8.2 Planetary gear drives mechanism with small teeth difference.

Planetary gear drive mechanism with few teeth difference

It is a kind of K-H-V or 2K-H type gear drive mechanism, which is formed by NGW type gear train who cut its sun gear and making the tooth number difference become lesser between ring gear and planetary gear ($z_2 - z_1 = 1 \sim 4$)(Figure 8-21). That means planetary gear drive mechanism with few teeth difference is a driving form that composed of some kind of internal gear pair with few tooth difference, offset element (planet carrier) and output mechanism. It adopts internal gear output mechanism with few tooth difference or zero tooth difference and K-H-V type becomes 2K-H type. In this mechanism, planet carrier (offset element) serves as the driving unit which runs in a high speed. The planet gear rotates itself in a low speed except for revolution. Generally, ring gear is fixed, and the planetary gear connect directly with the output mechanism and output its own rotation movement, forming speed-reducing movement mechanism or that connect ring gear and the housing as well as the output mechanism.

Planetary gear drive mechanism with few teeth difference has compact structure, small volume, light weight, large range of transmission ratio, high transmission efficiency, long service life, good workmanship and low cost. That's why it is widely applied in many cases. But the design of some planetary gear train with few tooth difference is difficult. The processing is also hard to achieve.

At the moment, the commonly used planetary gear train with few tooth difference are:

Involute planetary gear train with few tooth difference (K-H-V type or 2K-H type); circular arc spur planetary gear train with few tooth difference (K-H-V type); bevel gear planetary gear train with few tooth difference (K-H-V type); cycloid gear train with few tooth difference (K-H-V type); oscillating-tooth planetary gear train with few tooth difference (K-H-V type).

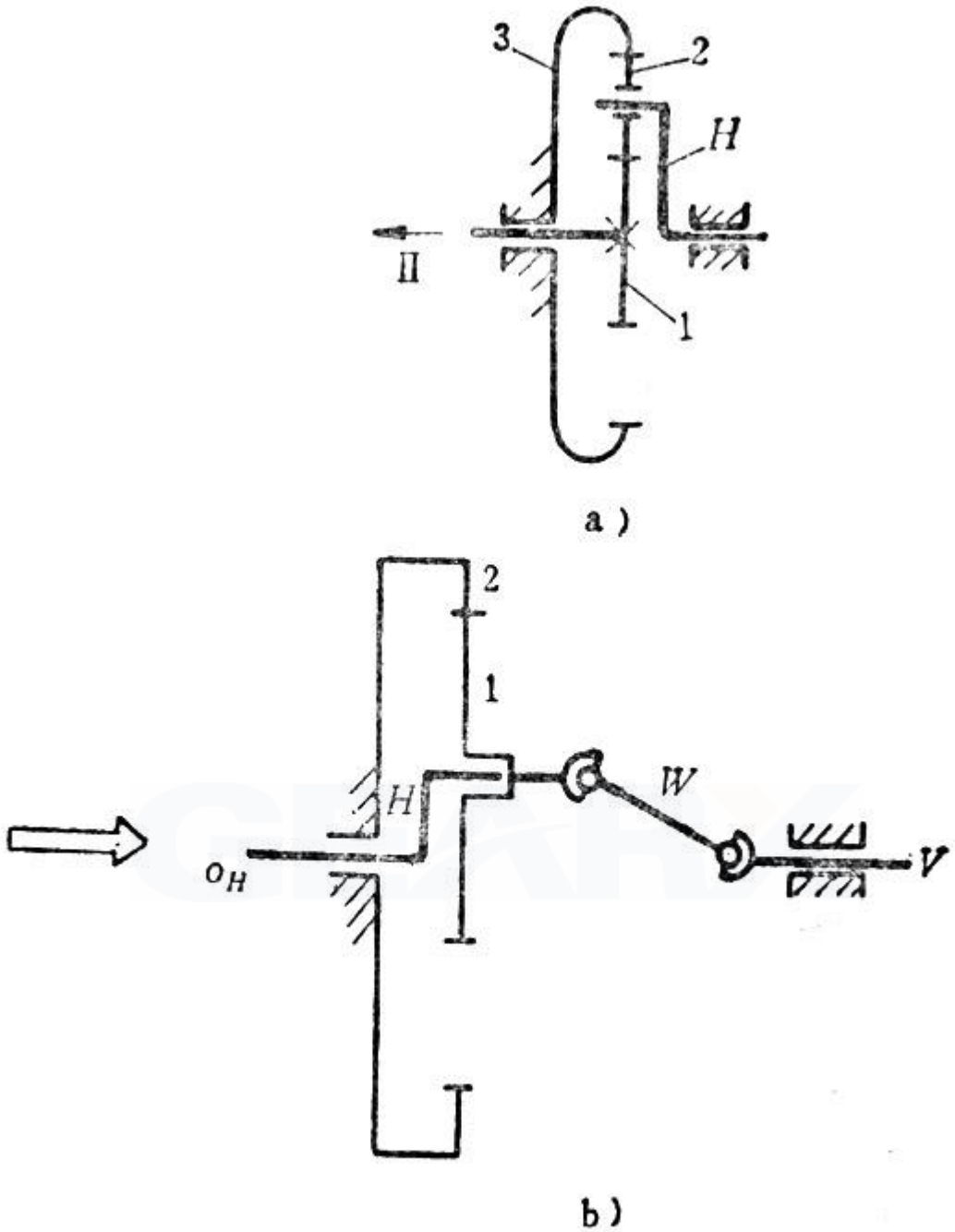


图 8-21

Transmission ratio of planetary gear drive mechanism with few tooth difference

The ratio of the angular velocity (or speed) of input axis and the angular velocity of output axis (or speed) is called transmission ratio. The calculation of transmission ratio is determined by the type of mechanism. They can be listed as follows in general:

1. K-H-V type (N type)

(1) The fixation of ring gear (Figure 8-22 a).

$$i_{H1} = -\frac{z_1}{z_2 - z_1}$$

In the formula, "-" refers to the opposite rotation direction of gear 1 and planet *H*. The value of transmission ratio is determined by not only the value of z_1, but also, most importantly, the number of tooth number difference. In order to get the big transmission ratio $z_2 - z_1 = 1$, planet driving mechanism with 1 tooth difference are seen more and more frequently.

(2) Ring gear output (Figure 8-22 b)

$$i_{H2} = \frac{z_2}{z_2 - z_1}$$

From the formula one can know that the rotating direction of gear 2 and planet carrier H is the same and the value of transmission ratio is affected by z_2, $z_2 - z_1$.

2.2 K-H type

(1) The fixation of ring gear 4, $\omega_2 = \omega_3$ (Figure 8-22 c).

$$i_{H1} = -\frac{z_1 z_3}{z_2 z_4 - z_1 z_3}$$

$$(z_4 - z_3 > 0,\ \ z_2 - z_1 > 0)$$

(2) The sun gear 1 is fixed, $\omega_2 = \omega_3$ (Figure 8-22 d)

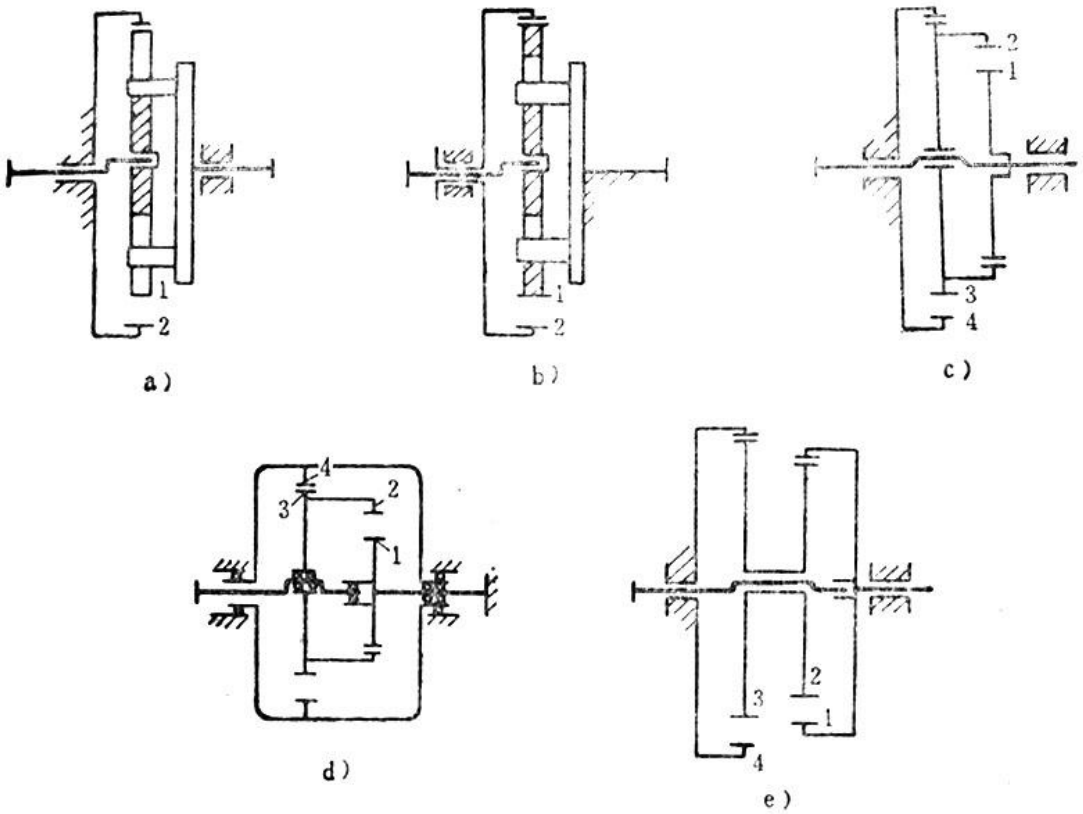


图 8-22

$$i_{H4}=\frac{z_2z_4}{z_2z_4-z_1z_3}$$

$(z_4-z_3>0, z_2-z_1>0)$

(3) The ring gear is fixed and the planetary gear is duplicate gear (Figure 8-22 e)

