5. Gear Parameter and Geometric Dimensions

5.1 General Terms

5.1.1 Gear Parameter

Module

The division of the tooth pitch divided by Pi is called module (in mm). The commonly used modules are transverse module, normal module and axial module. They are artificial given geometries set to provide convenience for gear design, calculation, manufacturing and inspection and make the gear system more systematized, standardized and generalized. At present, different countries or different gear types have their own standard module value. Most of their sizes are indicated by the series of preferred numbers--R10, R20.

Gear taking module as its length measurement unit is called "module system gear". What china uses is modulus system gear.

Transverse Module

The division of transverse circular pitch divided by Pi is called transverse module. The relation between transverse module and normal module is: $m_t = m_n / \cos\beta$; the relation between transverse module and axial module is: $m_t = m_x tg\beta$.

Axial Module

The division of axial pitch divided by Pi is called axial module (in mm). The relation between axial module and normal module is: $m_x = m_n / \sin\beta$; the relation between axial module and transverse module is: $m_x = m_t / tg\beta$.

Normal Module

The division of normal pitch divided by Pi is called normal module (in mm). The relation between normal module and transverse module is: $m_n = m_t \cos\beta$; the relation between normal module and axial module is: $m_n = m_x \sin\beta$.

Diametral Pitch

The standard definition of diametral pitch in GB3374—82 is: The quotient calculated in the division that Pi is divided by pitch (in mm) is called diametrical pitch. This value is equal to the inverse of module.

Gear taking diametral pitch P as geometric measurement unit is called "gears measured by diametral pitch". Gears measured by diametral pitch are mostly used in countries where imperial units are used. In these countries, diametral pitch is defined as the quotient calculated through the gear teeth dividing by the diameter (in in). At this time, the relation between the module and diametral pitch is P=25.4 / m.

Transverse Diametral Pitch

The transverse diametral pitch means the quotient calculated through which Pi is divided by the transverse circular pitch. This value is equal to the inverse of transverse module. The relation between transverse diametral pitch and normal diametral pitch is: $P_t = P_n / \cos\beta$. The relation between the transverse diametral pitch and axial diametral pitch is: $Pt=P_x tg\beta$.

Axial Diametral Pitch

The axial diametral pitch means the quotient calculated through which Pi is divided by the axial pitch (in mm). This value is equal to the inverse of the axial module. The relation between the axial diametral pitch and the transverse diametral pitch is: Px=Pt/tgβ ; the relation between the axial diametral pitch and normal diametral pitch is: Px=Pn/sinβ .

Normal Diametral Pitch

The normal diametral pitch means the quotient calculated through which Pi is divided by normal pitch (in mm). This value is equal to the inverse of normal module. The relation between normal diametral pitch and transverse diametral pitch is: $P_n = P_t \cos\beta$. The relation between normal diametral pitch and axial diametral pitch is: $P_n = P_x \sin\beta$.

Metric Gear

Metric gear takes module as its length measurement unit. What China uses is metric gear.

Double Modulus Gear

Double modulus gear takes two kinds of module as its unit for geometric measurement.

DP gear

Gear taking pitch as its unit for geometric measurement is called pitch gear, also known as diametral pitch gear (DP gear).

Double Diameter Pitch Gear

The definition of double diametral pitch gear and the method of its calculation is the same as double module gear. See "double module gear".

Addendum Coefficient

The addendum coefficient means the quotient calculated through which the addendum of standard gear is divided by modulus, namely $h_a^* = h_a / m$. According to GB1356-87, the normal tooth is $h_a^* = 1$.

Transverse Pressure Angle

In the gear end plane and the intersection point of the transverse tooth profile and the reference circle, there is an acute angle formed between the radial diameter and the tangent existing at the point of the intersection. This acute angle is called transverse pressure angle (see figure 5-1). The relation between the transverse pressure angle and normal pressure angle is: $tg\alpha_t = tg\alpha_n / \cos\beta$.

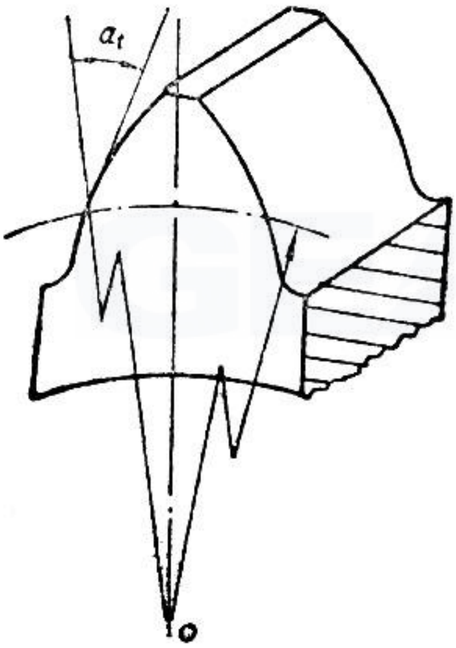


图 5-1

Normal Pressure Angle

On the tooth of a gear, the acute angle formed by the intersection of an radial line found at a point of tooth trace and the tangent plane at the same point of this tooth flank is called normal pressure angle (see figure 5-2). The relation between normal pressure angle and transverse pressure angle is: $tg\alpha_n = tg\alpha_t \cos\beta$

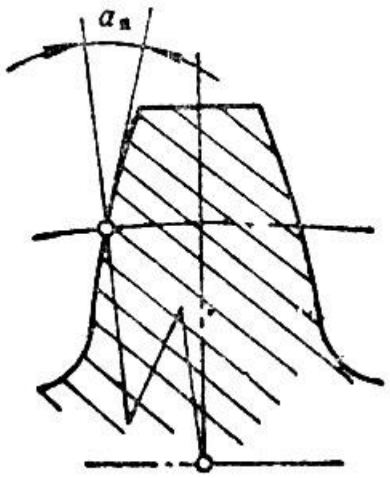


图 5-2

Transverse Pressure Angle at a Point

In gear end plane, the acute angle formed by the intersection of a radial line at any point M on the transverse tooth profile and the tangent at the same point is called transverse pressure angle at a point.

Normal Pressure Angle at a Point

The acute angle formed by the intersection of a radial line at a point of the tooth surface and the tangent at the same point is called normal pressure angle at a point.

Nominal Pressure Angle

The normal pressure angle of basic rack is called normal pressure angle (see Figure 5-3). According to GB1356-88, the normal pressure angle is $\alpha_n = 20°$. Some countries adopt the angle 14.5^o and 15^o. Currently, extensive research has been carried out on gear with large nominal pressure angle, such as $\alpha_n = 25°、28°、30°$.

Researches show that this kind of gear has great advantage in loading capacity.

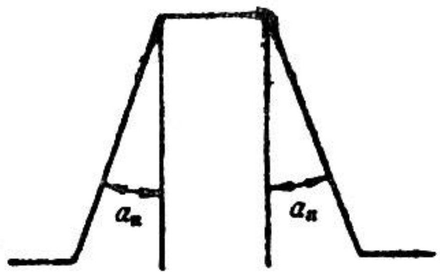


图 5-3

Big Pressure Angle

Big pressure angle refers to those normal (end surface or axial) pressure angle whose pressure angle is greater than 20^o. Big pressure angle can do benefits to gear's bending strength and contact strength but not to the bearing. The adopted big pressure angles nowadays are $25^o, 27^o, 28^o$ *and* 30^o etc.

Small Pressure Angle

Small pressure angle refers to normal pressure angle whose pressure angle is less than 20^o.

5.1.2 Reference Plane, Tooth Profile and Tooth Trace

Transverse Plane

Transverse plane refers to the plane that is vertical to the axis of gear.

Normal Plane

Generally, normal plane refers to the plane containing one point M in the tooth trace and also vertical to the tooth trace (See figure 5-4). This kind of plane is called normal plane. For most of the gears, the standard references are stipulated on normal plane.

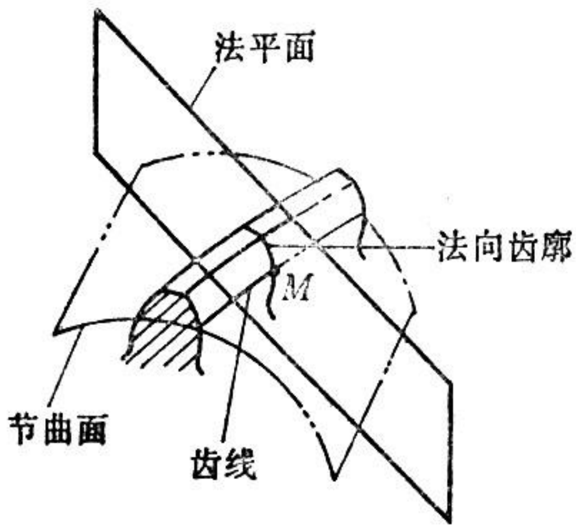


图 5-4

Axial Plane

Any plane containing gear axis can be called axial plane. Axial plane plays an important role in the usage of helical gear and worm.

Transverse Plane of Tooth

Transverse plan of tooth refers to the plan that is vertical to the generatrix of reference surface of the gear (see figure 5-5).

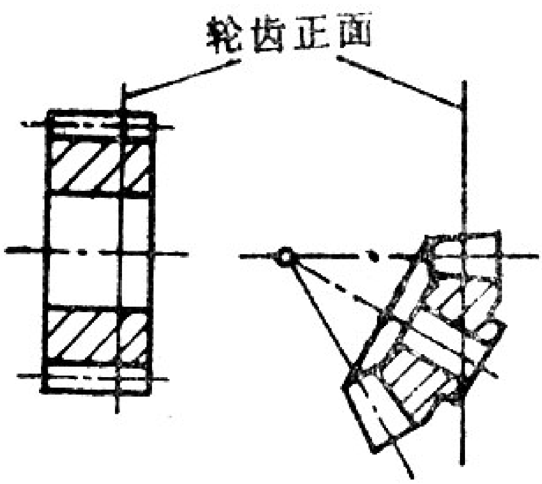


图 5-5

Tooth Profile

Tooth profile refers to a transversal cut by a fixed surface intersecting with tooth trace. See Figure 5-4, Figure 5-6 and Figure 5-7.

Normal Profile

Normal profile refers to the transversal cut by the normal plane. Normal profile is one of the basic terms used in geometry relating to helical-spur gear, cylindrical worm gear and cylindrical worm.

Transverse Profile

Transverse profile refers to the transversal cut by transverse plane (see Figure 5-6). Transverse profile is a basic geometric terms used in cylindrical gear. The transverse tooth profile of straight-tooth cylindrical gear is overlapped with its normal profile.

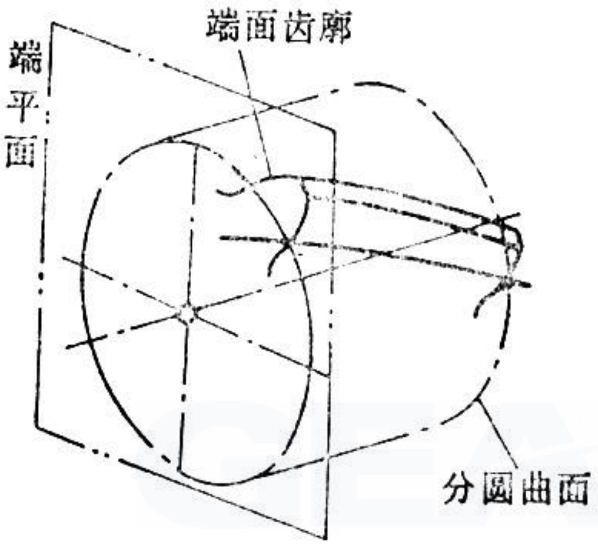


图 5-6

Axial Profile

Axial profile refers to the transversal cut by axial plane. Axial profile is a basic term used in worm and worm gear.

