

## 7 New type gears and their gear pair

### 7.1 Gear pair with parallel axes

#### Parabolic gear

Parabolic gear is a new cylindrical gear invented by Wen Zhifu, a professor of China Textile University. The product has been qualified the national patent (the patent number: 86 1 005449). The tooth profile of parabolic gear is a special parabola. The curve at the top of basic tooth profile and the curve at the root are symmetric at the origin, thus creating condition for line contact. Under the intrinsic characteristics of parabolic line, the tooth profile of gear at top is convex and the bottom is concave. This can help get convex-concave meshing gear pair. This kind of gear has good performance and there is no undercutting circumstance. The minimum tooth number is 3.

#### Parabolic gear

Parabolic gear pair is composed of two matched parabolic gears. It is a new type of cylindrical gear invented by Wen Zhifu, a professor of China Textile University. Professor Wen Zhifu has published his own monograph. Parabolic gear is a kind of convex-concave line contact gear pair.

Compared with involute gear pair, under the same circumstance, parabolic gear has larger bearing capacity (it can improve multiply) with high transmission efficiency and large transmission ratio, it also has compact structure. Parabolic gear is worth attention and further researching.

#### Involute gear with variable tooth thickness

The tooth profile of involute gear with variable tooth thickness is involute and its tooth form has different variable coefficient in different transverse plane. Gears whose outer profile are cone-shaped and pinion type cutter of involute gear have the same geographical features. As the outline is cone-shaped, it is also called involute bevel gear.

Involute gear with variable tooth thickness can be straight toothed and helical toothed. For straight toothed involute gear with variable tooth thickness, there is a symmetrical plane that passing through axial line. Its tooth surface is spiral involute surface. Helical toothed involute gear with variable tooth thickness doesn't have this plane, but its tooth surface is also involute spiral surface. The processing process of this kind of gear is relatively complicated.

#### Involute gear pair with variable tooth thickness

Involute gear pair with variable tooth thickness is composed of involute gears with variable tooth thickness. It can be classified into straight toothed and helical toothed involute gear pair with variable tooth thickness with parallel axes, straight toothed and helical toothed involute gear pair with variable tooth thickness with

intersecting shaft and helical toothed involute gear pair with variable tooth thickness with alternating shaft. Among all these three, involute gear pair with variable tooth thickness with alternating shaft is the most commonly seen, while the others are special cases.

Involute gear with variable tooth thickness can easily adjust the tooth gap between two conjugate tooth surfaces by axial movement. It is suitable for some strict requested and precise transmission equipment. Besides, if geometrical parameter can be chosen properly in the design of involute gear with variable tooth thickness with alternating gears, one side of gear tooth can realize line contact. These merits cannot be realized in the common involute gear pair. Figure 7-1 shows the involute gear pair with variable tooth thickness with parallel axes.

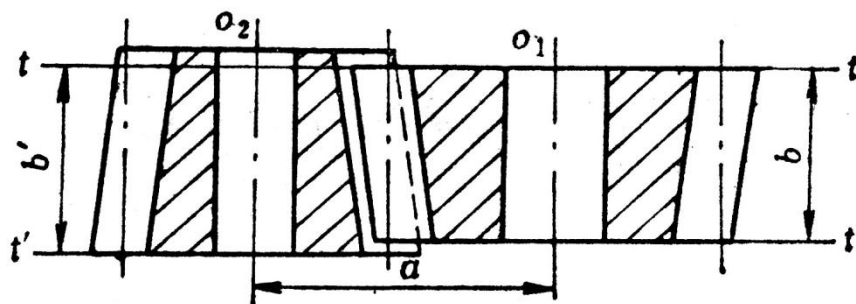


图 7-1

### Change long line cylindrical gear

Change long line cylindrical gear refers to helical cylindrical gear whose tooth profile is concave-shaped extensive involute. It is the tooth profile formed by addendum within the base circle when the reference line of rack cutting tool making pure rolling on the reference circle of tooth blank. Therefore, the working tooth profile is inside of the base circle, namely, there is no addendum but dedendum (Figure 7-2) and mostly used in driven gear.