$$i_{H1}=\frac{z_1z_3}{z_2z_4-z_1z_3}$$

3. The planetary driving mechanism with few tooth difference of the mentioned three internal gears can be obtained from the Figure 8-23.

$$i_{6H}=1-\frac{z_1z_3z_5}{z_2z_4z_6}$$

$$i_{H6}=\frac{1}{1-\frac{z_1z_3z_5}{z_2z_4z_6}}$$

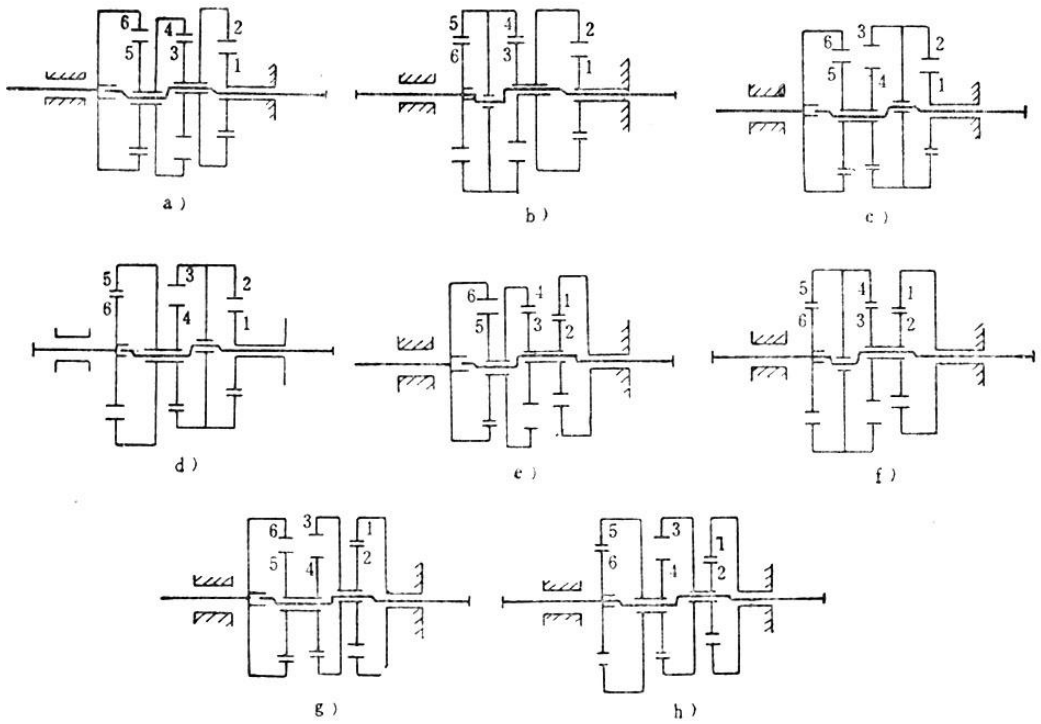


图 8-23

K-H-V type planetary involute gear drive mechanism with few teeth difference

It is composed of involute internal gear pair with few tooth difference (z_2-z_1=l～4), offset element and output mechanism. Figure 8-24 shows that the ring gear and planet carrier are fixed and connected, and the external planetary gear is engaged with the ring gear under the driving of offset element (planet carrier). The productive resistance is overcome by the output of torque and movement through *W* output mechanism.

Planetary involute gear drive mechanism with few teeth difference has meshing and working characteristics of planetary gear drive mechanism with few teeth difference. But there are various limitations on the interference of internal gear pair engagement, which cause difficulties on the design.

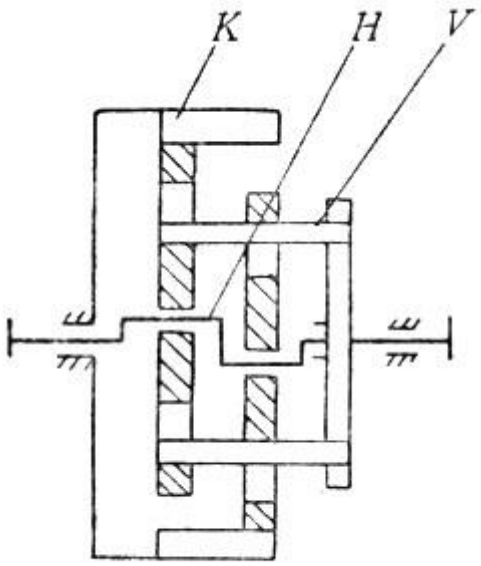


图 8-24

Cycloidal pin wheel planetary drive

Cycloidal pin wheel planetary drive is a kind of K-H-V type gear drive (Figure 8-25) composed of internal gear pair with 1 tooth difference (consisting of curtate epicycloid gear and pin gear), offset element (planet carrier) and output mechanism.

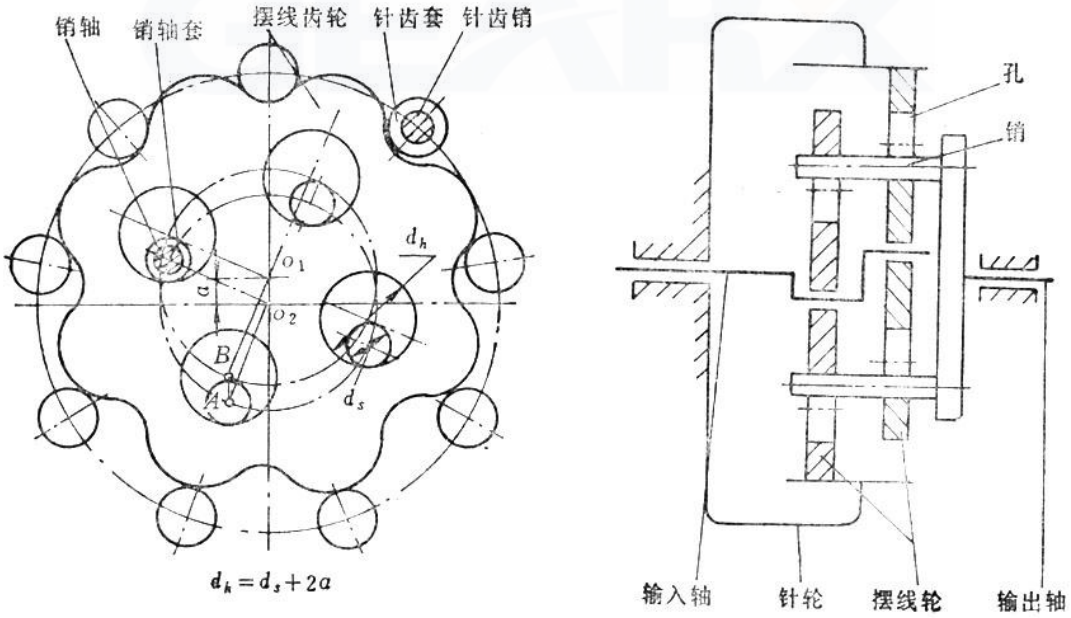


图 8-25

For cycloidal pin wheel gear pair, the base circle and pitch circle of curtate epicycloid gear. Its rolling circle serves as the pitch circle of pin gear, then: $i_{12} = \omega_1 / \omega_2 = r_2' / r_1' = r_b / r_c = constant$ with fixed transmission ratio. $r_2' - r_1 = a$, $z_1 = r_1' / a = positive - integer$, $z_2 = z_1 + 1$, from which one can see the tooth number

difference is 1, which consist of planetary gear drive with 1 tooth difference.

