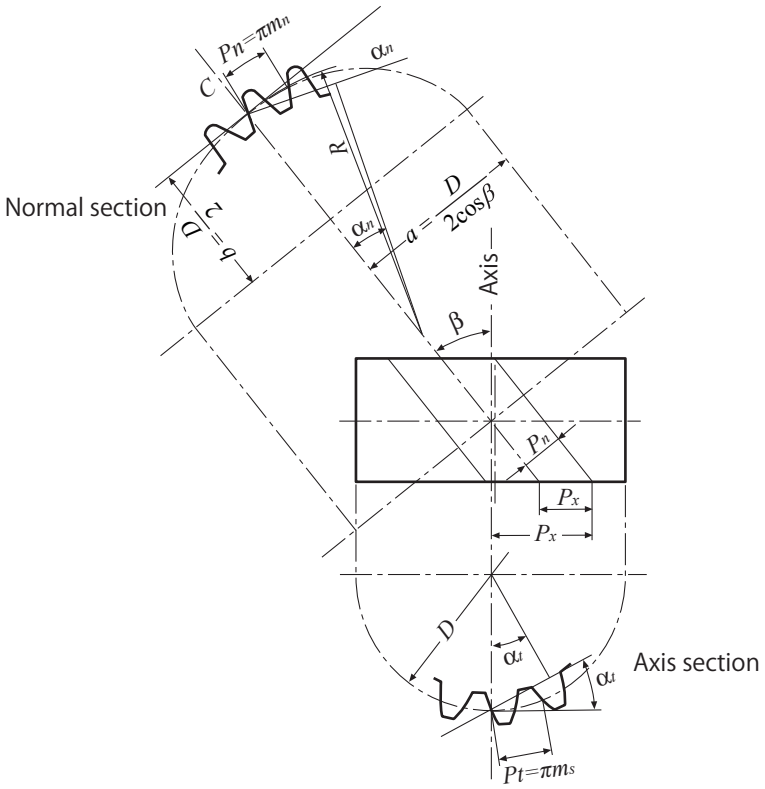


Fig. 10 Types of Normal and Axial

Regarding to manufacturing method, the same hob cutter and grinding wheel can be used to fabricate any helix angle gear. As long as the Normal type of Helical gear has same Normal module m_n (called module of hob cutter) and same Normal pressure angle a_n (called pressure angle of hob). Even if helix angle β was changed
Therefore, stock of hob cutters (tools) and manufacturing cost can be saved making Normal type of Helical gear economic and widely used generally.
However, calculating Centre distance for Normal type of Helical gear, it is necessary to adjust the helix angle to obtain an integer number for Centre distance due to the $\mathrm{cosine}\,\beta$ in the denominator.
Regarding the manufacturing method, the hob cutter (tool) and grinding wheel must be changed to fabricate Axial type of Helical gear if helical angle β is changed. Therefore mass production for this type of gear is very limited.
Since calculation for Helical gear is the same as Spur gear, integer number for centre distance is easily obtained.
Note (1) Adopted old gear terms.

At the above Fig. 10, under perpendicular section to Tooth trace, the Pitch diameter becomes oval. Half of length of oval with major and minor axis is used for calculation below.

$$a = \frac{D}{2\cos\beta} \qquad b = \frac{D}{2}$$

Formula for the radius of curvature R of oval at the C-point is as follows,

$$R = \frac{a^2}{b} = \frac{D}{2\cos^2\beta}$$

Therefore assuming this is a Spur gear with Radius of pitch circle R, it is commonly called [(1)]Virtual spur gear for Helical gear.
The relation between [(1)]Virtual number of teeth of Spur gear z_v and actual number of teeth z of Helical gear is as follows.

$$z_v = \frac{z}{\cos^3\beta}$$

[(1)] The Virtual number of teeth of Spur gear becomes the standard for strength calculation of Helical gear, calculation of profile shifted gear and selection of hob cutter.

(Reference)

The Crossed helical gear (Screw gear) is simply a type of Helical gear. The Parallel helical gear has the same helix angle with opposite helix hand. Where as the Crossed helical gear (Screw gear) is engaged with Non-parallel and Non-intersecting axis with any optional helix angle.