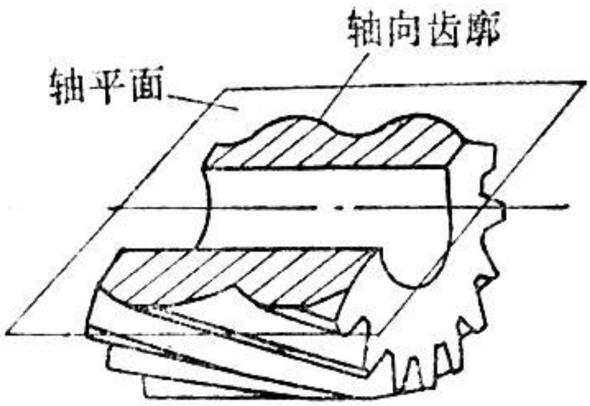


图 5-7

Tooth Trace

Tooth trace is the intersection line between flank and reference surface (see Figure 5-8). Tooth surface can be straight line, curved line or spiral line.

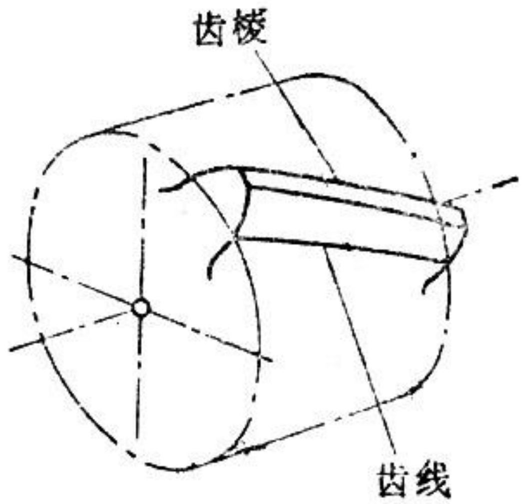


图 5-8

Tip/Tooth Tip

The intersection line between the tooth flank and the surface of tooth tip is called tooth tip. Tooth tip can be straight line, curved line or spiral line.

5.1.3 Tooth Thickness and Slot Width

Transverse Tooth Thickness

In the end face of cylindrical gear, the arc length of reference circle between two sides of tooth profile is called transverse tooth thickness (see Figure 5-9). In terms of standard gear, the value is equal to the width of tooth space. According to GB1356-88, the transverse tooth thickness: $s=\frac{1}{2}m\pi$ .As for the deflection gear: $s'=s\pm 2mxtg\alpha$. ("-"used in inner gear while "＋"used in external gear)

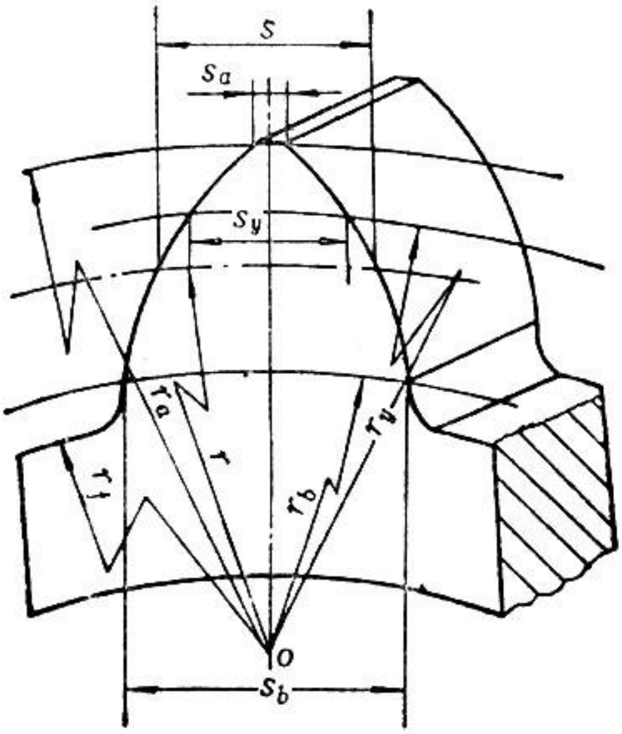


图 5-9

Crest Width

In transverse plane of a gear, the arc length of addendum circle between two end surfaces of tooth profile is called crest width.

Transverse Base Thickness

In the end face of involute cylindrical gear, the arc length of base circle between the starting points of involute tooth profile on both sides of the gear teeth is called transverse base thickness. The formula is $s_b = \cos(s \pm 2mxtg\alpha \pm mzinv\alpha)$. See Figure 5-9.

Tooth Thickness at a Point

In the end face of a cylindrical gear, the arc length cut reversely from any arc of a circle is called tooth thickness at a point (see Figure 5-9). The value is $s_i = r_i / r(s \pm 2mxtg\alpha) \mp r_i[inv\alpha_i - inv\alpha]$, in which the upper symbol of "$\pm 2mxtg\alpha) \mp$" is applied in external gear while the lower symbol is used when it comes to internal gear.

Normal Tooth Thickness

As for helical-spur gear, herringbone cylindrical gear and cylindrical worm, the arc length of the normal spiral line of tooth trace between the two sides of the tooth surface is called normal tooth thickness (see Figure 5-10). The value is $s_n = s_t \cos\beta$.

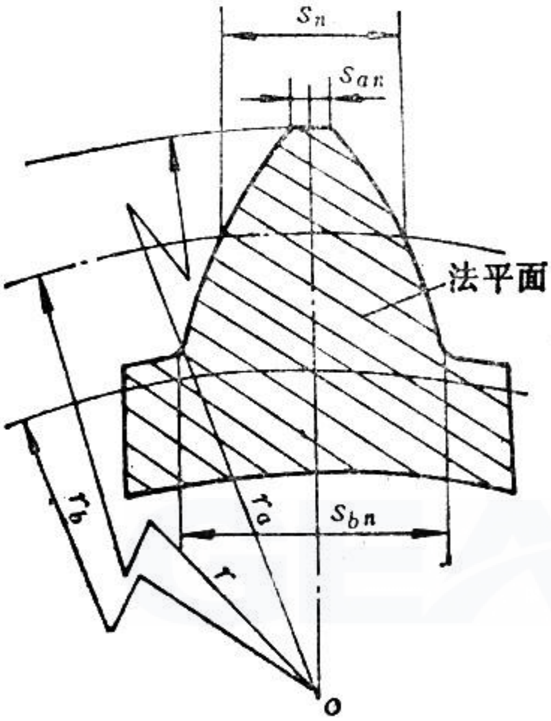


图 5-10

Normal Base Thickness

In involute helical (or herringbone) cylindrical gear and involute cylindrical worm, the arc length of the two sides of base spiral line measuring along its normal spiral line is called normal base thickness. It is represented by s_{bn}. See Figure 5-10.

Normal Crest Width

In helical (or herringbone) cylindrical gear and cylindrical worm, the arc length of normal spiral line between the cylindrical spiral lines on both side of the tooth top. The value is $s_{\alpha n}= s_{\alpha t} \cos\beta$. See Figure 5-10.

Transverse Chordal Tooth Thickness

In the end plane of the gear, the chord length corresponding to the indexing arc between the end tooth profiles of the gear tooth is called transverse chordal thickness. It is shown by $\bar{s}$ (See Figure 5-11).

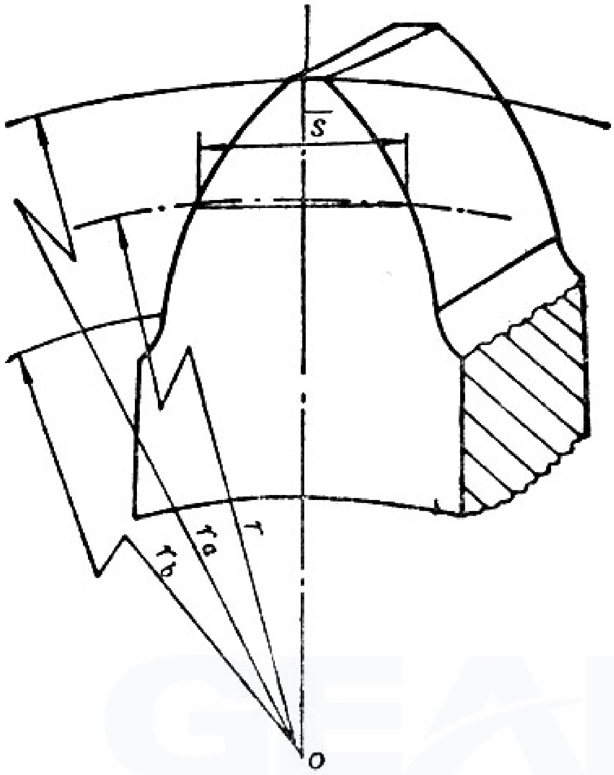


图 5-11

Normal Chordal Tooth Thickness

The shortest distance between the two sides of tooth trace of gear teeth is called normal chordal tooth thickness. It is also equal to the chord length corresponding to normal tooth thickness.

Constant Chord

When a tooth of an involute gear symmetrically contacts with two teeth of a basic rack, the shortest distance between the contacting lines distributing on the two sides of the tooth surface is called constant chord (see Figure 5-12). According to the tooth profile prescribed in GB1356-88, the constant chord is

$$\bar{s}_c = m\cos^2\alpha(\frac{\pi}{2} \pm 2xtg\alpha)$$

=m(1.387－0.6428x).

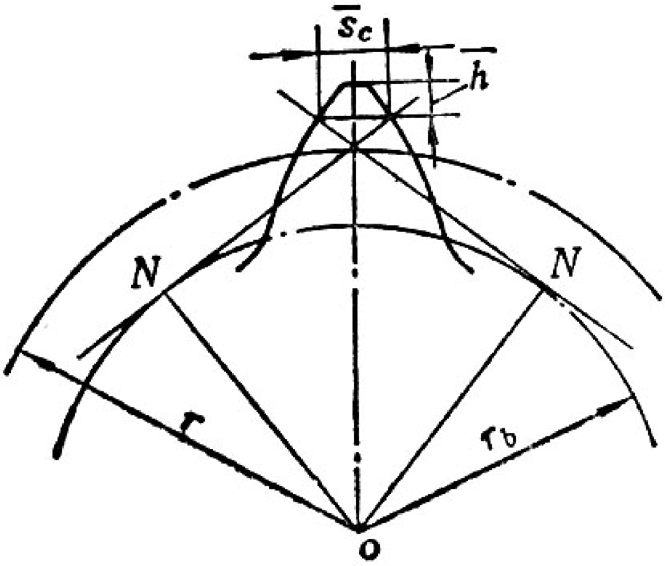


图 5-12

Tooth Space

Tooth space refers to the space between two adjacent teeth. The size of tooth space is often represented by the arc length of reference circle.

Transverse Space width

In the end plane of a gear, transverse space width refers to the arc length of reference circle between the two sides of the transverse tooth profile (see Figure 5-13). The value is $e_t=p_t-s_t$.