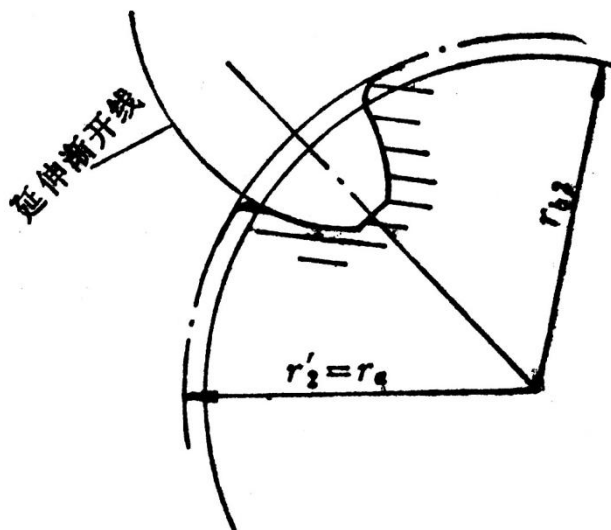


图 7-2

### Change long line cylindrical gear pair

Change long line cylindrical gear pair is point meshing involute cylindrical gear pair with parallel axes composed of helical toothed involute cylindrical gear and its matched change long line cylindrical gear. This kind of gear inherits the merits of involute cylindrical gear pair and circular-arc cylindrical gear pair. They are mainly showed in: large induced curvature radius of concave-convex tooth profile conjugate engagement, with circular arc root. This can improve the tooth surface and root strength; the geometric shape and motion characteristics between conjugate tooth surface is similar to that of circular-arc cylindrical gear, which help the formation of dynamic pressure oil film and improve the lubrication condition, reduce abrasion and improve efficiency; it can be manufactured with common rack tool which has low cost; it can be separated and not sensible to the deviation of center distance. With same modulus, relatively reduce the size of bull gear can narrow the depth of tooth cutting so as to improve production efficiency. This can save material and lower costs. This kind of gear has a promising prospect.

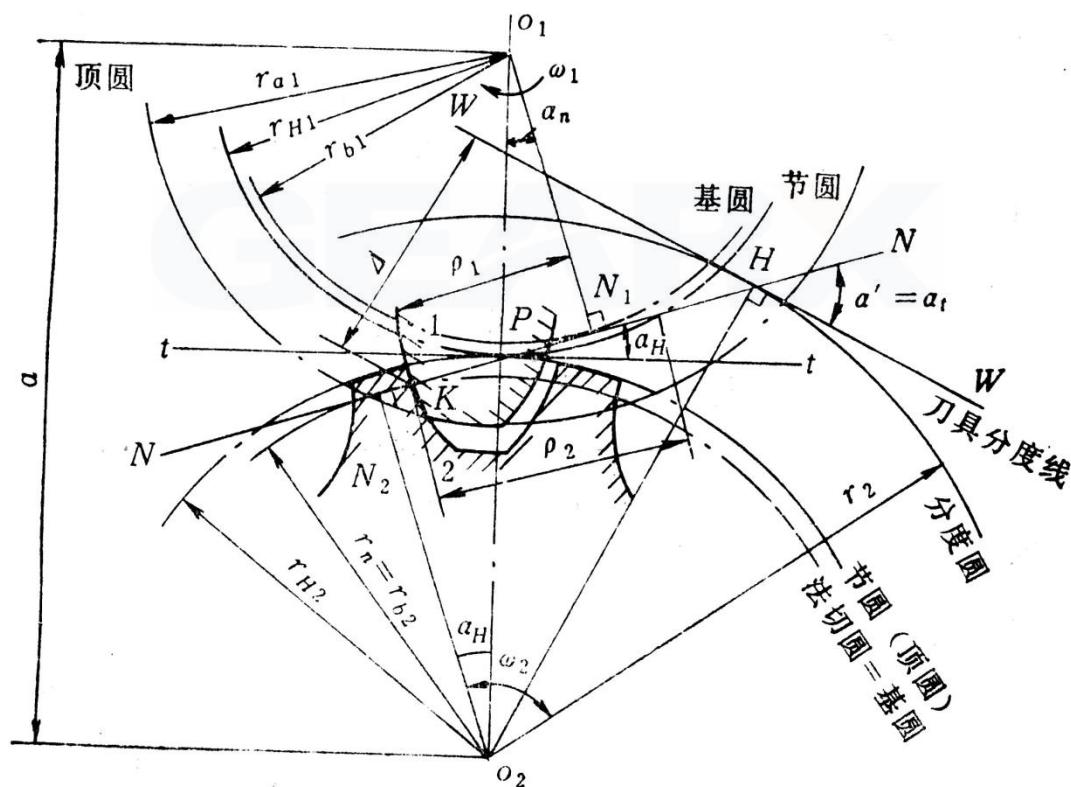


图 7-3

### Variable involute circular arc spur gear

The tooth profile of variable involute circular arc spur gear is similar to circular arc. It is a kind of cylindrical spur gear. Its approximate circular arc is the equidistant curve of variable involute. Therefore, it is called general variable involute circular arc spur gear. Together with internal gear with pin gear, variable involute circular arc spur

gear can compose internal gear pair with few tooth difference, which is used to form circular arc planetary gearing with few tooth difference.