Cycloidal pin wheel planetary drive has no tooth top collision and trochoidal interference of tooth profile; there are lots of engaged teeth and half of the gear teeth are used to transmit torque; it has large overlap ratio and bearing capacity and long service life; the average value of engaged angle is smaller than that of involute planet gear with 1 tooth difference; it has simple structure, small volume and light weight; the transmission ration is big, which is 9～115; the transmission efficiency is high, which is 90% to 94%; the gear teeth roll in a pair in a high speed and the abrasion is small; the radius of curvature is big. The defects are that equal angular velocity ratio mechanism must be applied and special purpose machine tool is needed because the processing workmanship is complicated.

Pin wheel housing, gear pin and wheel roller

Pin wheel housing, gear pin and wheel roller are three basic components of pin gear.

Pin wheel housing: there are equally distributed holes and grooves along the circumference direction so as to allocate the housing of gear pin. The tooth body of pin gear.

Ring gear pin refers to cylindrical pin serving as gear teeth allocating on the corresponding hole of pin wheel housing.

Wheel roller refers to the cylindrical cover that covering gear pin and engaging with the gear teeth of curtate epicycloid gear.

Pin diameter coefficient of pin teeth

The ratio of the chord length l on the distribution circle of two adjacent centers of gear pin and the external diameter of gear pin (if the sleeve's external diameter is adopted as the diameter of sleeve) is called pin diameter coefficient of pin teeth.

$$K_2 = l / d_z$$

Pin diameter coefficient refers to the density of gear pin distribution. The smaller K_2 is, the closer each pole of gear pin will be. The closeness degree is presented by K_2, which is a crucial parameter in designing cycloidal pin wheel planetary drive. The most widely adopted number is K_2=1.3～2. If the number is less than 1.3, the distribution of gear pin would be too close and it would affect the strength of pin wheel housing. Therefore, tooth-choosing method is always adopted to solve this problem, that means to reduce the tooth number for half in a intermittent way.

Circular arc planetary gear drive mechanism with few tooth difference

Circular arc planetary gear drive mechanism with few teeth difference is composed of circular arc internal gear pair with few tooth difference, offset element (planet carrier) and output mechanism. Compared with cycloidal pin wheel planetary drive, the tooth difference is not supposed to be 1. The tooth profile of internal gear pair is different and this is the only difference. Their structure and movement figure are universal.

Circular arc gear pair with few tooth difference

Circular arc gear pair with few tooth difference refers to internal gear pair composed of circular arc spur gear and gear pin internal gear whose tooth number difference is quite little $(z_2 - z_1 = 1 \sim 4)$. Compared with cycloidal internal gear pair with few tooth difference, the tooth number difference of this kind of internal gear pair may not be 1, and it can be 1-4.

Curtate coefficient of curtate epicycloid

It refers to gear pin internal gear pair composed of pin gear internal gear and curtate epicycloid gear. The pitch circle is the base circle and rolling circle of curtate epicycloid, respectively. If presenting it with r_b and r_c, the pitch circle of gear is r_b' while the pitch circle of pin gear is r_c'. The gear pin of pin gear is located evenly on a circle, which is called distribution circle (the circle where the center of gear pin locates). At this time, the ratio of the radius of rolling circle r_c and that of distribution circle r_2 is the curtate coefficient of curtate epicycloid K_1.

$K_1 = r_c / r_2$ curtate coefficient is a crucial parameter in designing cycloidal pin wheel planetary drive. Their important relations are listed in the following design.

$$r_c' = K_1 r_2$$

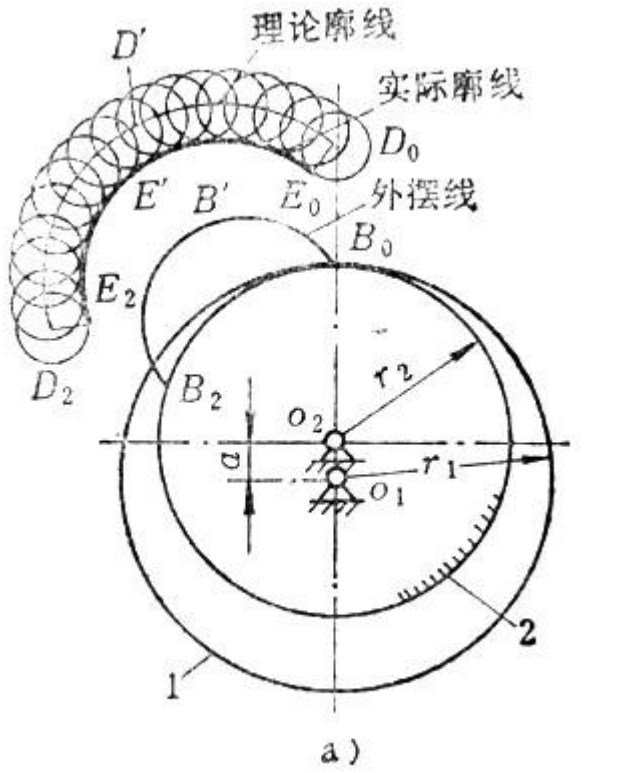
$$r_b' = K_1 r_2 \frac{z_1}{z_2}$$

$$a = K r_2 / z_1$$

Curtate epicycloid gear

Curtate epicycloid gear refers to gear taking curtate epicycloid formed by the internal tangent of rolling circle and base circle as theoretical profile (Figure 8-26). The real tooth profile is the equidistant curve of contour line. The equidistant value is the radius of the outer circle of pin gear.

Most of curtate epicycloid gears are spur-teeth type. In general, it engages with pin gear and form K-H-V type gear driving mechanism with 1 tooth difference. This kind of gear has a range of merits (see “cycloidal pin wheel planetary drive”). But as it needs special machine tool processing, the processing technology is complicated and it requires high precision.



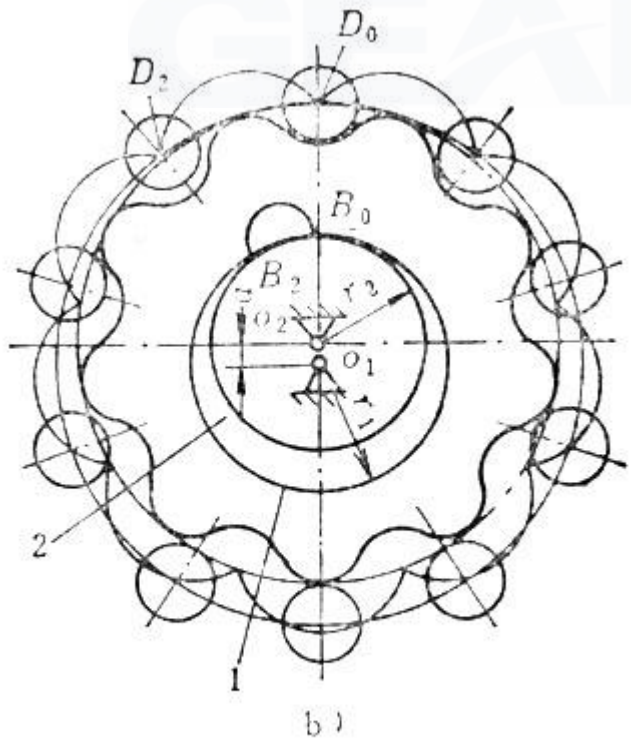


图 3-26

Double-cycloidal roller planetary drive

Double-cycloidal roller planetary drive refers to the assembling of pin wheel planetary drive that has both internal and external cycloid. Generally speaking, the tooth profile of external-toothed planetary gear of external cycloidal pin wheel planetary drive is the equidistant curve of curtate cycloid while the ring gear is pin wheel; the external toothed planetary gear of internal cycloidal pin wheel planetary drive is usually pin gear and the tooth profile curve of ring gear is the equidistant curve of curtate internal cycloid. Therefore, both internal and external cycloidal pin wheel planetary drive have one pin gear. The former pin gear belongs to external gear while the latter belongs to ring gear. Under certain condition, the two pin gears can be combined and the internal and external cycloidal pin wheel can be assembled and a new type of double-cycloidal roller (pin gear) planetary drive can be formed. (See “double-cycloidal roller planetary speed reducer”).

Eccentric element

In planetary gear drive with few tooth difference, the center distance supporting the offset unit of planetary gear, planetary gears and central gear (ring gear) is called the eccentric value of eccentric element. Detail can be seen from the Figure 8-23.

Harmonic gear drive mechanism

Harmonic gear drive mechanism is a modified form of planetary gear drive. It is a kind of mechanical drive mechanism which consists of wave producer (H), flexible gear (r) and rigidity gear (g) (Figure 8-27).The working principle is: under the wave producer, elastic deformation may occur, making the flexible gear and rigid gear engaging with each other and fulfilling the purpose of transmitting movement and torque between two gears. Harmonic gear drive mechanism has three basic structural units, which are producer, flexible gear and rigid gear. If one of the units is fixed, then the other two will become driving and driven units respectively and a simple variable planetary gear drive will be formed; if all the three are active units, then variable differential gear drive will be formed.