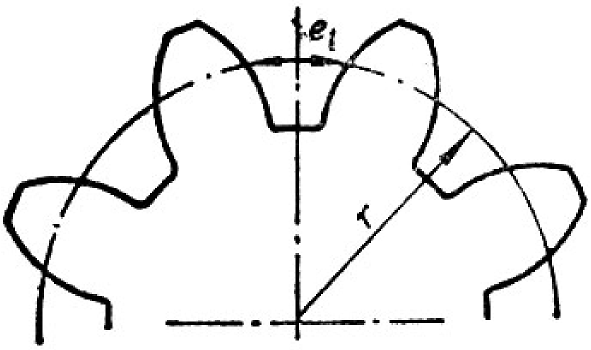


图 5-13

Normal Space width

In the tooth space of a helical or herringbone gear, the arc length of the normal spiral line between the two sides of the tooth trace is called normal space width (see Figure 5-13). It is represented by e_n.

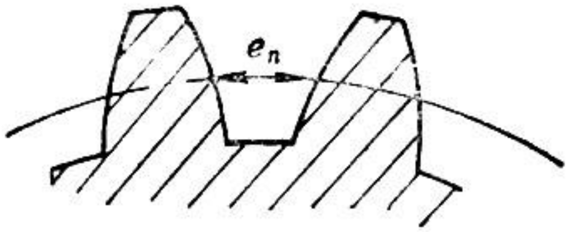
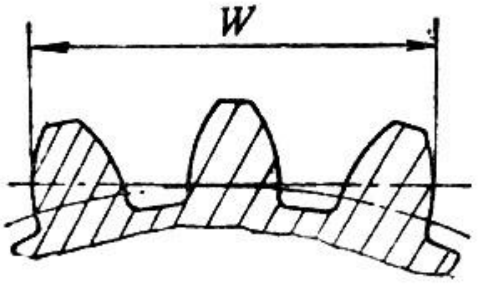


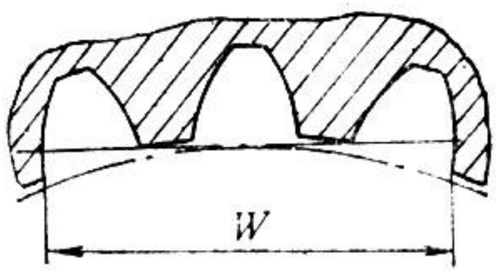
图 5-14

Base Tangent Length

For external gear, base tangent length refers to the base tangent distance (see Figure 5-15a) measured on the two outer sides of tooth surface of several adjacent teeth. As for internal gear, base tangent length refers to the base tangent distance measured on the two outer sides of tooth surface of several adjacent tooth spaces. In regard to involute spur gear, the base tangent length is calculated in the end plane. The formula is listed as $\overline{W}_t = m_t \cos\alpha_t\left[(k-0.5)x + zinv\alpha_t\right] + 2m_t x_t \sin\alpha_t$.



a）



b）

图 5-15

a） 外齿轮 b） 内齿轮

Tooth Thickness Half Angle

Tooth thickness half angle refers to half of the central angle corresponding to the transverse tooth thickness. It can be represented with ψ. See Figure 5-16.

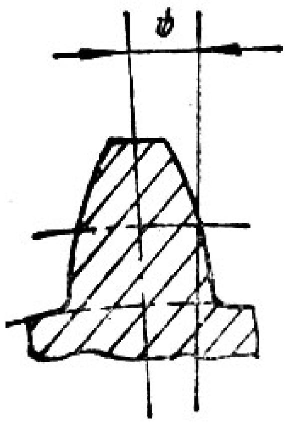


图 5-16

Space Width Half Angle

Space width half angle refers to half of the central angle corresponding to transverse tooth space. It is represented by η (see Figure 5-17).

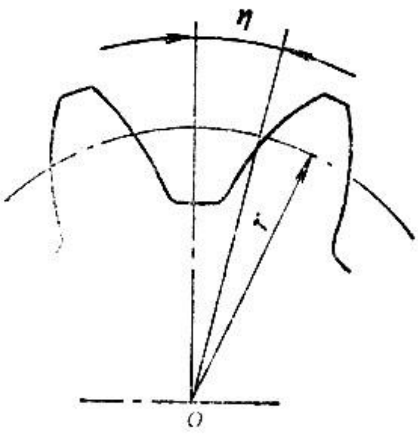


图 5-17

5.1.4 The Tooth Surface and Tooth Direction

Tooth Flank

The tooth surface between the tip surface and root surface is called tooth flank (see Figure 5-18). Tooth flank consists of three parts: the addendum flank, the dedendum flank and the blending surface.

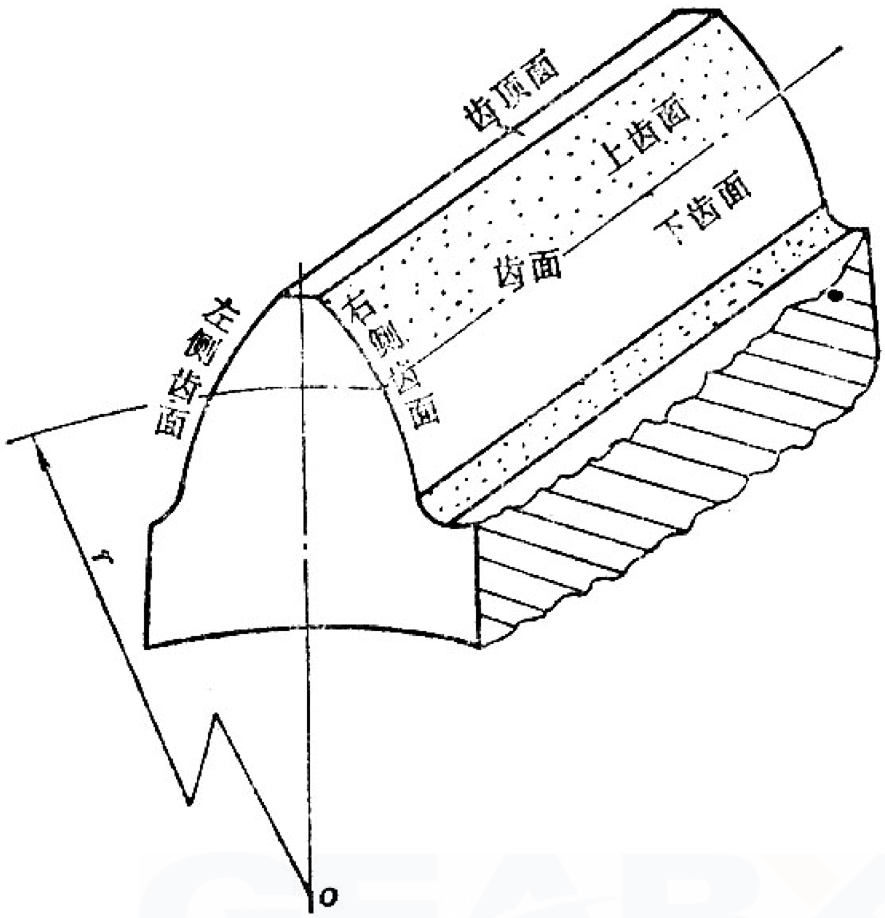


图 5-18

Addendum Flank

Addendum flank refers to the tooth flank between the tip surface and reference surface (see Figure 5-18). Generally speaking, addendum flank is part of the active flank.

Dedendum Flank

Dedendum flank refers to the tooth flank between the reference surface and root surface (see Figure 5-18). Dedendum flank consists of blending root surface and part of usable flank.

Right Flank

Taking the transverse plane as the datum plane, the observer's sight should be vertical to the transverse plane. Looking at a gear whose addendum being upward, then we can call the tooth flank on the right side the right flank. See Figure 5-18.

Left Flank

Taking the transverse plane as the datum plane, the observer's sight should be vertical to transverse plane. Looking at a gear whose addendum being upward, then we can call the tooth flank on the left side the left flank. See Figure 5-18.

Fillet

Fillet refers to the tooth flank between usable flank and bottom land. See Figure 5-18.

Crest，Top Land

Crest refers to the tooth surface contained by the tip surface. It is located at the top of the gear. See Figure 5-18. Crest is non-working flank. For external gear, crest refers to the farthest tooth surface apart from the gear axis. For internal gear, crest refers to the nearest tooth surface apart from the gear axis.

Bottom Land，Bottom of Tooth Space

Bottom land refers to the tooth space which is at the bottom of the tooth space, contained by the root surface and connecting with the blending root surface. See Figure 5-19. Bottom land is non-working tooth surface. In some cases, the bottom land may abrade into a simple line.

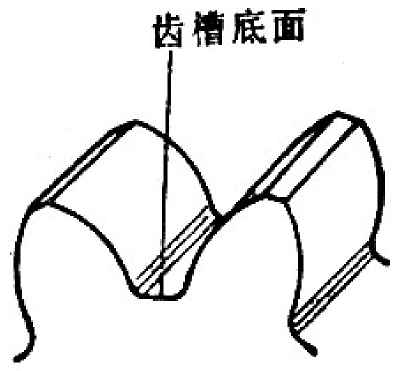


图 5-19

Usable Flank

Usable flank is enveloped with theoretical machine tool tooth flank. The meshing area on the working flank is called usable flank. The proportion of usable flank is only affected by the geometric shape of the active face of the tool and the corresponding installation sites of gear blank.

Non-working Flank

Non-working flank refers to the opposite tooth surface of the working flank. The non-working flank doesn't participate in conjugate meshing when the gear pair is in operation. See Figure 5-20.

Working Flank

Working flank refers to the conjugate meshing surface joined by a pair of gear tooth when the gear pair is transmitting its movement and torque. See Figure 5-20.

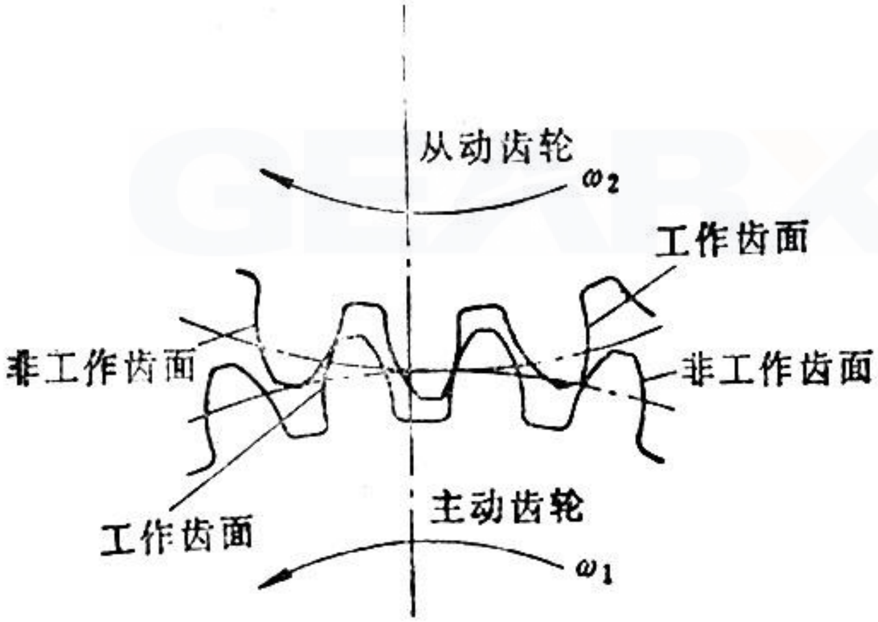


图 5-20

Corresponding Flanks

Corresponding flanks refers the surfaces at the same side (all of the left or right) of a gear. See Figure 5-21.