### Variable epicycloid gear

The rolling circle  $r_2$  and the base circle  $r_{b1}$  are internally tangent. When rolling, the trace of M inside or outside the rolling circle is long or short epicycloid. Gears taking variable epicycloid as the theoretical tooth profile are called variable epicycloid gear. Its actual profile is the equidistant curve of variable epicycloid. The equidistant amount is the radius of pin gear. The variable epicycloid gear and pin gear can compose epicyclic internal gear with few tooth difference. It is the main part of epicyclic pin planetary gearing. Short epicycloid gear is the most widely used type among all the variable epicycloid gears.

### The involute gear whose tooth surface has honeycombed oil groove

It refers to involute cylindrical gear whose tooth surface has reticular and edged gear surrounded by many concave oil groove (Figure 7-4). The reticular oil groove presented on tooth surface is similar to honeycomb, which is favor to improve the lubrication condition between conjugate tooth flanks. After working or gear lapping, the height of edge is lower but the oil pool formed under the influence of oil groove remain exist, forming honeycombed oil groove that can save lubrication. This provides help for sufficient oil and the formation of dynamic pressure oil film. Gear pairs composed of this kind of gear has improved tooth surface strength and working stability. It is mostly used in dynamic gears applied in machinery.

This kind of gear can be manufactured with two methods: first, processing with multiple thread hob, but it needs to meet the following demand: there is no common factor between the number of cutter and tooth number, the same goes for the number of tooth and its chip groove; second, it cuts under the guidance of vertically tangent, double direction cutting method. Besides, tooth surface running-in or gear lapping need to be carried out.

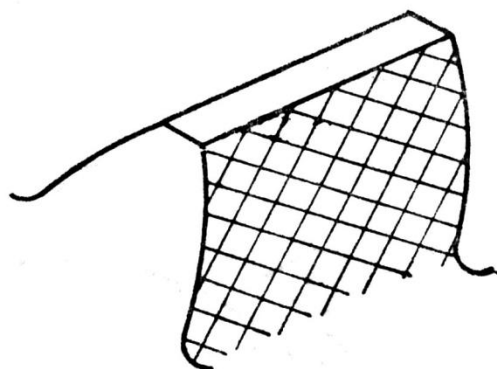
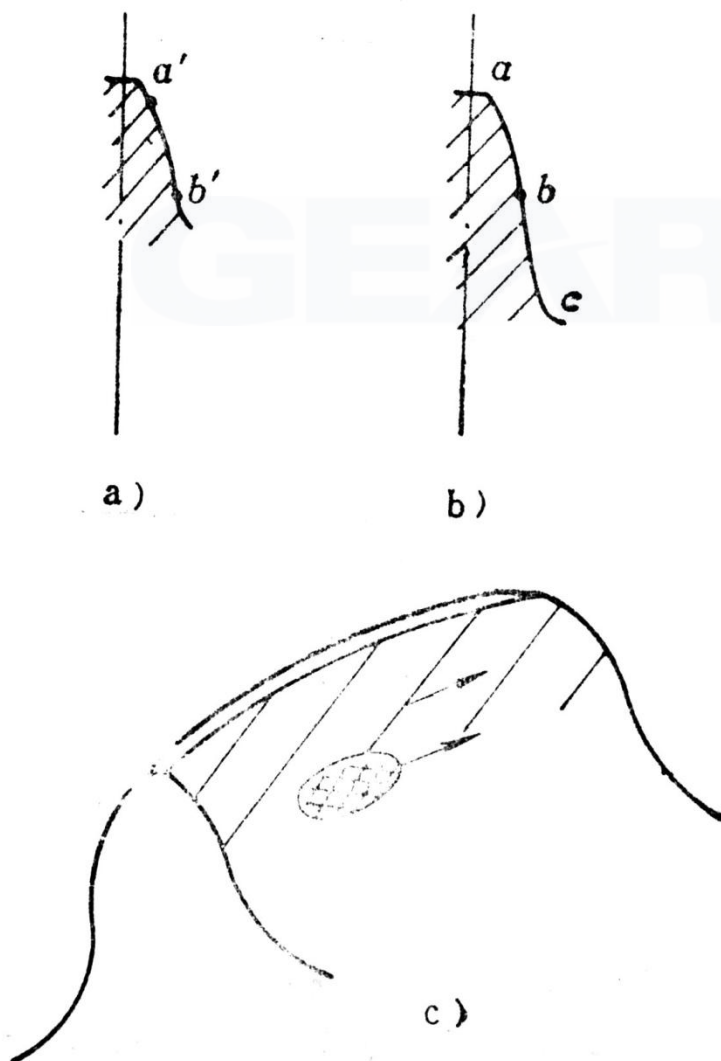