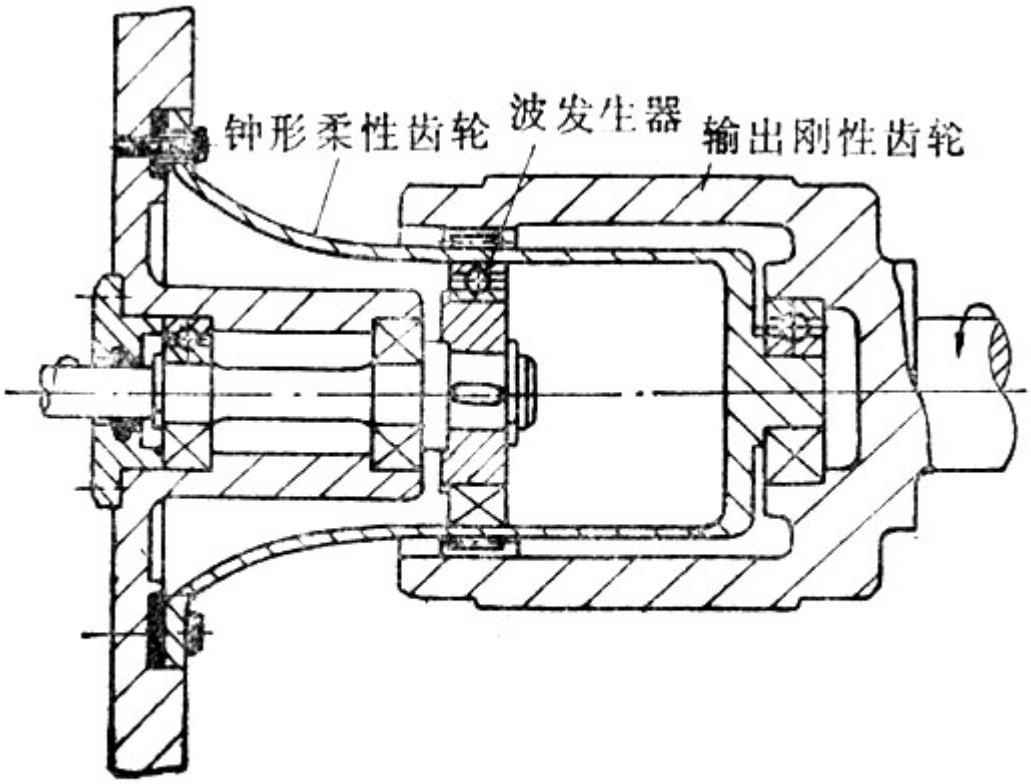


图 8-27

There are lots of characteristics in harmonic gear drive mechanism. They are mainly presented as simple structure, small volume and light weight; the range of transmission ratio is big, and generally $i=60\sim320$. The most commonly used transmission ratio is $i=80\sim200$. The transmission ratio of double typed changes in the range of $(50\sim90)\times10^3$ and the transmission ratio of planetary double harmonic gear drive can reach to over 10^7; there are lots of simultaneous engaged tooth number with large bearing capacity, large overlap ratio, smooth working process and small noise; the transmission efficiency is high; the tooth space can be adjusted with high movement precision; it can be made into enclosed driving and transmit movement in high temperature, high pressure and high vacuum circumstance and the environment that is filled with poison gas, atomic energy radiation. The coaxial performance of both output and input shaft is good; it is easy to maintain and to be repaired. But it has high requirement on the material and heat treatment technology of flexible gear.

Flexible gear

Flexible gear is one of the basic structural units in harmonic gear drive mechanism. It is a kind of gear with thin wall in which controllable elastic deformation will occur under the function of wave producer. The structural type of flexible gear can be mainly classified into cylindrical flexible gear and bell-shaped flexible gear.

Rigid gear

Rigid gear is one of the basic structural units in harmonic gear drive mechanism. It is also a gear that keeps the original shape during the working process. Most of them are internal gears and fixed units. Sometimes, the tooth width is 2 times larger in flexible gear, which is determined by the row number used in flexible gear.

Tooth profile of harmonic gearing

Tooth profile of harmonic gearing refers to the tooth profile of rigid gear or flexible gear in harmonic gearing.

Elastic deformation will occur in flexible gear under the working of harmonic producer. The engagement of flexible gear and rigid gear is relatively complicated. Its theoretical tooth profile is a complicated curve. Generally, the theoretical tooth profile curve is replaced by a tooth profile curve that can be easily realized in technology, and their difference is quite small. At the moment, the most commonly used three basic tooth profiles are: first, straight-side tooth profile, which has relatively large pressure angle ($28°36'$ or $30°$). It is a tooth profile curve (Figure 8-28 a) obtained by the measurement of flexible gear in deformation law movement. Straight-side tooth profile has the basic characteristics of involute tooth profile. *d* refers to harmonic height in Figure 8-28 a. The black points are tooth profile curve obtained in test. The second type is involute tooth profile. At this time, harmonic gear pair can be seen as involute internal gear pair with elastic deformation feature. It has involute gear pair of wide-gash (Figure 8-28 b, in which the dotted line is the imaginary eradicated teeth) and involute gear of narrow-gash. The third type is circular arc tooth profile and its substitutive tooth profile. Figure 8-28 c and Figure 8-28 d show the basic circular arc tooth profile of rigid gear and flexible gear respectively.

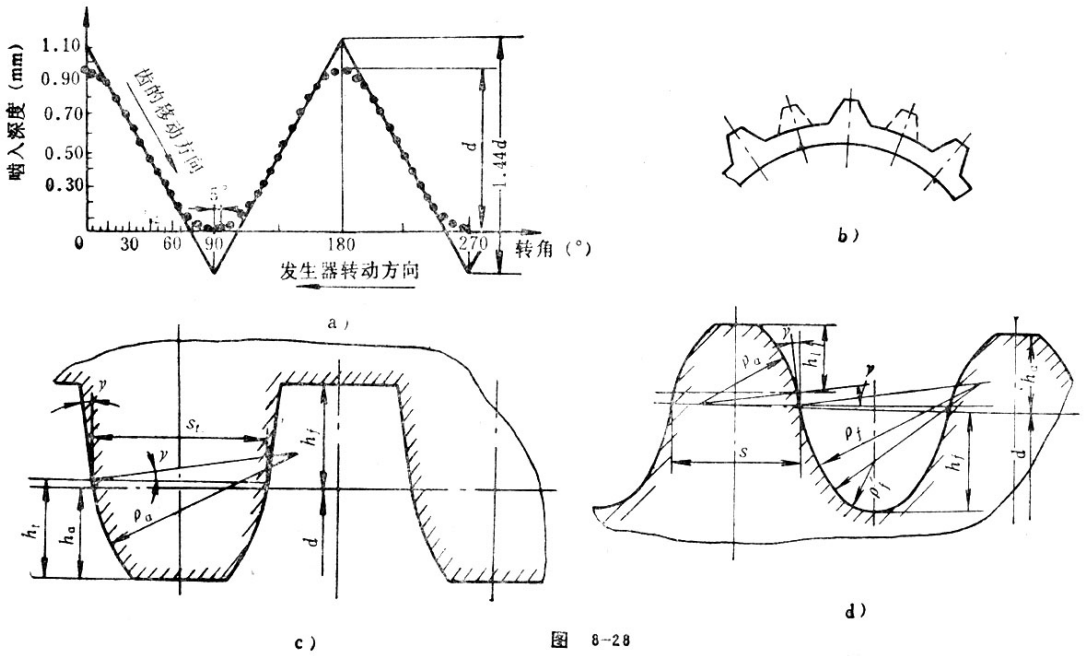


图 8-28

Side set motion

Harmonic wave producer makes flexible gear produce elastic deformation wave, which bring in engaging in, out, engaged and getting out of engaged situation. These four motion condition is called side set motion. As one can see in Figure 8-29, when the tooth of flexible gear and rigid gear at the ends of long axle of oval cam of wave generator are engaged in whole number, the teeth on the ends of short axle gets out of gearing. For gear teeth between long axle and short axle, when they are on the half-engaged condition of gradually meshing in or getting out at different section of its perimeter, they are called meshing in and meshing out respectively. From the figure one can see that the wave generator here serves as driving units, and the rigid gear is fixed while flexible gear is used in outputting.

图 8-29

Wave generator

Wave generator is one of the basic structural units in harmonic gear drive mechanism. In harmonic gear drive mechanism, wave generator serves as an unit that

make flexible gear produce elastic deformation wave based on certain deformation law. Most of them are active units. They are commonly driving units. Wave generator can be mechanical, hydraulic, barometric or electromagnetic. Most of the wave generators are mechanical. The other types are only used in special cases.

Mechanical wave generator has many types: contact type, cam type and controllable type, etc.

Besides, wave generator can also be classified into internal generator and external generator. From Figure 8-30 a, b, we can infer that the most commonly used type is internal generator.