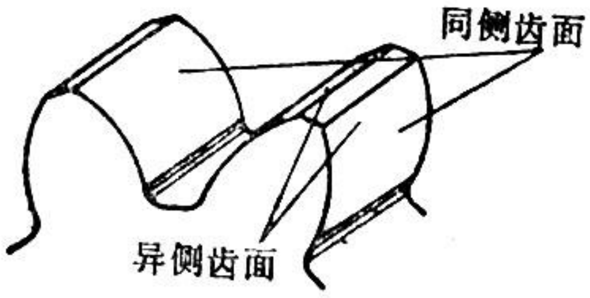


图 5-21

Opposite Flanks

In a gear, the right flank and the left flank are opposite flank of each other. See figure 5-21.

Coast Side

Coast side is a term used in vehicles when bevel gear is applied. As the vehicle moves backwards, the flank on which the bull gear (or pinion gear) and its matched gear contacting each other is called coast side. It also refers to the meshing flank of gear pair when the vehicle moving backwards.

Drive Side

Drive side is a term used in vehicles when bevel gear applied. As the vehicle moves forwards, the flank of bevel gear pair on which the bull gear (or pinion gear) and its matched gear contacting each other is called drive side. It also refers to the meshing flank of gear pair when the vehicle moving forwards.

Active Profile

In a pair of gear, the profile that can be meshed is called active profile. Active profile also refers to the profile formed between two tip surfaces of the meshed gears.

Active Flank

In the meshing process of gear pair, the flank that actually participates in conjugate meshing is called active flank. The size of active flank is not only affected by the shape of tooth flank, but also affected by the location and relative movement relation of the two matched gears. The maximum area of active flank is equal to the area of usable flank.

Conjugate Profile

The two mating flanks meeting the condition of $\vec{n} \cdot \vec{v}^{(12)} = 0$ are called conjugate profile.

Mating Flank

In a gear pair, the working flank that can mesh with each other is called mating flank.

Left-hand Teeth

If taking the left spiral flank as gear teeth, we call the gear teeth the left-hand teeth. See Figure 5-22.

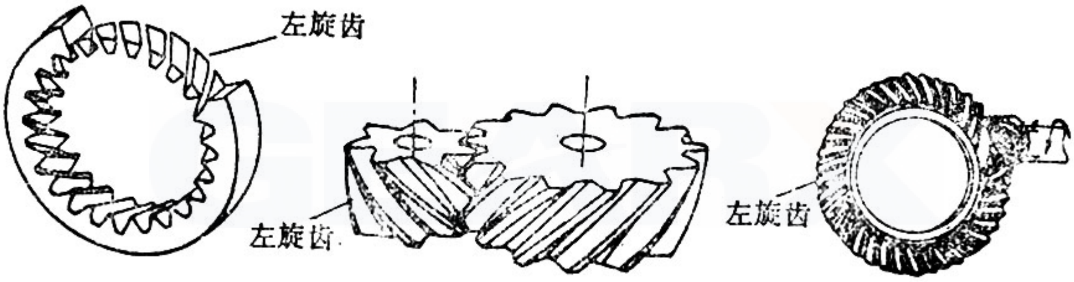


图 5-22

Right-hand Teeth

If taking the right spiral flank as gear teeth, we call the gear teeth the right-hand teeth. See Figure 5-23.

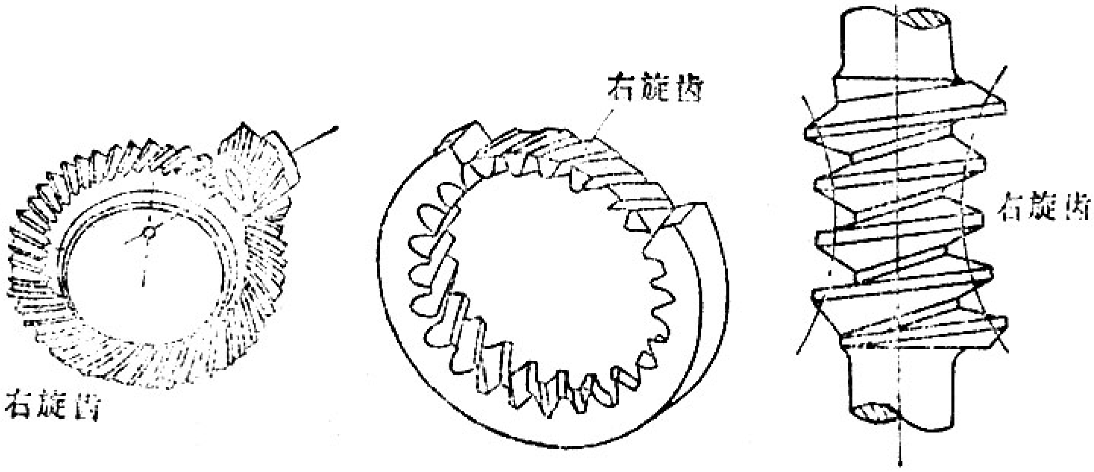


图 5-23

5.1.5 Gear Teeth, Tooth Depth and Facewidth

Gear Teeth

Every bulge in a gear used in meshing is called gear teeth, teeth, for short.

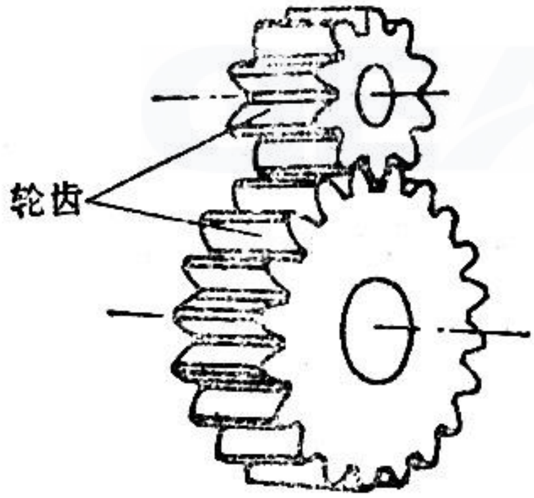


图 5-24

Tooth Depth

Tooth depth refers to the radial distance (h) between addendum circle and dedendum circle. See Figure 5-25.

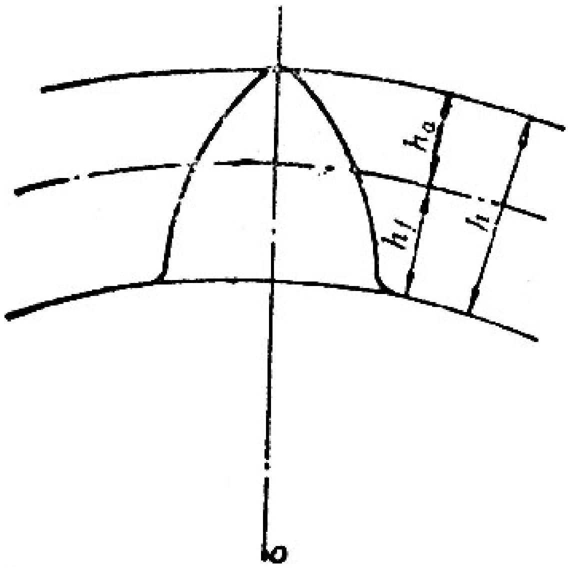


图 5-25

Tooth depth includes addendum and dedendum. The formula is $h = m_t(2h_o^* + c^* + \Delta y_t) = m_n(2h_{\alpha n}^* + c^* + \Delta y_n)$. The Δy here is the coefficient of variation of the addendum circle.

Addendum

Addendum refers to the radial distance (h) between addendum circle and reference circle (see Figure 5-25). The value is $h_a = mh_a^* + \Delta y_m + mx$. Here, Δy is the coefficient of variation of addendum circle.

Dedendum

Addendum refers to the radial distance (h) between dedendum circle and reference circle (see Figure 5-25). The value is $h_f = m(h_a^* + c^*) - mx$.

Working Depth

Each of the tip cylinders of the two mating gears has an intersection point with the line of centers. The shortest distance of the two intersection points is called working depth. See Figure 5-26.

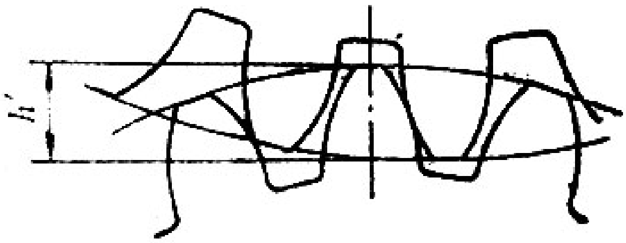


图 5-28

Chordal Height

Chordal height refers to the shortest distance from the center point of normal chordal tooth thickness to the crest. See Figure 5-27.

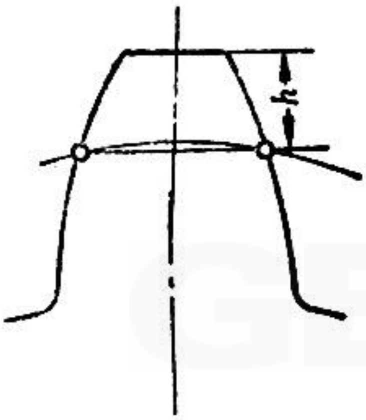


图 5-27

Constant Chord Height

Constant chord height refers to the shortest distance between the center point of constant chord and the top land (see Figure 5-28). The formula for constant chord height is:

Standard involute cylindrical gear:

$$\bar{h}_c = h_\alpha^* - \frac{1}{8}\pi \sin 2\alpha) m + \Delta h$$

As for external gear, Δh=0; As for internal gear, $\Delta h = \frac{1}{2} d_a (1 - \cos \delta_a)$,

$\delta_a = \frac{\pi}{2z} - \mathrm{inv}\alpha + \mathrm{inv}\alpha_a$, when α=20 and $h_\alpha^* = 1$, $\bar{h}_c = 0.7476m + \Delta h_o$

Modified involute cylindrical gear:

$\bar{h}_c = \frac{(\pm d_a \mp d)}{2} - \frac{\bar{s}_c' \, tg\alpha}{2} + \Delta h$. In this formula, as for “"±"*and*"∓"”, the upper symbols are applied in external gear while the lower symbols applied in internal gear.

When α=20, $\bar{h}_c = \frac{(\pm d_a \mp d)}{2} - 0.182\bar{s}' + \Delta h_c$, for external gear, Δh=0; for internal gear,

$\Delta h = \frac{1}{2} d_\alpha (1 - \cos\delta_\alpha)$, $\delta_\alpha = \pi / 2z - (2xtg\alpha / z) - inv\alpha - inv\alpha_a$.

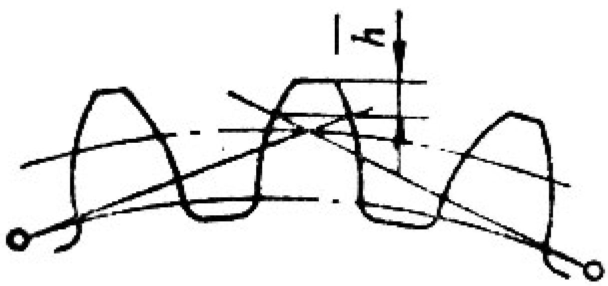


图 5-28

Full-depth Tooth

Generally, full-depth tooth refers to the tooth depth with the addendum coefficient (h^*_a) being 1. With many merits, full-depth tooth is the most widely used depth nationwide.