Method of correct engagement, Normal module m_n and Normal pressure angle α_n must be the same.

When two non-profile shifted gears are engaged, each Reference cylinder helix angle are indicated as β_1 and β_2,

Where helix direction of both gears are the same, the formula for shaft angle Σ is ,

$$\Sigma = \beta_1 + \beta_2$$

Where helix direction of both gears are different, formula for shaft angle Σ is,

$$\Sigma = \beta_1 - \beta_2 \quad \text{or} \quad \Sigma = \beta_2 - \beta_1$$

Therefore these become the relation of Shaving cutter and Machined gear.

In Theory, Crossed helical gear (Screw gear) has spot contact and can only take small loads.

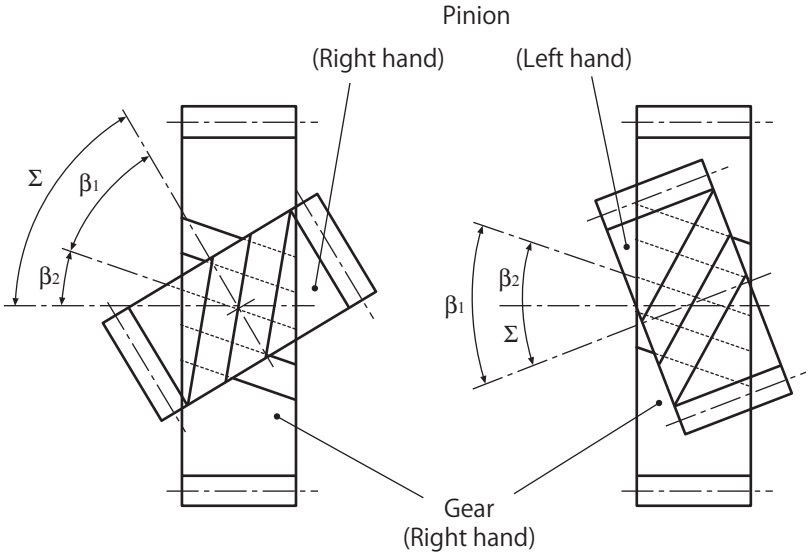


Fig. 11 Engagement of Crossed helical gear (Screw gear)

Bevel gear

This is Bevel gear, that is formed by making gear teeth to the Reference surface of a coned friction wheel. Usage of this conical gear is to transfer power to Crossed or Angular axis of gear. This Reference surface is called Pitch cone of Bevel gear.

Classification by shape of tooth trace that straight Tooth trace to axis direction is called Straight bevel gear. Spiral Tooth trace to axis direction is called Spiral bevel gear.

In Fig. 12, Spur gear with Radius of pitch circle R_{v1} and R_{v2} of Back cone is thought to be Tooth profile of Bevel gear.

This Spur gear is an incomplete circle. The incomplete circle Spur gear after being completed is called a Virtual spur gear [(1)], which is equivalent to a Bevel gear.

The relationship between Virtual number of teeth of Spur gear z_v and Actual number of teeth z of Bevel gear is as follow.

$$z_v = \frac{z}{\cos\delta} \qquad (\delta\text{: Pitch angle})$$

The Virtual number of teeth of Spur gear is standard for strength calculation of Bevel gear and selection of hob cutter.

This is Crown gear where Pitch surface of Bevel gear is changed into a flat surface and perpendicular to axial direction. Using high gear ratio and using creative motion of Bevel gear for examination from imaginary Tooth profile of Crown gear.

Bevel gear with shaft angle of 90° and gear ratio 1:1 is commonly called Miter gear.