图 7-4

### Involute point meshing gear pair

Involute point meshing gear pair is a new type of helical gear pair put forward in 1980s. The pinion of this kind of gear pair is a modified short-toothed involute gear (Figure 7-5aa'—6'). The tooth profile of bull gear is a long-toothed gear (Figure 7-5b) composed of involute ( $a-b$ ) and transitional curve ( $b-c$ ). Gear pair composed of the two gears is presented with point and line conjugate meshing (Figure 7-5c). The meshing of involute tooth profile of two gears ( $a-b$  and  $a'-b'$ ) is presented as line contact. The meshing characteristics and meshing principle is totally the same with that of helical involute gear pair, while the meshing of point  $a'$  of pinion and the point  $b$  of bull gear is presented as point contact (Figure 7-5c), which holds the characteristics of circular arc gear pair. The characteristics of these kind of gear are listed as follows: it has transverse contact ratio and two overlap ratios; it has good dynamic pressure lubrication condition; it has constant transmission ratio and separability; good workmanship; large bearing capacity and high transmission efficiency; work smoothly with little noise; it is easily to be promoted and used in various fields.



7-5

## Involute gear pair of wide-gash

It is a kind of tooth form in harmonic driving. The slot width on dedendum circle is larger or approaching to tooth thickness. This kind of gear is called involute gear of wide-gash (Figure 7-6). The stress of rim of flexible gear in harmonic drive will be reduced as the slot width increases on the root circle. Increasing the slot width can be made through cutting one tooth of flexible gear every other tooth orderly. The cut tooth is shown in dotted line (Figure 7-6a) while the rigid gear stays complete. There will be two rigid teeth in one tooth space of flexible gear when meshing. In light of their function, two teeth are similar to one thick tooth, but the tooth number of simultaneous meshing cuts by half. From the Figure 7-6b, we can see special cutting tool is taken to decrease the addendum of rigid gear  $b$  so as to eliminate interference, decrease the dedendum of flexible gear  $g$  so as to widen tooth space. The cut part is shown in imaginary dotted line.

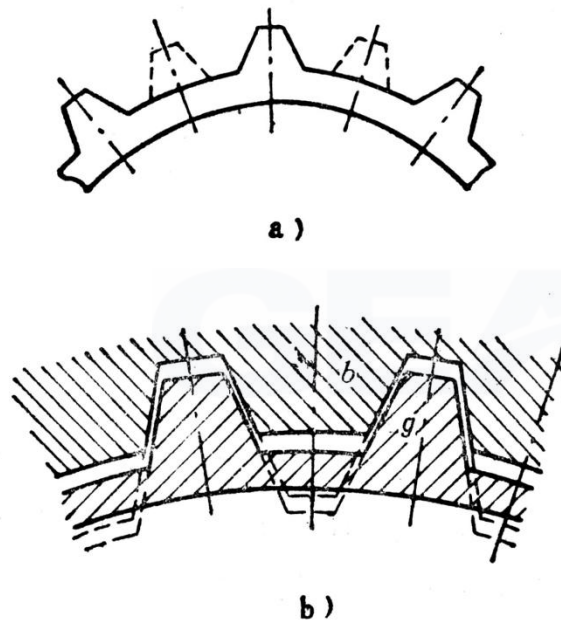
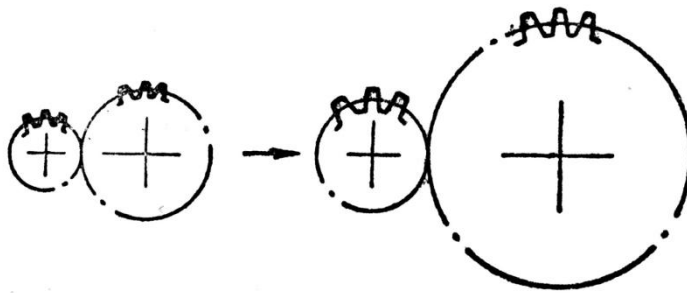


图 7-6

## Standard pitch gear pair

Standard pitch gear pair is a kind of gear pair replacing modulus system with standard pitch system (Figure 7-7, 7-8). This kind of gear pair allows the increase of gear diameter while not changes the size of gear teeth. The conjugate tooth profile of matched gear is convex-arc shaped. In order to improve the flexibility of gear teeth, the dedendum should be 2~3 times the addendum of the matched gear. The transverse tooth profile of the two gears is non-conjugate, and the continuous conjugate can be realized through helical gears' overlap ratio. The characteristics of this kind of gear pair are: the tooth is not conjugate when light loaded (point contact) while relatively high overlap can be realized when heavy-loaded.