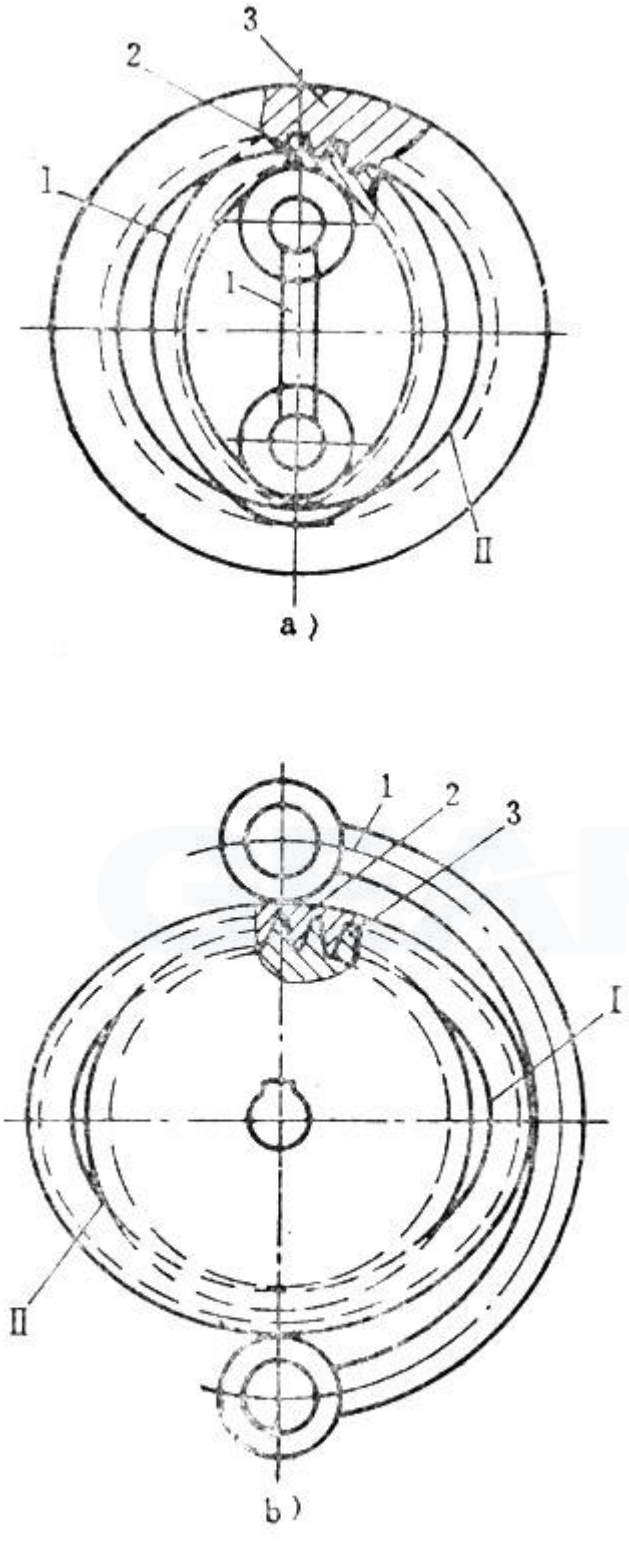


图 8-30

Ⅰ—柔轮的节曲线 Ⅱ—刚轮节圆

1—发生器 2—柔轮 3—刚轮

Disc type wave generator

It is composed of two or more discs installed on the offset shaft. (Figure 8-31) Each disk is installed on two bearings. Bearing and disk should have reliable axial positioning. In order to eradicate the bending moment developed by radial force, three discs and four discs can be applied. This kind of wave generator has small moment of inertia and high engagement precision. Generally, it is used in general power drive and automatic control system. The Figure shows a double eccentric two-disc wave generator. Here, 2β angle is called angle of contact to increase rigidity and the simultaneous engaged tooth number. 2=~Can $\beta = 60° \sim 70°$ can be adopted.

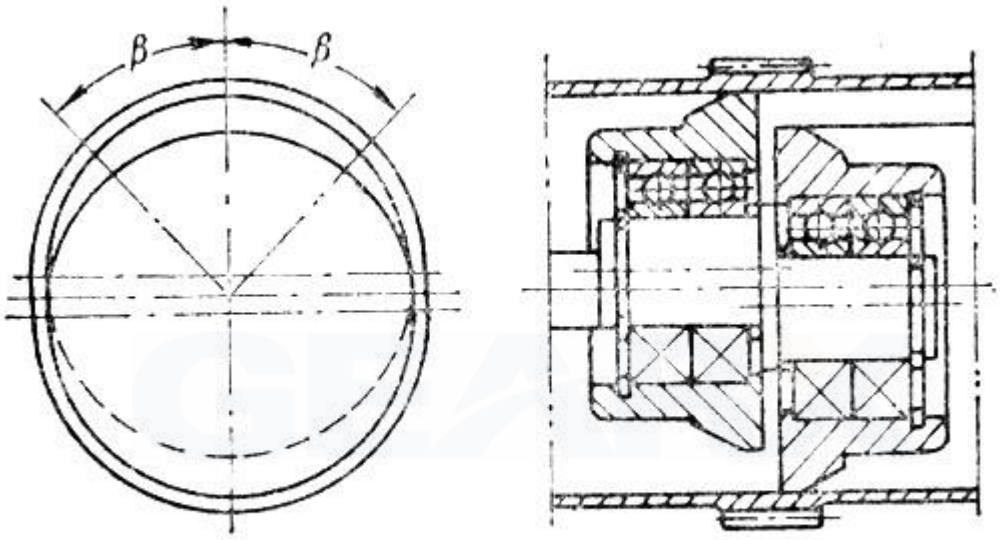


图 8-31

Cam type wave generator

It is composed of cam and thin-walled rolling contact bearing (Figure 8-31). The cam profile can be designed based on the elastic deformation law needed in flexible gear. Under this situation, the theoretical engagement of flexible gear and rigid gear can be realized and it can work smoothly with large bearing capacity and high-precision engagement.

Cover the rolling bearing bore with the designed cam and assemble them as a whole, then the profile of inner and outer circle of rolling bearing with thin wall and the profile of cam become equidistant curve. That's why cam type wave generator can realize controllable elastic deformation of flexible gear (Figure 8-32). It can be used in situation that requires large transmission power and high-precision.

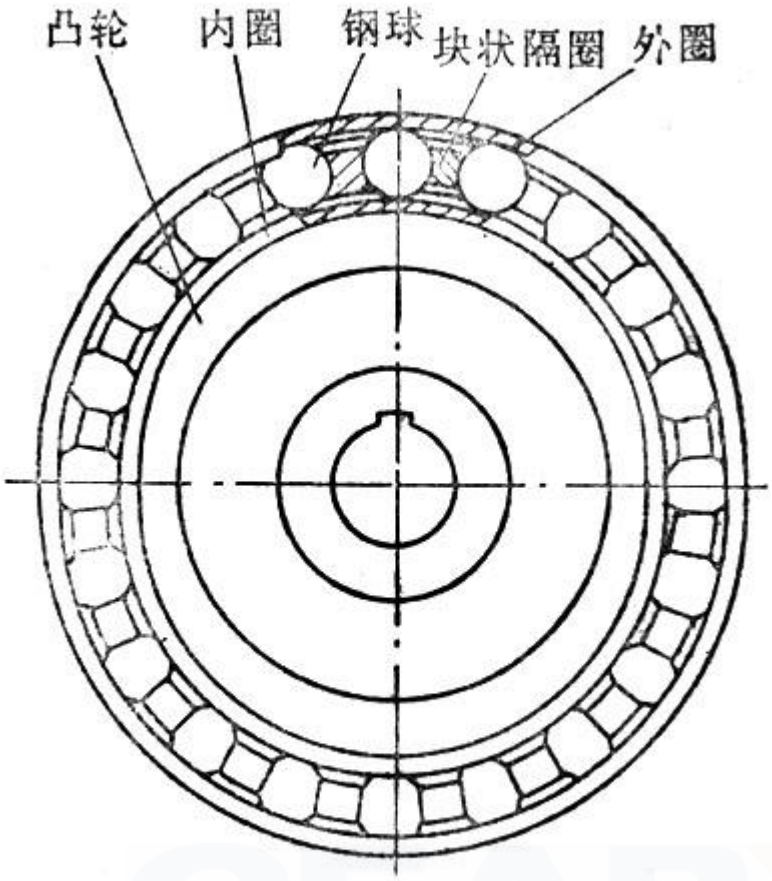


图 8-32

Wave generator of pneumatic machine

It refers to wave generator driven by compressed air. We can see from the Figure 8-33 that the gas that ejected from nozzle 4 or 5 will produce counteractive moment of force to make the cylinder rotate; the deformation of flexible gear 1 relies on the gas ejected from bore 2 of the rotating cylinder 3.