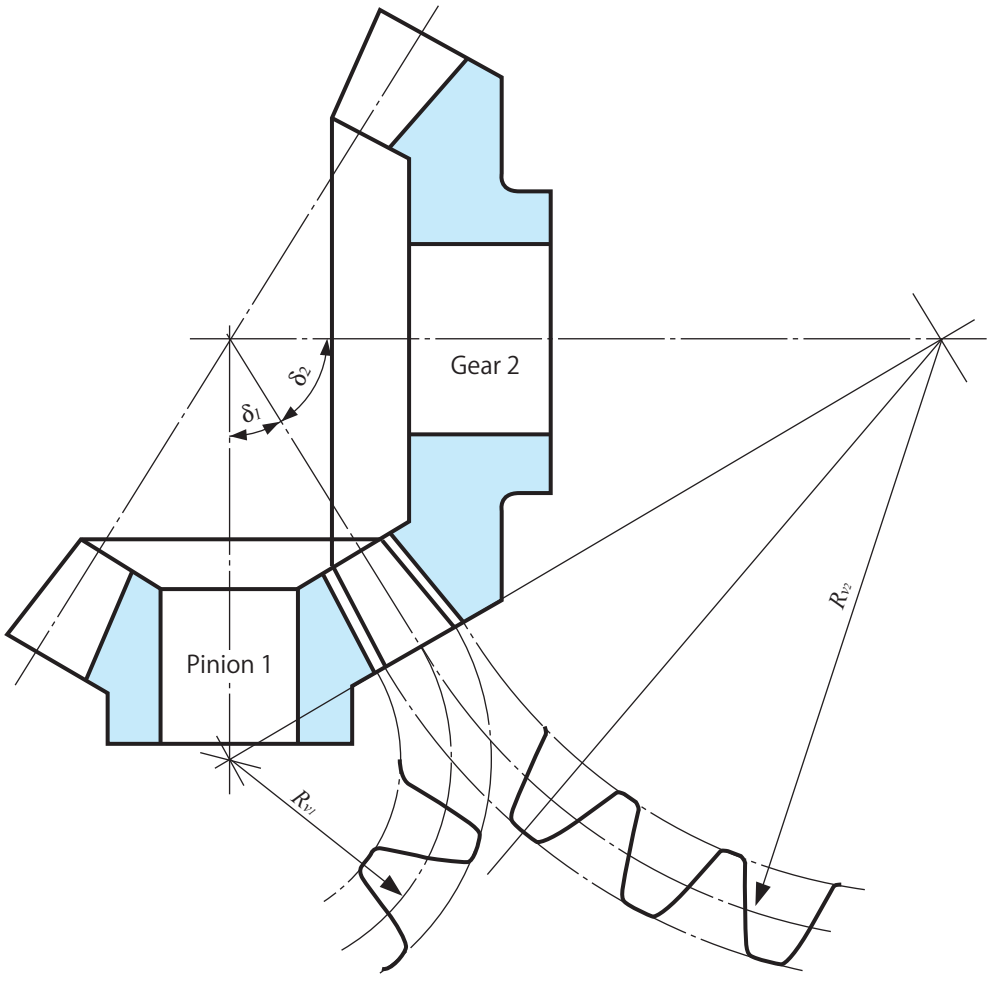


Fig. 12 Virtual spur gear [(1)] for Bevel gear

Note(1) Adopted old gear terms

(1) Straight bevel gear

Straight bevel gear has a straight Tooth trace. Standard straight bevel gear and Gleason system straight bevel gear are common types.

A Standard Straight bevel gear is equivalent to a Standard spur gear due to Virtual spur gear. Undercut occurs in small Number of teeth.

However, Gleason system for Straight bevel gear provides fewer problems of Undercut in small Number of teeth of Pinion because Gleason system for Straight bevel gear is designed to become profile shifted gear between Pinion and Gear. Refer to the below Table 7 for comparison table of the features between Standard system and Gleason system.

Table 7. Comparison table for the features between Gleason system and Standard system

	Gleason system	Standard system
Cause of Undercut	There are fewer problems in Pinion due to positive Rack shift (Gear is negative Rack shift)	It is designed without rack shift and Undercut occurs easily.
Balance of strength for Pinion and Gear	Maintains excellent balance by Rack shift	Unbalanced without Rack shift
Bottom clearance	There is no Tip interference at Toe due to Parallel bottom clearance.	Occur Tip interference at Toe easily due to not Parallel bottom clearance

∗ Miter gear is designed without Rack shift.

Coniflex® gear has Tooth trace with Crowning to Straight bevel gear as named by Gleason company.

Due to above features and Crowning, Gleason Straight bevel gear provides much lesser single contacts and assembly problems as compared to other methods.

Table 8 classifies the minimum Number of teeth to prevent Undercut for Gleason Straight bevel gear.