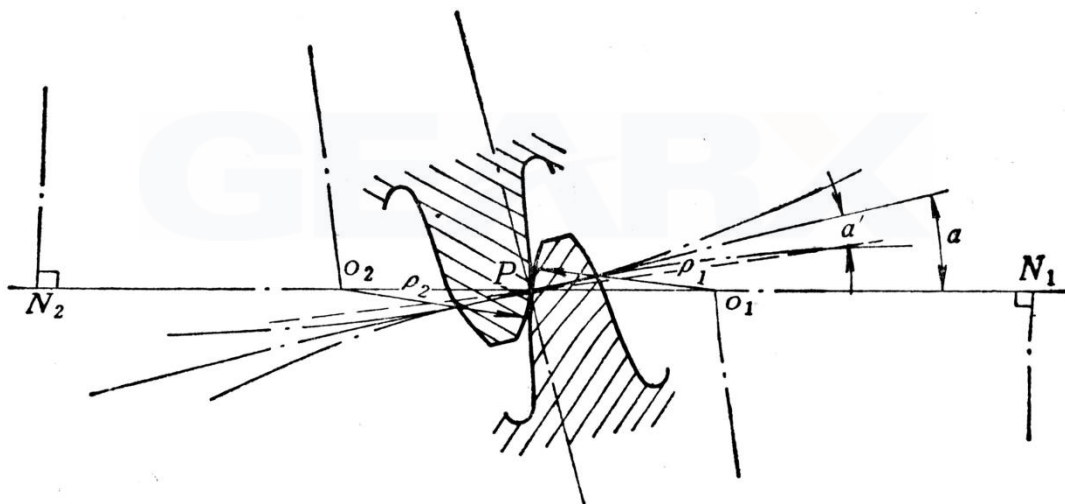




■ 7-7

Standard pitch gear pair can be used to reduce friction, heating, abrasion and noise.

From Figure 7-8, we can see the tooth profile circular arc radius  $\rho_1, \rho_2$  and the circular arc center  $o_1, o_2$ .



■ 7-8

### Ceramic gear

Ceramic gear is made of ceramics. With good thermal stability and relative strong mechanical strength, ceramic gear has good performance in anti-scuffing and anti-abrasion and it doesn't need lubrication. Its anti-impact capacity is relatively poor, but this shortcoming can be offset when it works with plastic gears. As it is widely used in many fields, it is necessary to pay more attention to this kind of gears.

### Pin gear

Pin gear refers to external gear or internal gear taking straight pin or bush roller as gear teeth (Figure 7-9). It also refers to cylindrical or circular gear whose teeth is composed of a number of ring gear pin (including gear pin cover when there are

covers). The axial trace of these ring gear pin is evenly located in the same circumference and parallel to the axial trace of gear. Ring gear pin is installed on the housing of pin gear. Generally, there are three forms (Figure 7-9a, b, and c): foldable, non-foldable and two-row foldable. Driving pair can be composed when cover the bush cover on round pin, together with round pin. Generally as driven gear, pin gear and cycloid gear can compose external gearing pin gear pair and internal meshing pin gear pair.

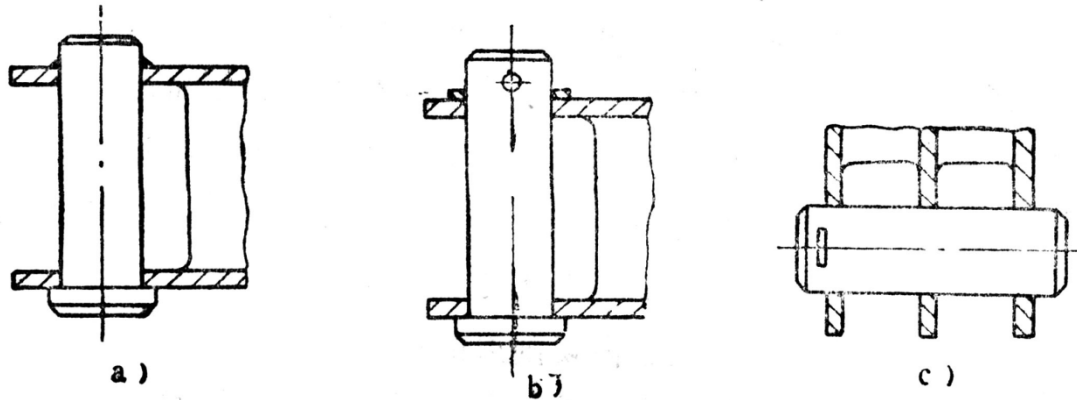


图 7-9

### Pin-gear drive

Pin-gear drive is composed of pin gear and its meshed gear (Figure 7-10). Bull gear (or rack) is always pin gear. The tooth profile of pinion is the equidistant curve of some curves. Pin-gear drive can be divided into pin gear pair, internal pin gear pair and rack pair. Generally, the gear is driving forced with high transmission efficiency. The driving speed  $v=0.05\sim 0.5\text{m/s}$ , transmission ratio  $i=5\sim 30$  and transmission efficiency  $\eta=0.9\sim 0.95$ . As pin gear is easy to make and cost little, it is also used to replace relatively large involute gear. Pin gear is always used in areas of transportation, chemical industry, mine and metallurgical departments featured by heavy-loaded, low speed transportation, lots of fine dust and bad lubrication condition.