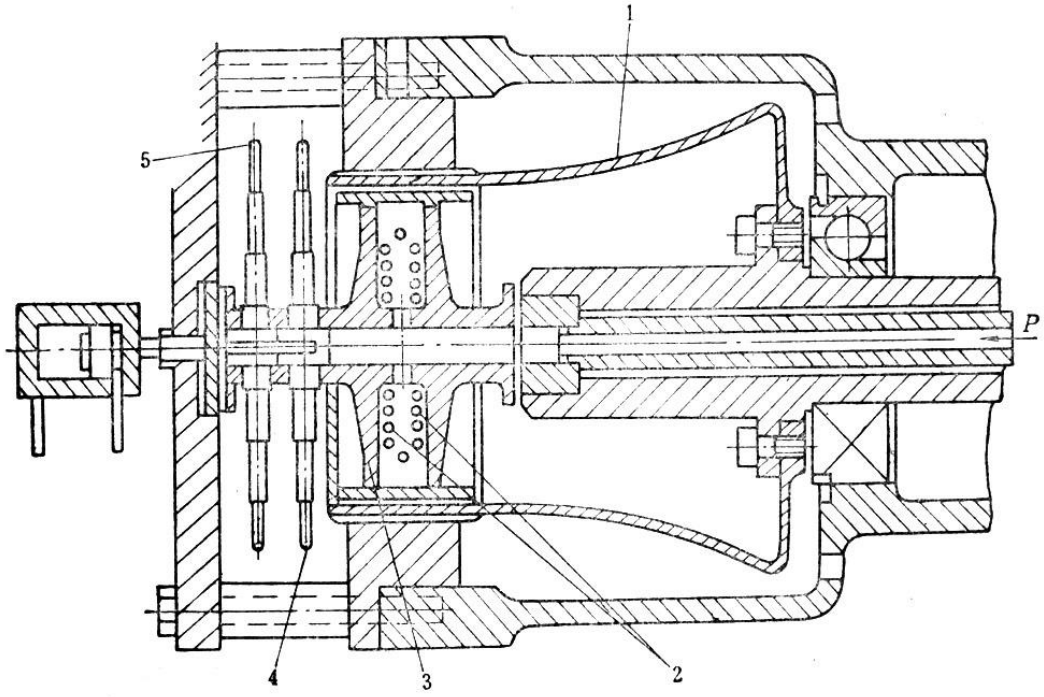


图 8-33

Electromagnetic wave generator

Electromagnetic wave generator uses electromagnetic field as its power. Figure 8-34 shows the simple picture of electromagnetic wave generator. Flexible gear is made by magnetic material and it makes the deformation wave of flexible gear move taking advantage of the rotating field. This magnetic field is reinforced by auxiliary magnetization. This kind of wave generator can install the harmonic wave directly in the motor. As it has relatively low bearing capacity, it is mainly used in instrument.

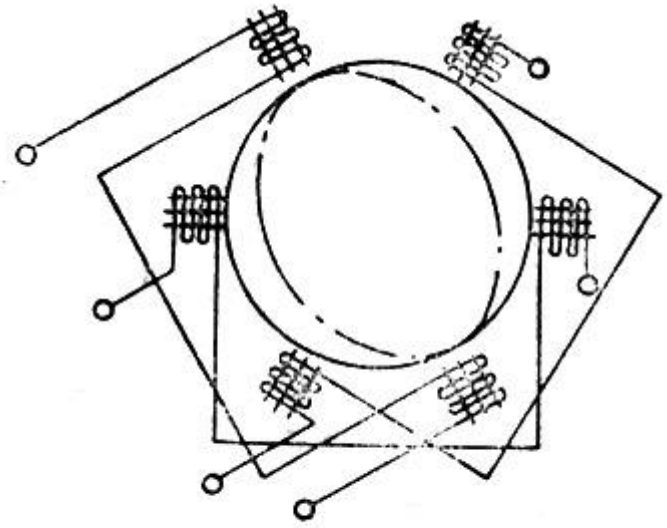


图 8-34

P1anetary type wave generator with anti-bending ring

In order to reduce abrasion and improve the service life and bearing capacity of flexible gear, we need to add an anti-bending ring in the bore of flexible gear. The anti-bending ring replaces the inner wall of flexible gear and contacts with the wave generator. This could help reduce the stress of flexible gear and keep the elastic deformation occur within a reasonable range. Figure 8-35 shows planetary ball friction wave generator with anti-bending ring. We can see from the figure that the ball here is equal to friction type planetary wheel.

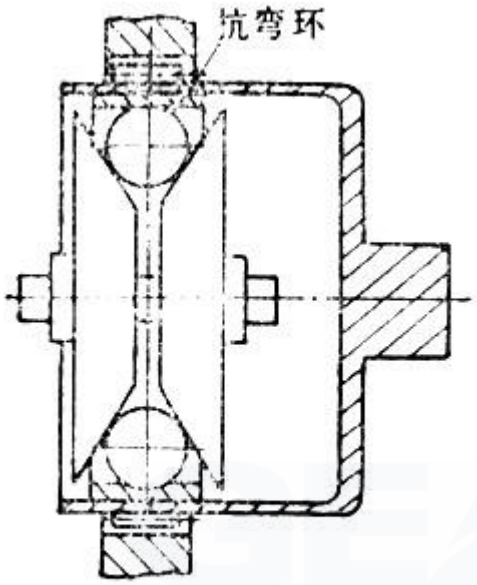


图 8-35

Contact type wave generator

In harmonic gear drive mechanism, contact type wave generator is a kind of machinery wave generator that is composed of rolling contact and tumbler. Generally, they can be classified into several types: that with double waves and double contacts, three waves and three contacts and that with four waves and four contacts. The Figure 8-36a shows double contacts and the Figure b shows three contacts. This kind of wave generator has simple structure and it is easy to process. But the deformation of flexible gear cannot be controlled strictly and the engagement precision is relatively low.

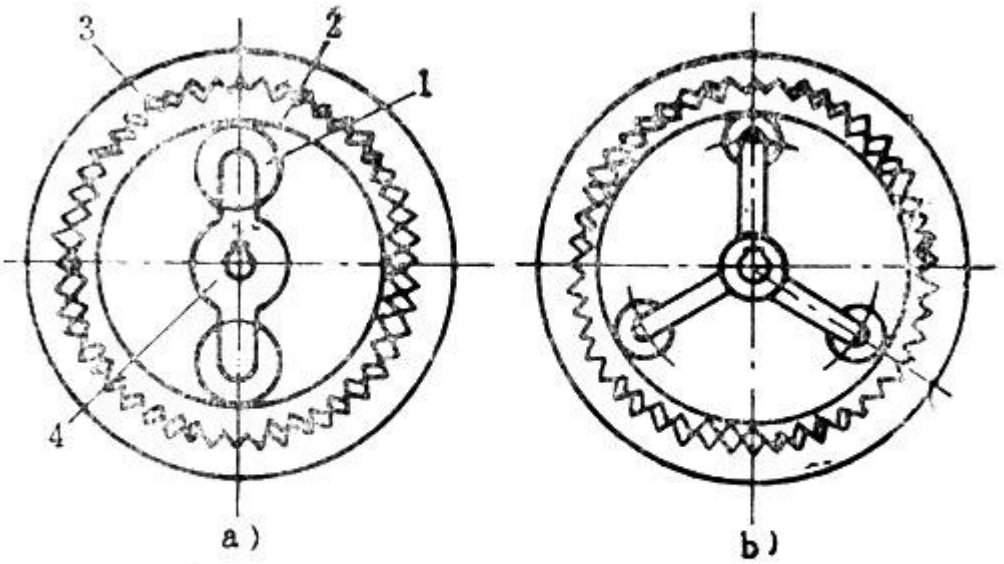


图 8-36

1—波发生器(滚轮) 2—柔轮 3—刚轮 4—转臂

Controlled wave generator

Controlled Wave generator follows strictly the deformation curve of needed flexible gear to design the profile of wave generator, which can help achieve theoretical engagement condition of flexible gear and rigid gear. This kind of wave generator that can be controlled based on the needed elastic deformation law is what we called controlled wave generator (Figure 8-37). The commonly used method is that to design cam combined by cam, cylinder and double-offset wheel in accordance of the trace of elastic deformation of flexible gear. It can be rolling friction type (see “cam type wave generator”) and rolling friction type (Figure 8-37a, b). It can also be external wave generator and internal wave generator.