Table 8. Classifies the minimum Number of teeth to prevent Undercut for Gleason Straight bevel gear.

α=20°		α=14.5°	
Number of teeth of Pinion	Number of teeth of Gear	Number of teeth of Pinion	Number of teeth of Gear
z_1	z_2	z_1	z_2
13	30	24	57
14	20	25	40
15	17	26	35
16	16	27	31
		28	29
		29	29

(2) Spiral bevel gear

Fig. 13, angle between Tooth trace and Pitch cone surface element in Bevel gear with curved Tooth trace is called Spiral angle.

Mean spiral angle βm is spiral angle at centre of Facewidth. Unless otherwise specified, this Mean spiral angle is commonly called spiral angle.

For Gleason system of Spiral bevel gear, Standard spiral angle is 35° with arc of Tooth trace. Gleason system cutter performs to produce Crowning at Tooth trace automatically.

In general, Shaft angle is 90° and matches with left and right hand gears.

Refer to Fig. 14 for Right and Left hand of Spiral gear.

To prevent thrust force to axis direction, due to curved tooth, thrust bearing is necessary. (Refer to the thrust force in Chapter 2)

Shown in Table 9. Comparison table for minimum Number of teeth to prevent Undercut for Gleason Spiral bevel gear.

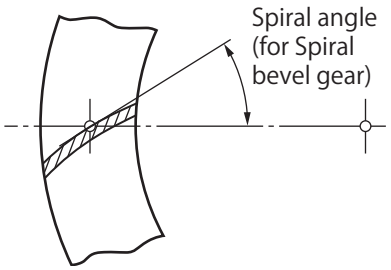
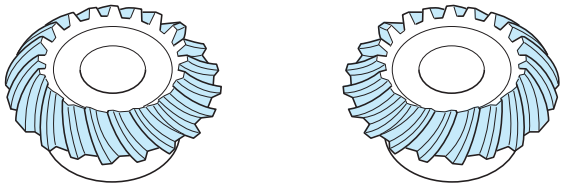


Fig. 13 Spiral angle at centre of Facewidth.



Left hand Right hand

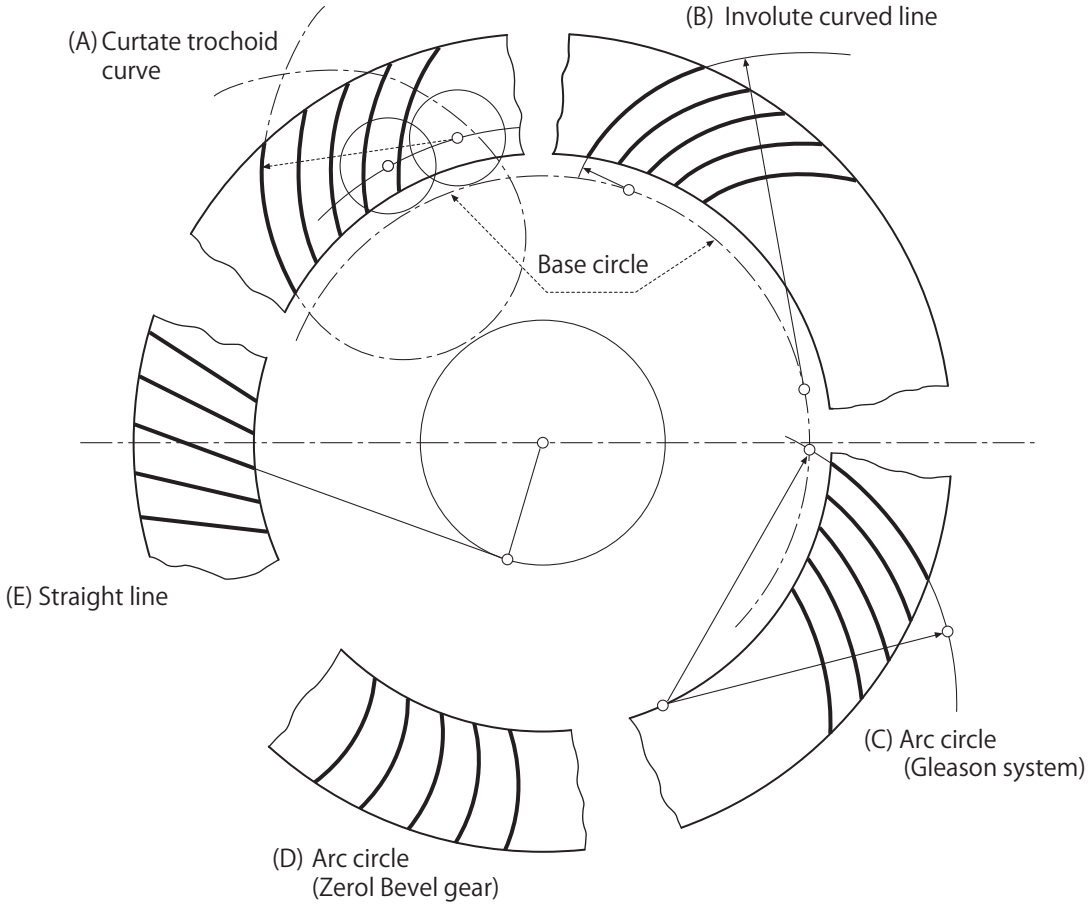
Fig. 14 Spiral bevel gear with Left and Right hand.