High Tooth

High tooth is higher than full-depth tooth. High tooth refers to those whose addendum coefficient is higher than 1. This kind of tooth height is flexible and it has larger overlap ratio. But until now it is rarely used and under research.

Shortened Tooth

The tooth depth of shortened tooth is shorter than full-depth tooth. Generally, it refers to the tooth depth whose addendum coefficient is shorter than 1. Some countries stipulate standards for this kind of tooth. As it has few merits, it is rarely used except for special cases.

Intersection Circle(of Opposed Involutes)

Intersection circle (of opposed involutes) refers to the circle which is made by taking distance from the intersection of left and right side tooth profile of the transverse tooth of spur gear (or equivalent spur gear) to the axial line as semi diameter. See Figure 5-29.

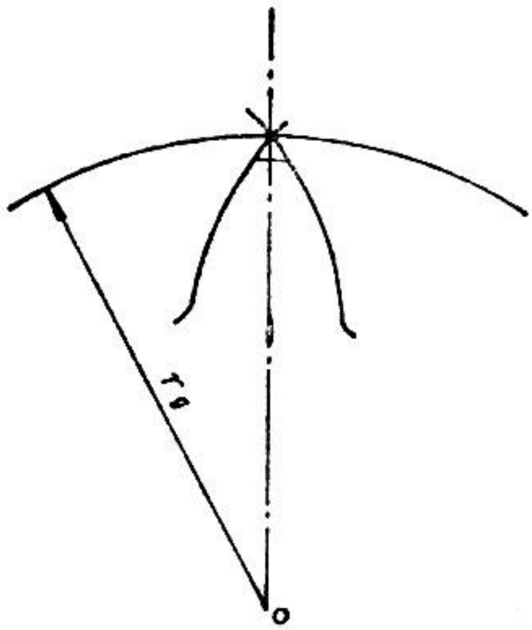


图 5-29

Face Width

Face width refers to the distance measured along the direction of reference cylindrical generatrix in the toothed portion of the gear. See Figure 5-30.

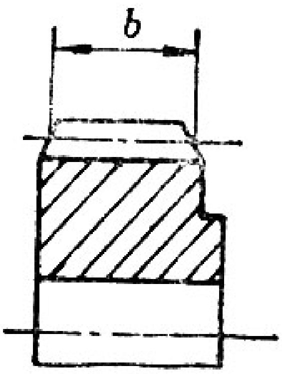


图 5-30

Effective Face Width

Effective face width refers to the contacting width of a pair of meshing gears. To ensure that the effective face width is no less than the face width affirmed during the calculation of strength, what is generally prescribed is that to take the width of bull gear as the face width of strength calculation. The face width of pinion gear is bigger than that of bull gear for 5-10mm. See Figure 5-31.

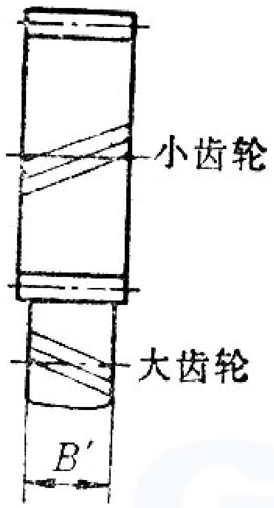


图 5-31

Empty Tool Flute

Empty too flute refers to the non-tooth flute between the left and right side of duplicate gear or herringbone gear (Figure 5-32).

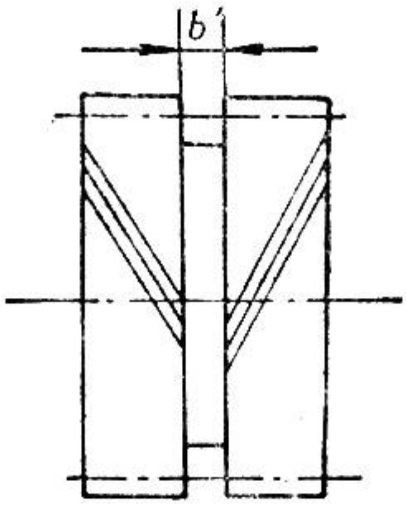


图 5-32

5.1.6 Pitch

Pitch

On a specified surface of a gear, the length of a specified skew curve cut by two adjacent corresponding flanks is called pitch. Pitch is one of the basic parameters of gear. The most frequently used terms about pitch are transverse pitch, normal pitch and axial pitch.

Transverse Pitch

In the transverse plane of a gear, the arc length of reference circle between two adjacent tooth profiles of the same side is called transverse pitch. $P_t = \pi m_t = \pi m_n / \cos\beta = \pi m_x tg\beta$. Transverse pitch is one of the basic parameters used in gear. See Figure 5-33.

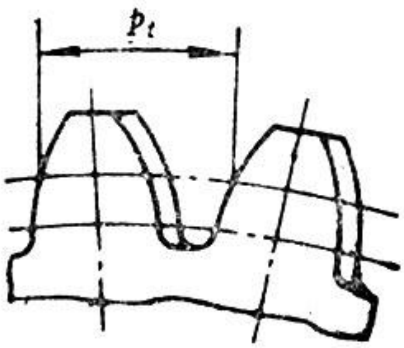


图 5-33

Normal Pitch

On the reference cylinder of helical gear and herringbone cylindrical gear and cylindrical worm, the arc length of normal spiral line cut by two adjacent corresponding flanks is called normal pitch. $P_n = m_n\pi = \pi m_t \cos\beta = \pi m_x \sin\beta$.

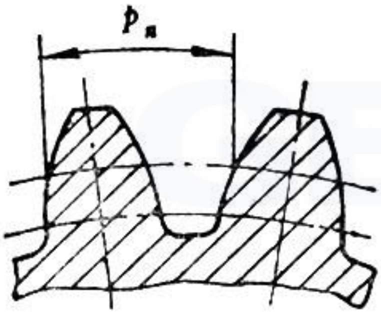


图 5-34

Axial Pitch

In the axial plane of helical gear, herringbone cylindrical gear and cylindrical worm and the transversal of reference cylinder, the distance between two adjacent tooth profiles of the same side is called axial pitch. $p_x=\pi m_x=\pi m_n/\sin\beta$.

Transverse Normal Pitch

In the transverse plane of involute cylindrical gear, the normal distance between two adjacent tooth profiles at the same side is called transverse normal pitch (see Figure 5-35). The value is equal to the transverse base pitch, $p_n=p_b=\pi m_t \cos\alpha$.

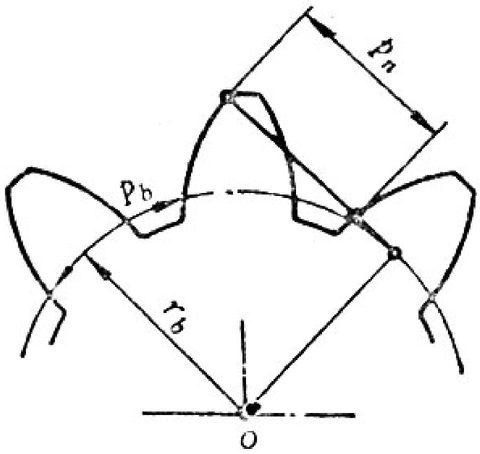


图 5-35

Transverse Base Pitch

As for involute spur gear, helical gear (or herringbone) cylindrical gear and involute cylindrical worm, the base arc length cut by two adjacent flanks of the same side is called transverse base pitch (see Figure 5-35). It was once called base pitch, $p_b=\pi m_t\cos\alpha$. The value is equal to the transverse normal pitch.

Normal Base Pitch

As for involute helical (or herringbone) cylindrical gear and involute cylindrical worm, their two adjacent tooth flank both have a base spiral line on the base cylinder and they are all equidistant spiral line. The arc length from their normal spiral line to the intersection of the two base spiral line is called normal base pitch.

Angular Pitch

Angular pitch is the quotient of the number 360 divided by the number of tooth (see Figure 5-36). For cylindrical gear, it also refers to the central angle of transverse pitch.

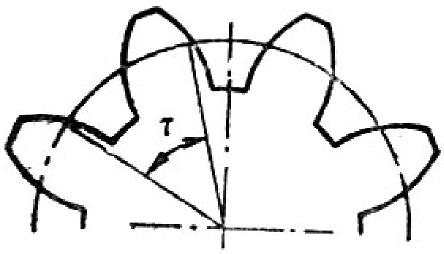


图 5-36

Number of Span Teeth

When measuring the length of common normal, the teeth number or the number of tooth space included by the two bases of caliper is called number of span teeth. See Figure 5-37. The formula is $k=\frac{\alpha^\circ}{180^\circ}z+0.5+\frac{2\times ctg\alpha}{\pi}$, if α =20, k=0.111z+0.5+1.749x (Note: x has its own signal and K is an integer).

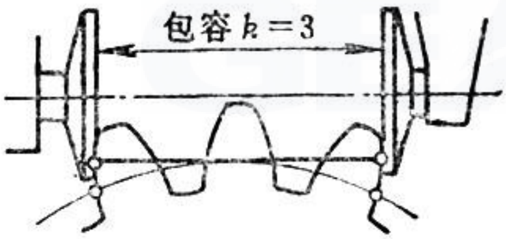


图 5-37

5.1.7 Imaginary Surface and Circle

Reference Surface

Reference surface refers to the imaginary surface which taking the axial line of the gear as its axial line. There are standard module in this surface. At the intersection of profile curve and reference surface, the pressure angle of tooth profile is a standard value. Reference surface is the base level for the measurement of gear size. Reference surface can divide the gear tooth into addendum and dedendum, it can also divide the tooth flank into the addendum flank and dedendum flank. See Figure 5-38.

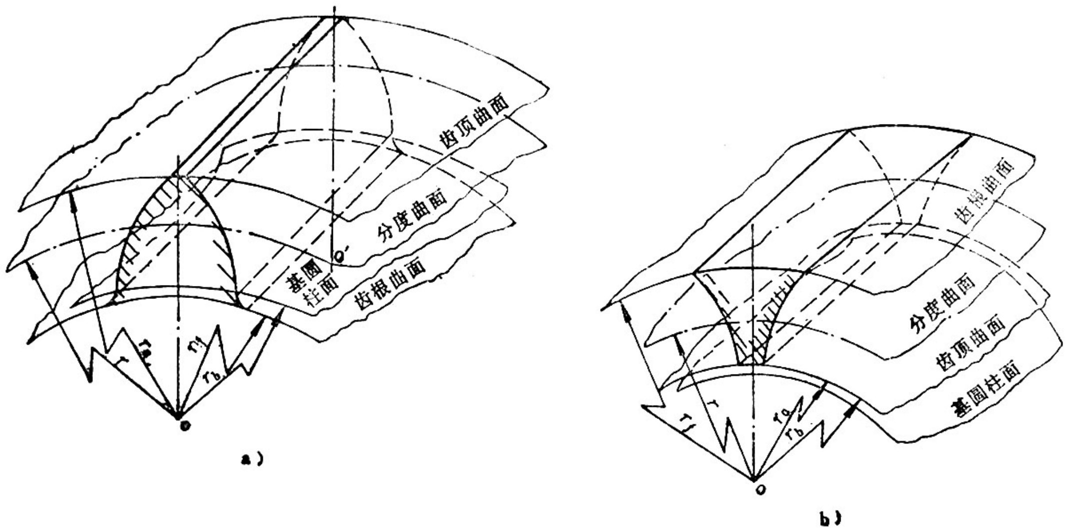


图 5-38

a) 外齿轮 b) 内齿轮

Tip Surface

Tip surface includes various imaginary surfaces of every addendum face of gear tooth. See Figure 5-38.