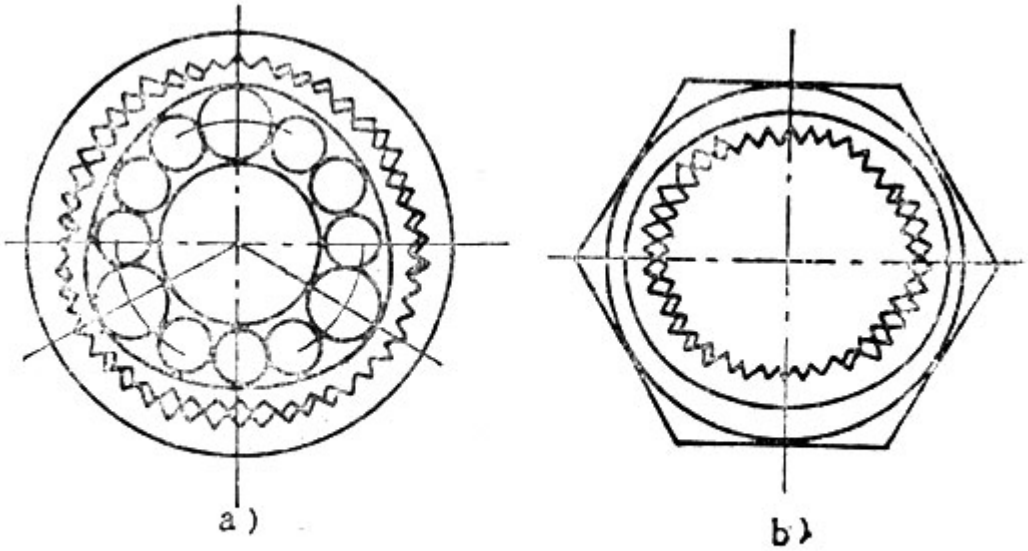


图 8-37

Double-wave generator of hydraulic machine

It is double-wave generator driven by hydraulic force. This kind of wave generator works by the motion of plunger pushed by hydraulic pressure. The harmonic transmission efficiency of hydraulic generator is relatively low.

Planetary type wave generator

It is composed of one center wheel and two or more planetary gears (Figure 8-38). Planetary gear and flexible gear wall contact in the form of rolling friction. The common rotation of planetary gear helps facilitate rolling friction. P1anetary type wave generator can increase the transmission ratio of harmonic gear drive obviously. Since it transmits power by friction, the transmission ratio is not constant. Figure 8-38a, b have double waves and three waves, respectively.

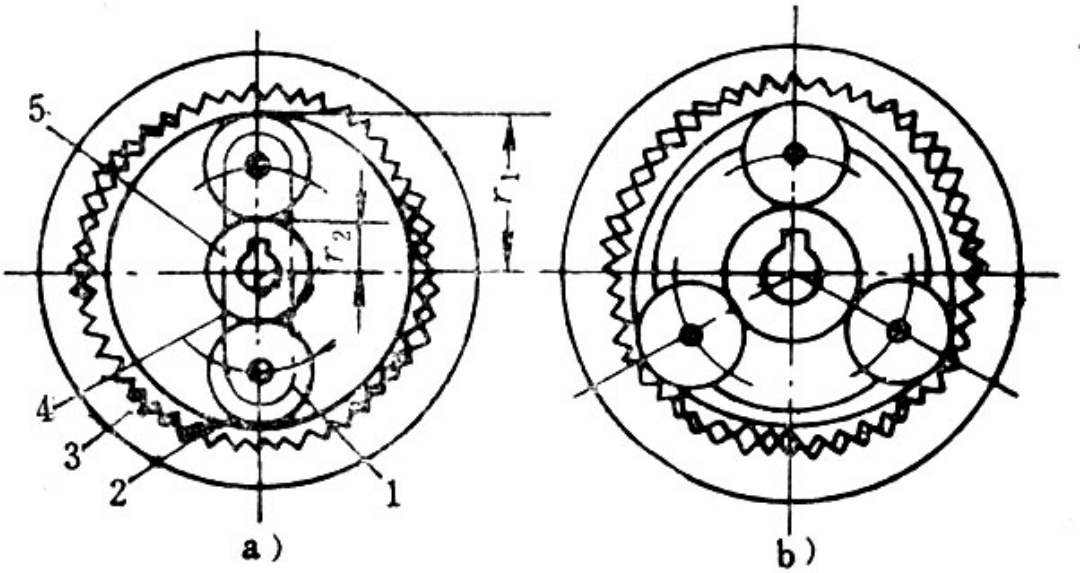


图 8-38

1—波发生器（行星滚轮） 2—柔轮 3—刚轮
4—转动杆 5—中心轮

Planetary wave generator can be classified into planetary wave generator and ball type planetary wave generator (see “p1anetary type wave generator with anti-bending ring”) and controlled p1anetary type wave generator (see “cam type wave generator” and “controlled type wave generator”).

Wave of harmonic gear drive

Wave of harmonic gear drive refers to the basically symmetrical tangential harmonic wave (Figure 8-39) formed when elastic deformation occurs under the influence of wave generator of flexible gear.

It is a kind of mechanical wave (wave of force). The times of circulatory deformation of flexible gear at a point is called wave number. The maximum deformation amount of flexible gear at a point is called wave height. The wave number produced by wave generator every round is determined by the number of wave generator contact terminal. The commonly seen are double waves and three waves. The figure shows the unfolded plan of flexible gear deformation. Figure *a* and b are double waves and three waves, respectively.

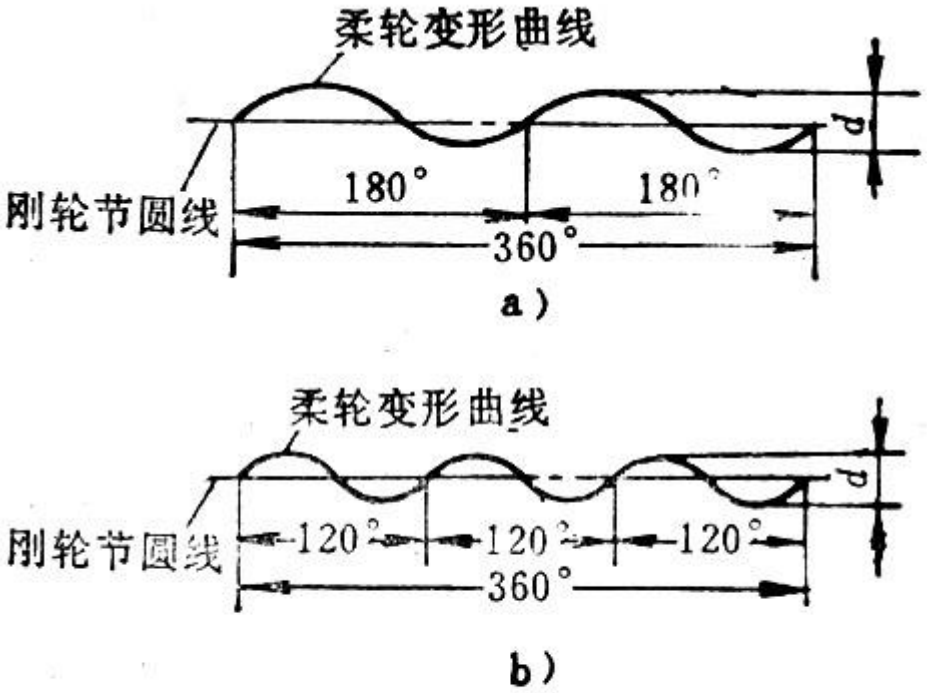


图 8-39

Harmonic bevel gear drive

It is composed of bevel gears. The main components are a pair of bevel gear 1, 2 of internal meshing, wave generator 4 that has declination angle and circumferential direction limited mechanism 7(Figure 8-40). When the input shaft 3 is rotating, the internal bevel gear 1 is forced to make to-and-from swings, and then the bevel gear 2 will be in an engaged or not engaged situation. Every round the input shaft runs, the output shaft 5 providing support at spherical hinges 6 will reverse one tooth pitch of the driven bevel gear. This kind of mechanism has compact structure and large transmission ratio but is has impact.

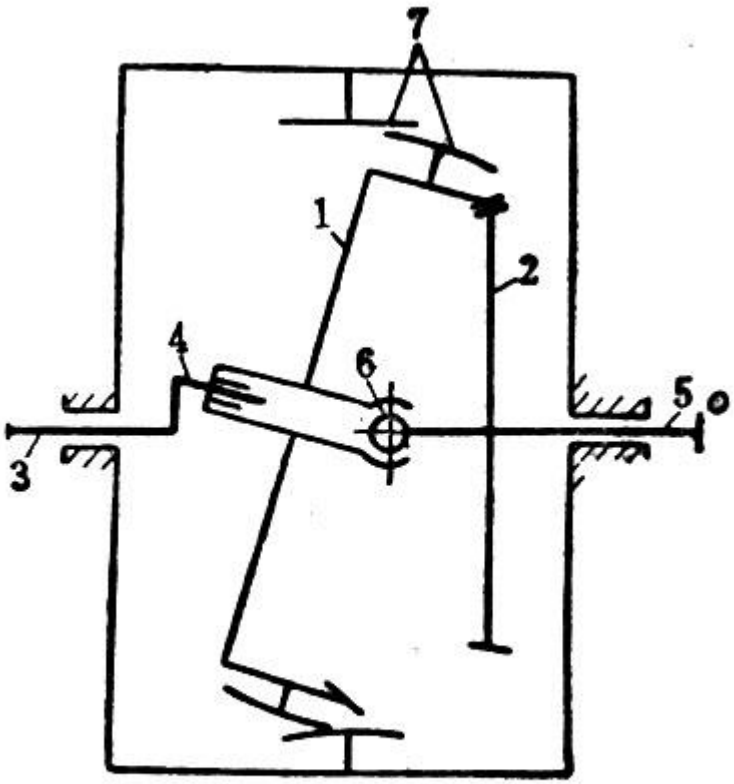


图 8-40

Transverse harmonic gear drive

Transverse harmonic gear drive refers to harmonic gear drive with transverse gear form.