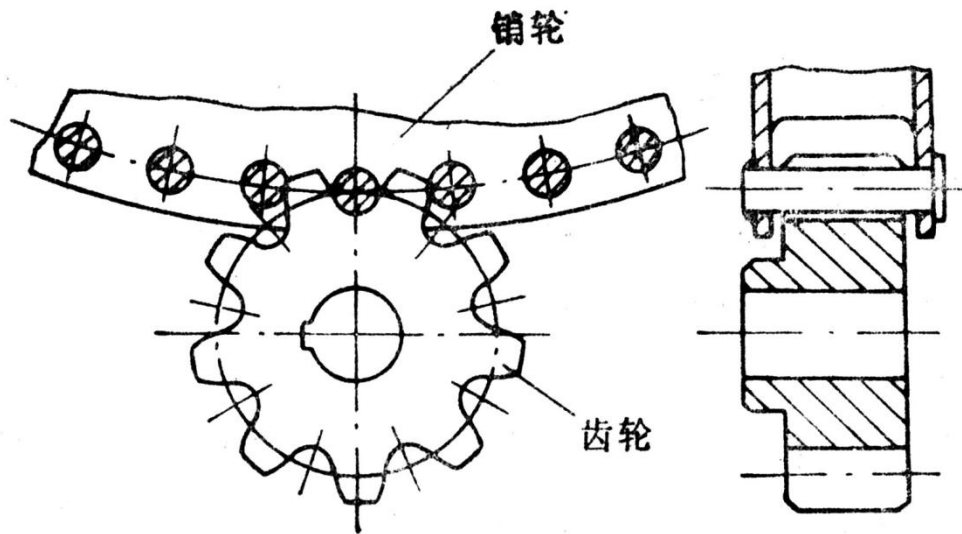


图 7-10

### Pin gear rack pair

Pin gear rack pair is composed of pin rack and involute gear (Figure 7-11). The gear teeth of rack are ring gear pin or pin gear with bush. Its meshing line is a straight line which is overlapped with the pitch line of pin rack. It is mostly used in low-speed, heavy loaded and large-size occasions.