Root Surface

Root surface refers to various imaginary surface of every bottom flank of tooth space. See Figure 5-38.

Reference Cylinder

The reference surface of cylindrical gear is in the shape of cylinder, so it is called reference cylinder. Reference cylinder is the base surface for the size calculation on the tooth of cylindrical gear. See Figure 5-39.

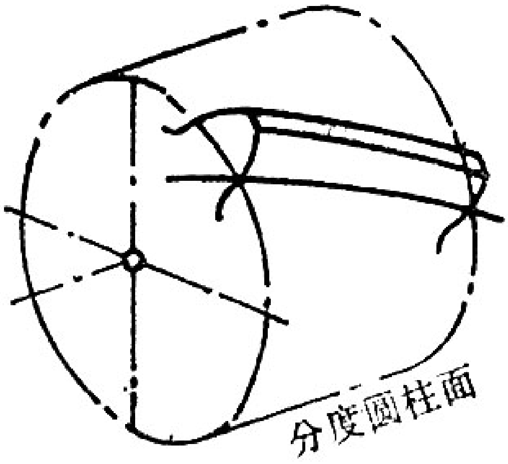


图 5-39

Reference Circle

Reference circle refers to those of cylindrical gear if no specific prescription. Reference circle refers to the intersection line between the reference cylinder and its transverse plane of cylindrical gear. See Figure 5-40. The size of reference circle bears no relation to variation but to module and tooth number. As a basic parameter of gear, it is a circle that has standard module and pressure angle and divides the gear tooth into addendum and dedendum. It is also a base circle for gear tooth size calculation.

Reference Diameter

Reference diameter refers to the diameter of cylindrical gear or the reference cylinder (or reference circle) of cylindrical worm. As for cylindrical gear, the formula for reference diameter is $d=m_tz$; as for cylindrical worm, d=mq. Reference diameter bears no relation to addendum modification. See Figure 5-40.

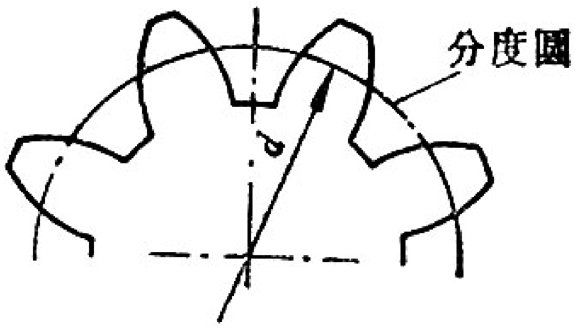


图 5-40

Root Cylinder

The root surface of cylindrical gear is cylinder, so it is called root cylinder. As for external gear, root surface refers to the smallest cylinder of the part of gear teeth. As for internal gear, root cylinder refers to the largest cylinder of the part of gear teeth. In general, it is the innermost imaginary cylinder around the gear teeth. See Figure 5-41.

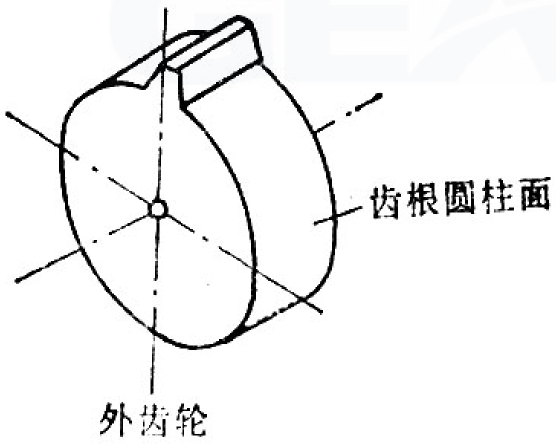


图 5-41

Root Circle

The intersection line between the root cylinder and transverse plane of cylindrical gear is called root circle. See Figure 5-42.

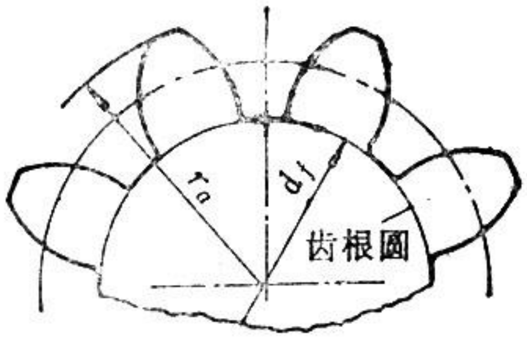


图 5-42

Root Diameter

Root diameter refers to the diameter of root cylinder or root circle. The formula is $d_f = m_t[z \mp 2(h_a^* + c^*) + 2x_t]$ in which "-" is applied in external gear while "+" is applied in internal gear. See Figure 5-44.

Tip Cylinder

Tip cylinder refers to the tip surface of cylindrical gear. As for external gear, tip cylinder refers to the largest cylinder on the part of tooth. As for internal gear, tip cylinder refers to the smallest cylinder on the part of tooth. In a word, tip cylinder is the most external imaginary cylinder. See Figure 5-43.

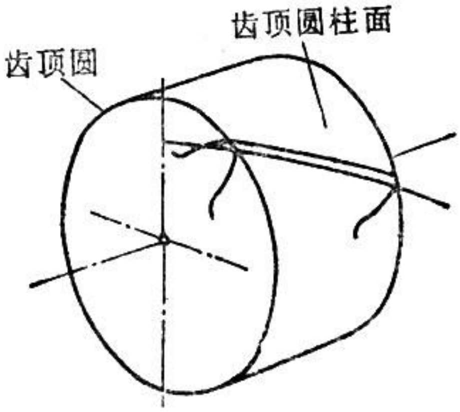


图 5-43

Tip Circle

Tip circle refers to the intersection line between the tip cylinder and transverse plane of cylindrical gear. See Figure 5-44.

Tip Diameter

Tip diameter refers to the diameter of tip cylinder or tip circle. The general formula for the calculation of tip diameter is $d_a = m_t(z \pm 2h_a^* + 2x - 2\Delta y)$ in which x and △y have their own symbols and "-" is used in internal gear. See Figure 5-44.

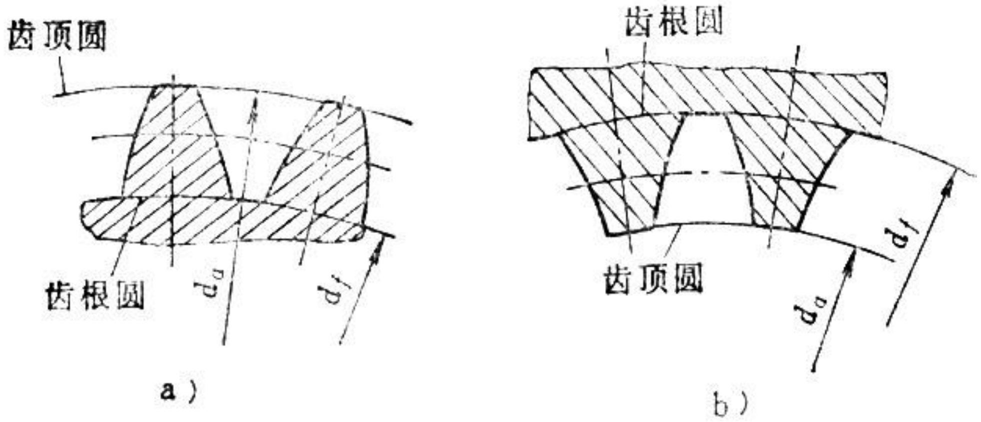


图 5-44

a）外齿轮 b）内齿轮

Fillet Radius

The smallest radius of curvature of the fillet surface of gear teeth is called fillet radius.

Fillet Ratio

Fillet ratio refers to the quotient of the fillet radius ρ_f of the basic profile divided by module. According to GBl356-88, fillet ratio is 0.38; according to GB10087-88, fillet radio is 0.3, 0.2 or 0.4 when necessary; and that of bevel gear is 0.3.

Base Cylinder

Base cylinder refers to an imaginary cylinder on involute cylindrical gear. This imaginary cylinder forms a tooth flank (involute flank or involute spiral line) and this imaginary tooth cylinder is called base cylinder.

Base Circle

Base circle refers to an imaginary circle formed when the generating line of involute tooth profile (or the generating circle of cycloidal tooth profile) making pure rolling on the circumference of this imaginary circle. Base circle is the intersection line between base cylinder and transverse plane. The size of base circle is the only factor that can affect the involute shape. It is also the function of tooth number, pressure angle and module. The formula is $r_b = \frac{1}{2} m_t z \times \cos\alpha$.

Base Diameter

The diameter of base cylinder of involute cylindrical gear, involute worm and cycloidal cylindrical gear is called base diameter. The base diameter of involute cylindrical gear is $d_b=m_t z\cos\alpha$.

5.1.8 General Terms for Gear and Meshing Gear

Geometric Parameter of Gear Pair

Geometric parameter of gear pair includes module, reference circle, tooth width, tooth thickness, tooth depth, choral tooth thickness, common normal length and pressure angle, etc.

Calculated Plane of Cylindrical Gear

The size calculation of cylindrical gear is carried out within transverse plane and the size measurement calculation within normal plane. Transverse plane and normal plane are called corresponding calculated plane. Geometric sizes of r、r_a、r_f、a、h、h_a、h_f, helical gear, straight gear, cylindrical gears with parallel axis as well as helical gear with alternating axis can all be presented in the following formula: $r = \frac{1}{2} m_t z$;

$a = \frac{1}{2} m_t (z_1 + z_2 + 2y)$; $a = \frac{1}{2} (m_{t1} z_1 + m_{t2} z_2 + 2y)$.

Toothed Gear

Tooth gear is a toothed mechanical component with not only invested tooth profile. It can also mesh with other toothed component under the circumstance of

$\vec{n}\cdot\vec{v}^{(12)}=0$. Toothed component that can transmit movement and torque is called toothed gear, for example, cylindrical gear, bevel gear, non-circular gear, and partial gear, etc.

Standard Gear

Standard gear refers to gear whose specific value between tooth thickness and tooth space is equal to that of basic rack. The tooth number of standard gear (z) should be more than the void-undercutting minimum tooth number.

O-Gear

0-gear is the abbreviation of standard involute gear prescribed in DIN870 (1931).

Gear of Standard Pressure Angle

Gear of standard pressure angle refers to the gear whose pressure angle has standard value. Generally, it refers to gear with 20° normal (or transverse or axial) pressure angle. This kind of gear has many advantages so they are widely applied.

Pinion

Pinion refers to the smaller gear with less tooth number in two mating gears. See Figure 5-45.