Table 9. Comparison table shows the minimum Number of teeth to prevent Undercut for Gleason Straight spiral bevel gear.

α=20°		α=16°		α=14.5°	
Number of teeth of Pinion	Number of teeth of Gear	Number of teeth of Pinion	Number of teeth of Gear	Number of teeth of Pinion	Number of teeth of Gear
z_1	z_2	z_1	z_2	z_1	z_2
12	26	16	59	19	70
13	22	17	45	20	60
14	20	18	36	21	42
15	19	19	31	22	40
16	18	20	29	23	36
17	17	21	27	24	33
		22	26	25	32
		23	25	26	30
		24	24	27	29
				28	28

(Reference)

These are types of Crown gear (similar relation between Rack and Spur gear) with curved line Tooth trace. Spiral bevel gears have following types shown in Fig. 15.



∗Gleason system of large size Spiral bevel gear is close to rectilinear tooth but there is a slight spiral Tooth trace by modified rolling.

Fig. 15 Types of Spiral bevel gear (curved line of Tooth trace for Crown gear)

Worm gear pair

This is a Worm gear pair used as one pair of Threaded worm gear engaged with Worm wheel. It is commonly used in high speed reducing ratio.
Due to the low efficiency character, it is an important point to use proper lubricant oil to prevent heat generation.
To prevent thrust force to axis direction due to curve tooth, thrust bearing is necessary. (Refer to thrust force in Chapter 2)
Helix angle of Tooth for Worm gear is called Lead angle. Helix angle for Worm Wheel is called Helix angle same for Helical gear.
Generally Worm gear and Worm wheel match with Non-parallel and Non-intersecting axis. Shaft angle is 90°. For example, right lead angle of Worm gear matches with right helix angle of Worm wheel.
Worm gear with 2 or more number of threads are commonly called Multi-threaded worm gear.
Use suitable lead angle from Worm gear to fabricate the Helix angle for Multi thread Worm wheel.
Regarding the engagement for KG-Worm gear and KG-Worm wheel, refer to Table 10.

Table 10. The Engagement of KG-Worm and KG-Worm wheel (Assembled Gear pair should have same module.)

	Worm gear	Worm wheel
Symbol for Direction of thread and Number of thread.	R1 (Right hand /Single thread) R2 (Right hand/Double thread) L1 (Left hand/Single thread) L2 (Left hand/Double thread)	R1 (Right hand, fabricate helix angle by single thread of Worm gear) R2 (Right hand, fabricate helix angle by double thread of Worm gear) L1 (Left hand, fabricate helix angle by single thread of Worm gear) L2 (Left hand, fabricate helix angle by double thread of Worm gear)

There are the types of Normal and Axis worm gear pair, same as Helical gear. Normal type of Worm gear pair has come into wide use generally because it is economical.
When calculating Centre distance for Normal type of Worm gear pair, fraction appears due to $\tan\gamma$. In case of small lead angles, adjust Worm wheel by method of Negative Rack Shift to designated centre distance.