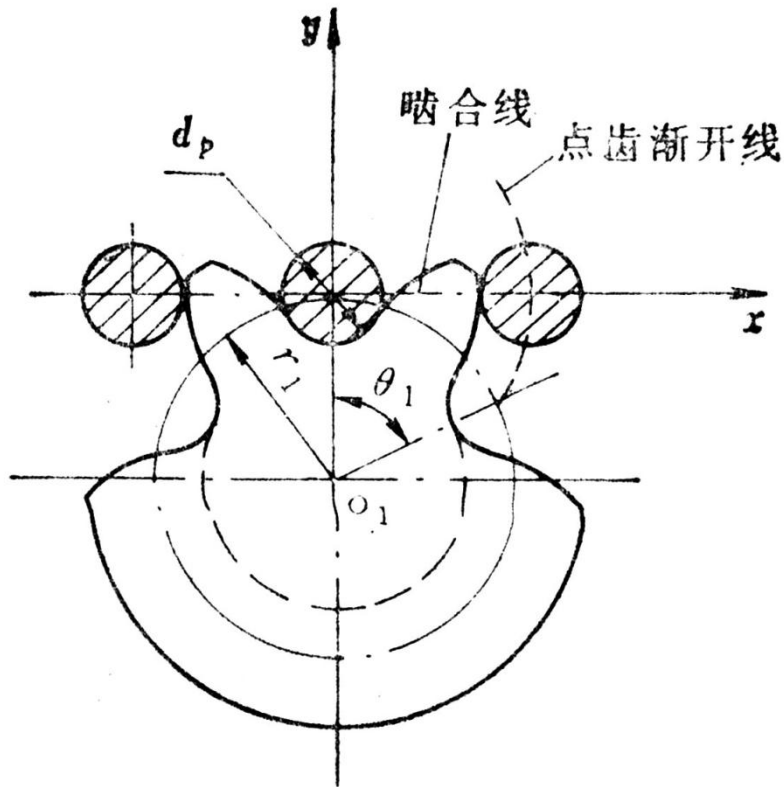
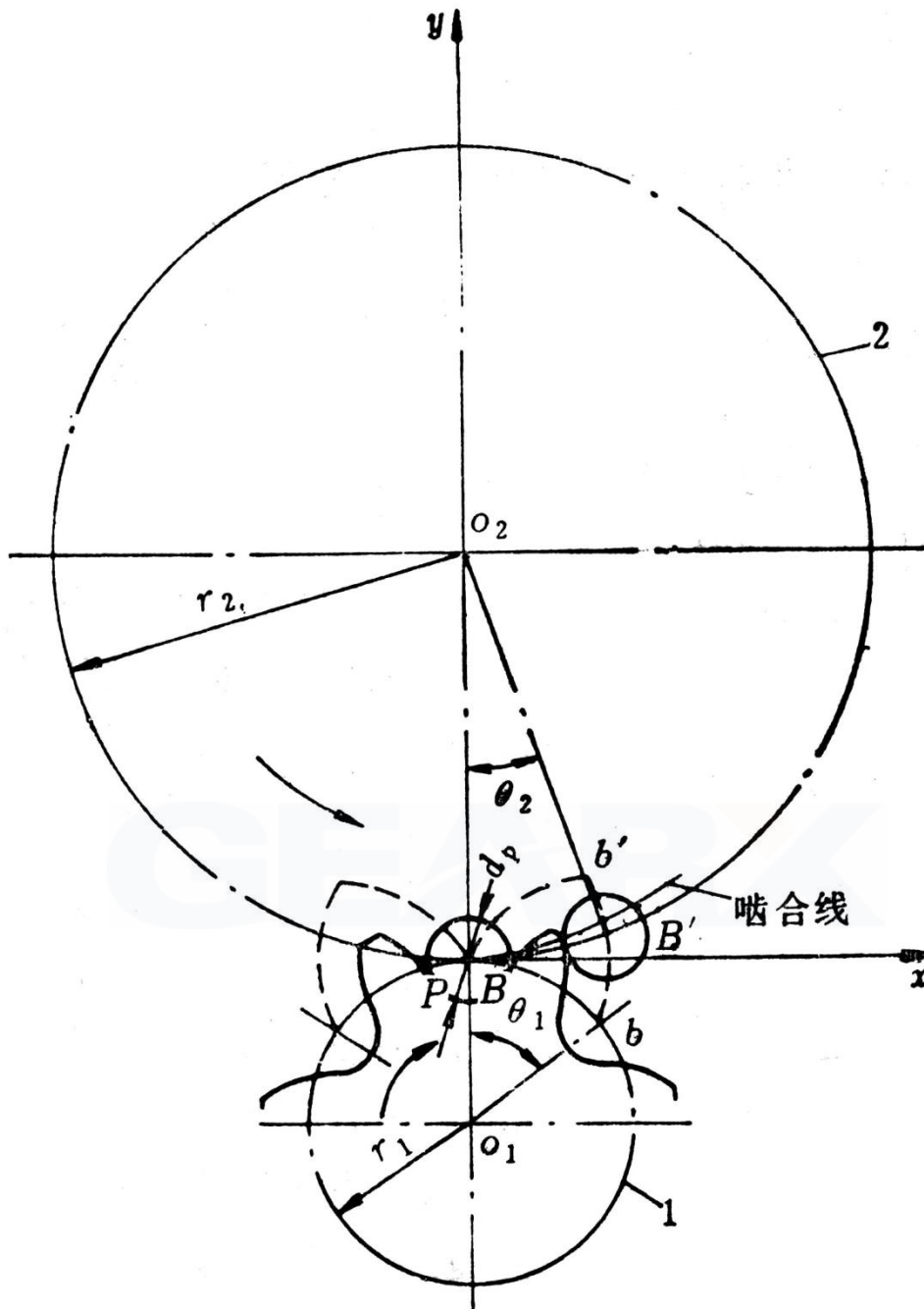


图 7-11

### External pin-gear drive

External pin-gear drive is composed of pin gear and its meshed gear. Figure 7-12 shows the equidistant curve of pinion whose tooth profile is epicycloids. Its meshing line is a limaçon curve, which is one of the most commonly seen pin gear drives.



▲ 7-12

### Variable epicycloid circular arc spur gear

The tooth profile of variable involute circular arc spur gear is similar to circular arc. It is a kind of cylindrical spur gear. The curve whose tooth profile is similar to circular arc is the equidistant curve of variable epicycloid. As the main part of circular-arc few tooth difference planetary gearing, it usually composes internal gear pair with pin gear external gear and it has been used in various fields.