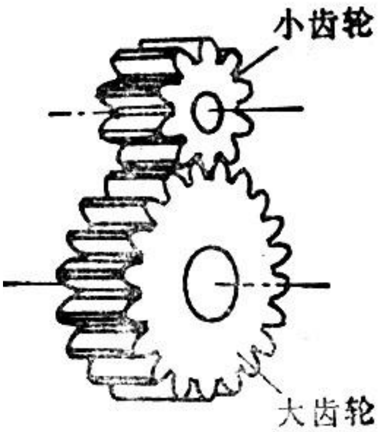


图 5-45

Wheel Gear, gear

Wheel gear refers to the larger gear with more tooth number in a gear pair. See Figure 5-45.

Master Gear

Gear that can be used to set the size and shape of tooth is called master gear. Master gear is an ideal gear without any manufacturing error. In fact, it is a kind of gear with high precision that can serve as a standard to measure the precision of other gears. Therefore, master gear is also called “standard gear” in several occasions.

Internal Gear

Internal gear refers to gear whose addendum surface is located within dedendum surface. See Figure 5-46.

External Gear

External gear refers to gear whose addendum surface is located outside of the dedendum surface. See Figure 5-46.

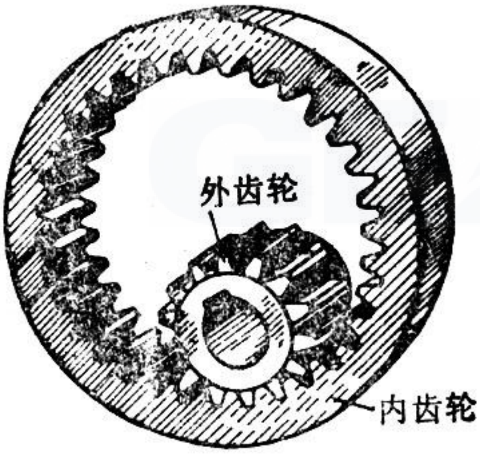


图 5-46

Number of Teeth

Number of teeth refers to how many teeth a gear has.

Mating Gear

Any of the two gear in a pair gear can be called mating gear of the other. The two gears can be matched with each other and can be also called conjugate gear.

Driving Gear

Driving gear refers to the gear which is used to drive its mating gear. That is, in a gear pair, driving gear can operate independently under given motion law. Here, when the smaller gear serves as driving gear, it is speed reduction gear pair; when the larger gear serves as driving gear, it is speed increasing gear pair.

Driven Gear

Driven gear refers to the gear driven by driving gear in a gear pair. The motion law of driven gear is subordinate to that of driving gear.

Gear Pair

Gear pair is a basic gear mechanism composed of two meshing gears. The mating flanks are contacting with each other by points or lines, therefore gear pair is addendum pair mechanism. There are many kinds of gear pairs; it can be divided into parallel gear, gear pair with intersecting axles and gear pair with non-intersecting axes according to the relative location of two gear axes. It can be also divided into point-based meshing gear pair and line-based meshing gear pair according to the nature of higher pair. According to the shape of tooth trace, gear pair can be divided into spur gear, helical gear, spiral teeth etc. According to the shape of reference surface, it can be divided into cylindrical, conical and elliptic gear pair. Gear pair can also be divided into pitch gear, large module gear in terms of the size of gear. It can also be divided into low speed, medium speed and high speed gear pair according to its speed.

5.1.9 Gear with Addendum Modification

Addendum modification

The tangent formed between the reference circle of tooling, or base line of tooling, and the reference circle of gear blank is called zero modification (standard configuration). Zero modification is formed under the foundation of generating method. Comparing to zero modification, addendum modification refers to the non-tangent between the reference circle of the base line of tooling or reference circle of tooling and the reference circle of gear blank. Gear manufactured in this way is called radial deflection gear.

Gear with Radial Modification

Gear manufactured under the installment of tooling modification is called gear with radial modification. Comparing to standard gear, the main difference of radial modification gear in its geometric size is:

$$d_a' = d_a + (2mx + 2m\Delta y)$$

$$d_f' = d_f + 2mx$$

$$s' = s + 2mxtg\alpha$$

$$w' = w + 2mx\sin\alpha$$

$$h_a' = h_a + (mx + m\Delta y)$$

$$h_f' = h_f - mx$$

……

But the base circle diameter, reference circle diameter and various standard parameter (m, α, h_a^*, c*…) remain unchanged.

Profile of Gear with Addendum Modification

Comparing to standard gear, profile of gear with addendum modification applies different involute segment because of the same base circle. Since the segment used in positive addendum modification is far away from the base circle, the pressure angle on any point of tooth profile, the curvature radius are all correspondingly increased. The negative addendum modification is on the contrary. Changes also occur in the thickness of gear teeth. As for positive addendum modification, its addendum become thinner, the dedendum thicker, the addendum flank higher and the dedendum flank smaller. The negative addendum modification is on the contrary. See Figure 5-47.

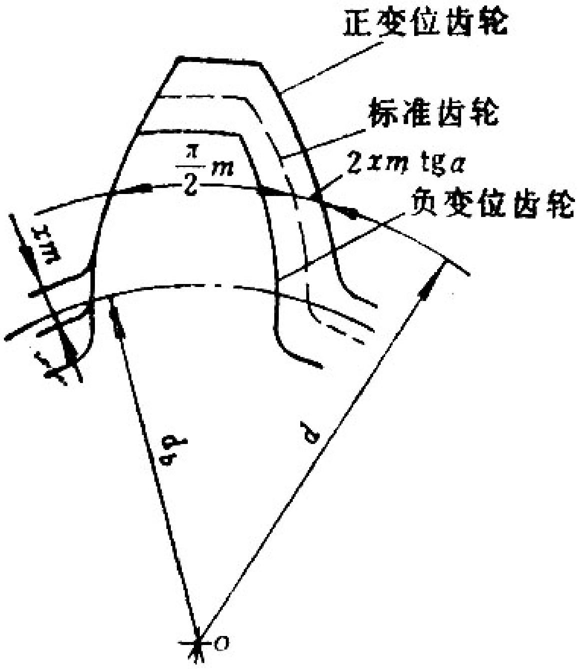


图 5-47

Addendum Modification (for External Gear), Dedendum Modification (for Internal Gears)

Under the condition of non-backlash meshing, the distance of cylindrical gear and counterpart rack, between the reference cylinder of gear and the datum plane of rack along the common vertical line is called addendum modification (for external gear), dedendum modification (for internal gear).

Addendum modification is presented by mx, x, here, is modification coefficient. As shown in the Figure 5-48, if L>r, then “mx” refers to positive addendum modification; if L<r, the “mx” refers to negative addendum modification. In other words, the addendum modification is positive when the master plane separates with the reference cylinder; the addendum modification is negative when the above two planes overlap.

As for bevel gear, addendum modification refers to the modification of equivalent cylindrical gear. As for cylinder or enveloping worm, addendum modification refers to the radial separation of reference surface of worm and its pitch surface.

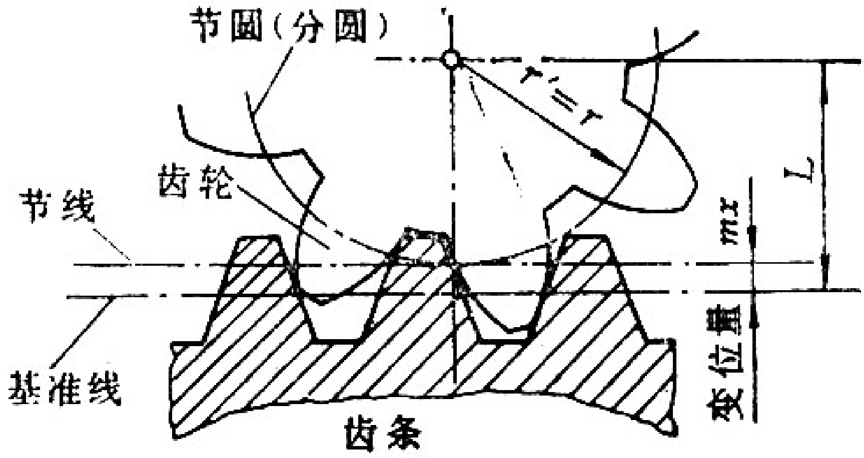


图 5-48

Addendum Modification of Rack Form Cutter

See "Gear with addendum modification".

Addendum Modification Coefficient

Addendum modification coefficient refers to the quotient (x) of addendum modification (mx) divided by the module (m); or it refers to the product of addendum modification (mx) multiplied by diametrical pitch (in mm). The minus sigh or plus sign of addendum modification coefficient is determined by addendum modification.

Modification Coefficient

Modification coefficient is a general term for "addendum modification coefficient" and "tangential modification coefficient". But it generally refers to addendum modification coefficient.

Increment Factor of Tooth Thickness

The thickness of reference circle of gears with addendum modification is different from those of standard gears. The variation $s' - s$ is called tooth thickness increment. Increment factor of tooth thickness (Δ) refers to the quotient of tooth thickness increment divided by module. When addendum modification coefficient is positive, Δ is positive. On the contrary, Δ is negative. The thickness increment of gear with addendum modification manufactured by rack tooling is 2mxtgα. The increment factor Δ=2xtgα.

Minimum Modification Coefficient

The modification coefficient which is rightly without tangent after the provision of tooth number when manufacturing gear with generating method is called minimum modification coefficient. Obviously, minimum modification coefficient is determined by the tooth number, basic tooth profile, the parameter of gear and the manufacturing method. Generally, the relation between minimum tooth number and the manufactured tooth number can be used to judge the plus or minus of the minimum modification coefficient. When z (or z_{υ})=zmin， zmin=0; when z(or z_{υ})<zmin, xmin>0; when z(or z_{υ})>zmin, xmin<0.

Line Graph of Modification Coefficient

Line graph of modification coefficient refers to a line graph used to choose modification coefficient under the condition of all given data, including the sum of tooth number of gear pair (z_{Σ}), gear ratio (u), engaged angle (α') and module (m). Using this kind of line graph to set coefficient can help satisfy some limiting condition and necessary quality indicators. It is very convenient to use graph line, especially under the condition of no closed graph.

The Figure 5-49 is a modification coefficient graph line (α=20, $h_a^* = 1$), which can be divided into two parts. The right part prescribes the limiting conditions and a line graph $x_{\Sigma} - z_{\Sigma}$ drawn when contact ratio ε⩾1.2. The left part is a line graph $x_1 - x_{\Sigma}$ drawn under the condition of equal sliding radio.

Steps to choose modification coefficient with line graph method：first, use m、α' and z_{Σ} (from the right part) to determine x_{Σ}, then, with u and x_{Σ} given in the left part to set x1，the X2 can be calculated by $x_2 = x_{\Sigma} - x_1$.