## Curved tooth cylindrical gear

It refers to cylindrical gear whose tooth trace is curve. Based on the nature of tooth trace, curved tooth cylindrical gear can be classified into curved tooth cylindrical gear, manufactured with Gleason cutter, whose tooth trace is circular arc; and curved tooth cylindrical gear manufactured with Ollie Kang cutter, and whose tooth profile is extensive epicycloid. It can be classified into involute tooth profile curved tooth cylindrical gear and circular arc tooth profile curved tooth cylindrical gear according to the difference of tooth profile. The commonly used type is involute tooth profile, circular arc tooth profile curved tooth cylindrical gear. The gear teeth of curved tooth cylindrical gear can be classified into convex tooth surface and concave tooth surface. In order to improve the meshing characteristics of curved tooth cylindrical gear, the curved tooth cylindrical gear can be profiled. This kind of gear is easy in gear grinding and relatively high precision is not hard to acquire. But the requirement on axial deviation of curve is quite strict. Therefore, modified tooth can be applied to avoid this shortcoming (Figure 7-13).

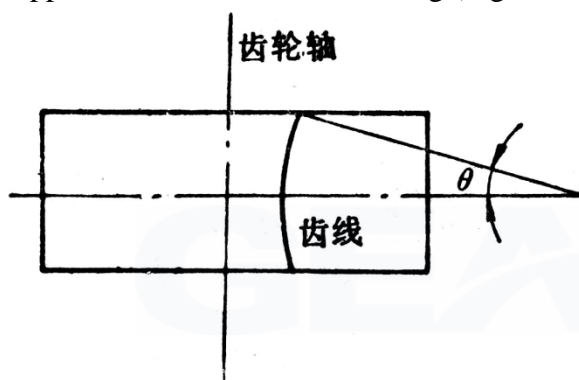


图 7-13

## Curved tooth cylindrical gear pair

Curved tooth cylindrical gear pair is composed of two matched curved tooth cylindrical gears. The most commonly used are involute curved tooth cylindrical gear pair and circular arc curved tooth cylindrical gear pair. Compared with common cylindrical gear, it has larger induced radius of curvature and overlap ratio due to its convex-concave curved tooth meshing. What's more, it has good lubrication condition, self-adjusting ability, even distribution of load and herringbone gear pair's features. Therefore, curved tooth cylindrical gear has good performance in its contact, bending, anti-scuffing ability. Besides, it can work smoothly with little noise and high transmission efficiency. It has good grinding performance and hard tooth surface gear pair can easily applied. Therefore, curved tooth cylindrical gear is suitable in high speed heavy-loaded gear driving. Besides, if this kind of gear is used in oil pump and oil motor, "trapping" case can be avoided. But unmodified gear pair is sensitive to the axial installation precision.

## Involute curved tooth cylindrical gear pair

Involute curved tooth cylindrical gear pair is composed of two matched involute tooth profile curved tooth cylindrical gears. This kind of gear pair has the common meshing characters of cylindrical gear pair and curved tooth cylindrical gear. Theoretical analysis show that its contact strength is  $1/\cos^2 \alpha \sin^2 \theta$  times of involute cylindrical gear pair and the transmission efficiency is also improved obviously. Its processing with Gleason cutter or Ollie Kang cutter are all more convenient than that on circular arc curved tooth cylindrical gear. So this kind of gear pair is easy to promote.

### Longitudinal correction curved tooth cylindrical gear pair

Longitudinal correction here refers to the profiling on tooth length direction. The purpose of longitudinal correction is to reduce or eliminate the uneven loading condition along tooth length direction and avoid meshing interference of concave-convex tooth trace caused by processing and installation error. It is convenient to modify curved tooth cylindrical gear. What one need to do is just to adjust the position of cutter tooth on cutter head and make the generating radius of outside cutting edge larger than that of inside cutting edge. This kind of profiling does not affect its meshing characteristics. Longitudinal correction curved tooth cylindrical gear pair can apparently improve its meshing characteristics and transmission quality so as to improve the bearing capacity of drive (Figure 7-14).

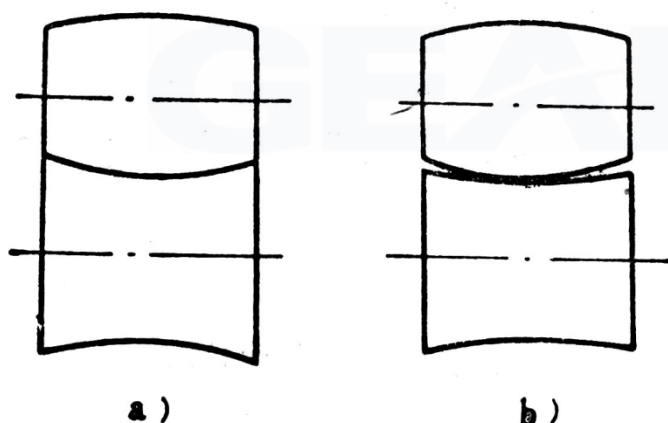


图 7-14

- a) 未修形的渐开线曲齿线齿轮
- b) 已修形的渐开线曲齿线齿轮