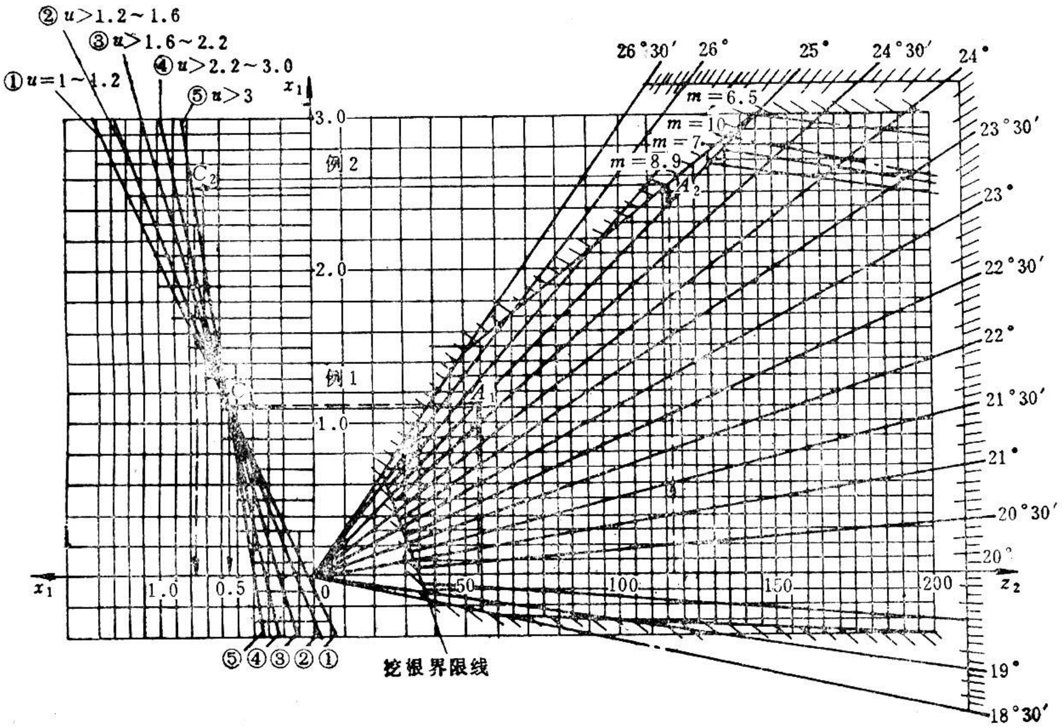


图 5-49

BS-436(1940)-modification system

British standard BS-436 provides the specific calculation formula for choosing modification coefficient. It can be divided into three cases:

(1) When（z1+z2）cosβ≥60, the cylindrical gear：

$$\left.\begin{aligned} & x_1 = 0.4(1-\frac{z_1}{z_2}) \\ & or x_1 = 0.02(30 - z_1 \sec^3 \beta) \end{aligned}\right\} \text{choose the maximum}$$

x_2=－x_1 only used in high modification.

(2) When（z1+z2）sec2β<60, the cylindrical gear pair: $x_1=0.02(30－z_1\sec^3\beta)$

$x_2=0.02(30－z_2\sec^3\beta)$

$$inv\alpha' = \frac{2tg\alpha(x_1+x_2)}{z_1+z_2} + inv\alpha$$

$$\Delta a = ym = \frac{1}{2}m(z_1+z_2)(\frac{\cos\alpha}{\cos\alpha'} - 1)$$

(3) Internal gear pair：

$x_1=0.4$，x_2=－$x_1$only used in high modification.

Closed Figure

When the parameter of tooth shape and tooth number are given, the result calculated under various limiting conditions of gear and gear pair can be drawn into curves taking the modification coefficient x_1 and x_2 as coordinate axis. The combination of these curves can form a closed graph which is called closed figure.

Currently, many kinds of gear pair have relatively complete or partial closed figure which helps lay the foundation for choosing modification coefficient. These kinds of gear pair includes external involute gear pair cut by rack-shaped cutter, external and internal involute gear pair cut by pinion cutter, external involute gear pair cut by rack cutter with large pressure angle, parts of cylindrical worm gear pair and planetary gear pair.

Modification coefficient is the main parameter for gears with addendum modification. The matching and choosing of modification coefficient not only affect the geometric size, meshing condition of gear and gear pair, but also affect the strength of gear. Nowadays, the best way to choose modification coefficient is close figure, which can comprehensively take various factors into consideration and also satisfy vested technical indicator. This method holds clear definition, convenient application, and strong comprehensiveness and can design different modification gear pair according to different working conditions. Therefore it is widely applied in many fields. But until now, there are still some new and widely used gear pair and worm gear pair which still don’t have “closed figure”. There still has a long way to go.

The Figure 5-50a shows a closed figure of external gear pair cut by rack cutter. The area within shadow allows to be used. There are three parts in this area: in the I part, the pitch point is located within meshing area; in the Ⅱ and Ⅲ part, and the pitch point is located outside the meshing area (pitch point is not included in the meshing operation). The closed figure is composed by limiting curve listed below: curve 1, 2 are limiting curves which are not interfered by transition curve formed between pinion and bull gear; curve 3, 4 are limiting curves whose tangent between pinion and bull gear is not getting over its working profile; curve 5,6 are limiting curves of addendum thickness s_{a1}=0、s_{a2}=0; curve 7, 8 are limiting gears with contact ratio being ε=1、ε=1.2; curve 9, 10 are limiting curves of minimum modification coefficient x_{1min}、 x_{2min}. The curves with technical criteria are: curve a,b present the gear pair with same material and heat treatment method and their bending strength are equal whatever pinion driving or bull gear driving. Curve $\eta_1=\eta_2$ holds equal dedendum sliding coefficient at the endpoints of actual meshing line. Curve δ_1=0、δ_2=1 refers to the graph whose pitch point is located at the cutting point of one pair of tooth engagement and two pairs of tooth engagement. The curve of δ=0.6 is a curve whose pitch point is located in double teeth-meshing area of the addendum of pinion and the dedendum of bull gear. The distance between this pitch point and the adjacent point of single and double pairs meshing engagement is 0.6m.

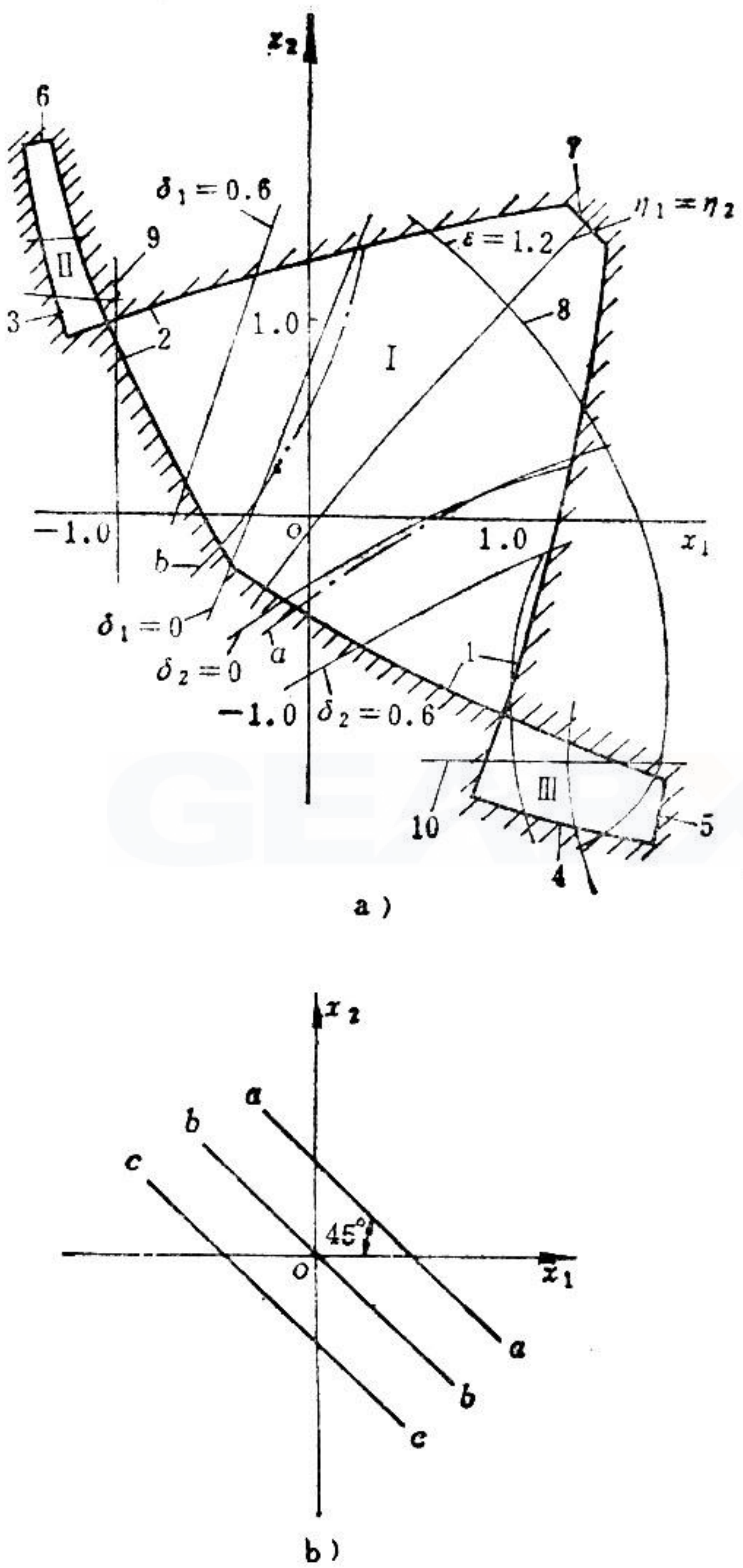
For non-backlash meshed gear pair with addendum modification, the relation among engaged angle, center distance and the sum of modification coefficient is:

$$a' = \frac{1}{2} m(z_1 + z_2) \frac{\cos \alpha}{\cos \alpha'}$$

$$\alpha' = \cos^{-1}\left[\frac{m(z_1 + z_2)\cos \alpha}{2\alpha'}\right]$$

$$x_\Sigma = x_1 + x_2 = \frac{z_1 + z_2}{2tga}(inv\alpha' + inv\alpha)$$

In the close figure given by z1, z2, draw a straight line which form a 45° angle with x1 or x2 axis and a nodal increment being x_Σ, obviously, $\alpha' = c$, x1+x2=c (c is a constant), and this line is called meshing angle line. From the Figure 5-50b, we can infer that the equivalent meshing angle line crossing 4, 1 and 2 quadrant has the characteristics of x1+x2>0, it is gear pair with positive modified center distance. The equivalent meshing angle line crossing 4, 0 and 2 quadrant has the features of x1+x2=0; it belongs to standard gear pair or gear pair with high modification. The equivalent angle line crossing 4, 3, 2 quadrant has the feature of $x_l + x_2 < 0$, it belongs to gear pair with negative modified center distance. If z_1、z_2 and x_Σ are already known, a line with 45° angle with x1 axis cut in x_Σ can be made, its intersection point with vested technical indicator is the coordinate point of x1and x2. If x_Σ can be cut by $z_1$and z_2, then a tangent of 45° can be made on the technical indicator curve, the tangent here is the coordinates of $x_1$and x_2. If it is not convenient to make a tangent, the coordinates of modification coefficient can be set according to the modification coefficient and the relation between vested technical indicator curves.



x_2
6
7
$\delta_1=0.6$
$\eta_1=\eta_2$
9
$\varepsilon=1.2$
II
3
2
1.0
8
I
−1.0
O
1.0
x_1
b
$\delta_1=0$
$\delta_2=0$
a
1
−1.0
$\delta_2=0.6$
III
10
5
4
a)
x_2
a
b
c
45°
O
x_1
a
b
c
b)

图 5-50

Combination of Modified Gear

Combination of modified gear refers to gear applying both addendum modification and tangential modification. This kind of gear pair features the meshing capability which is difficult to realize in single modified gear. Generally, it is widely used in bevel gear.

V-gear

V-gear is the code name of modified gear according to DIN870 (1931).