In the harmonic gear drive shown in Figure 8-41, there are transverse tooth on the plate-like flexible gear 2 in the shape of plain disk and the other end forms a shaft to output. The rigid wheel l is in the shape of circular cone. What this drive applies is double-wave planetary wave generator, which includes a circular disk 3, two steel balls 4 and a retainer 5. Circular disc 3 is a driving part. The flank tooth of flexible gear and rigid gear are plain and its apex angle is $60° \sim 40°$. The axial dimensions is relatively small, it can be used to transmit power and motion.

Planetary bevel drive with small teeth difference, bevel gear drive with small teeth difference

It is a kind of planetary gear drive composed of bevel gear pair with small teeth difference. Details can be seen from Figure 8-40. The main parts includes bevel gear pair with small teeth difference 1, 2, circumferential direction limited mechanism 7 and crank element 4. Bevel gear pair with small teeth difference is composed of bevel

gear with few teeth difference. The driving bevel gear serves as swing bevel gear, which moves by swinging the rotational motion input by the driving shaft 3 through crank element; the driven bevel gear is a rotating bevel gear which makes plane rotational motion. Crank element is an element that makes the driving bevel gear swing.

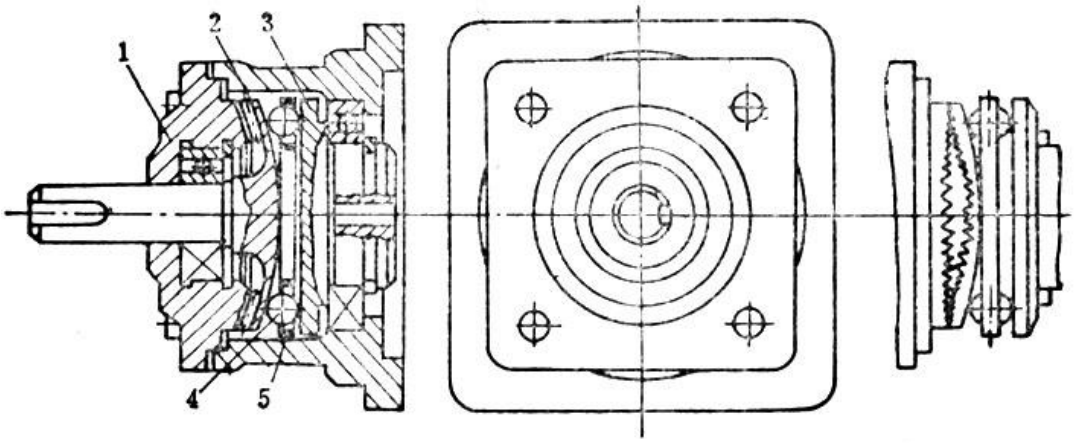


图 8-41

Then this bevel gear becomes a swing bevel gear. Circumferential-direction limited mechanism is a kind of output mechanism. It turns the space swing of swing bevel gear into plane rotational movement and output power through the output element 5.

Oscillating tooth planetary gear drive mechanism with few teeth difference

It is composed of inner gear pair with oscillating-tooth with few tooth difference and the eccentric element. It can be sorted into: rolling ball, roller, pin oscillating-tooth planetary drive mechanism with few tooth difference etc, among which the latter is most commonly used.

The difference between this kind of driving mechanism and harmonic gear drive mechanism is that one drives in rigid engagement while the other in flexible engagement.

The former makes oscillating-tooth rotational movement driven by impact wave equipment to engage in or out while the latter makes deformation on the flexible gear by using impact wave equipment to make the gear teeth engage in or out.

This kind of driving mechanism has many meshing characteristics: much instantaneous engaged tooth number (50% teeth); large volume loading (5-6 times of gear speed reducer); radically elastic oscillating-tooth which can help avoid interference; the range of transmission ratio is big $i_{12} = \pm z_1$; there is no output mechanism so the transmission efficiency is high; the processing technology is also good. Therefore, this kind of driving mechanism has quite promising future.

The diagrammatic chart can refer to “rod pin oscillating-tooth gear”.

Rod pin oscillating tooth planetary gear drive mechanism with few teeth difference

It is composed of inner gear pair with rod pin oscillating-tooth with few tooth difference and eccentric wheel impact wave equipment. Figure 8-42 shows that one can take advantage of the rotation of eccentric wheel impact wave equipment and drive periodically the rod pin oscillating tooth to make rotational movement along its track. Then the rod pin oscillating tooth with triangular straight profile and the ring gear pin of pin internal gear are engaged and form squirmy tangential wave. Therefore, driving and driven relation are formed and there are relative movement laws among the eccentric wheel impact wave equipment (eccentric element-planet carrier), oscillating tooth and pin gear. If any of the three is fixed, the other two can serve as driving and driven link. If they are all flexible, then it, as a whole, is differential mechanism.

Let us suppose that the rotational speed of eccentric element is n_H, the speed of oscillating-tooth carrier is n_J, the speed of pin gear is n_g and the wave number of impact wave equipment is a, then the transmission ratio is:

$$i_{Hg}^{J} = \frac{z_g}{z_g - z_J} = \frac{z_g}{a}$$

The impact wave number of eccentric wheel's impact wave equipment is $a=\pm 1$.

$$i_{hj}^{g} = \pm z_g$$

This kind of driving mechanism has a range of meshing advantages (see "oscillating-tooth planetary drive mechanism with few tooth difference") and technical characters.

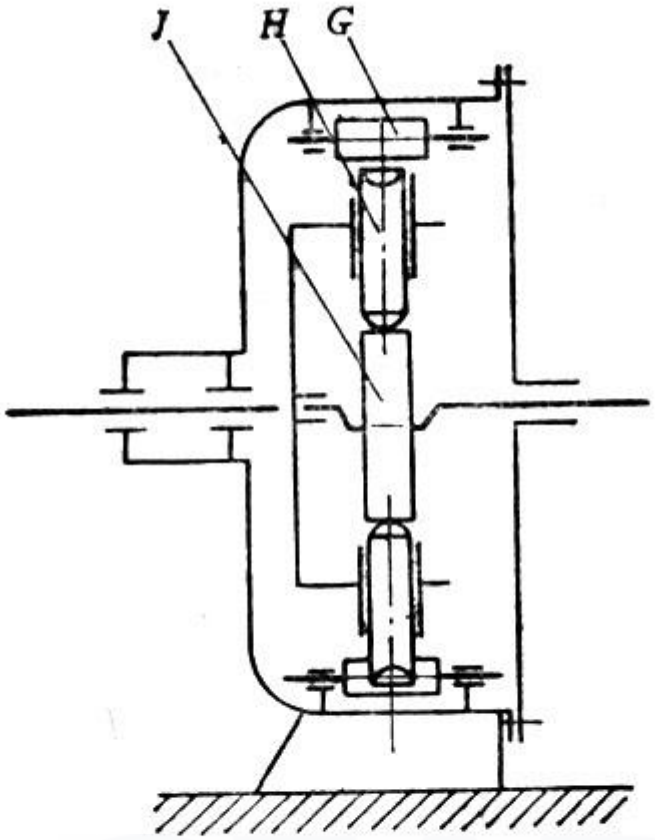


图 8-42

J—偏心轮激波器 H—活齿齿轮 G—针齿齿轮

Rod pin oscillating-tooth gear

It refers to gear taking rod pin as its oscillating-tooth. Rod pin oscillating-tooth gear is composed of eccentric wheel impact wave equipment, rod pin oscillating-tooth and oscillating-tooth carrier. As Figure 8-42 shows, there are evenly distributed radial round pin hole on the oscillating-tooth carrier and the rod pin tooth is put inside the round radial hole. It makes rotational movement when driven by running of eccentric wheel's impact wave equipment, which transmit power and motion by the engagement of oscillating-tooth and pin gear .The tooth profile of oscillating-tooth is triangle straight tooth profile.

Oscillating tooth gear pair with small teeth difference

Oscillating tooth gear pair with few tooth difference $(z_2 - z_1 = 1 \sim 4)$ refers to internal gear pair composed of internal gear (similar to circular arc gear) or gear pin internal gear and oscillating-tooth gear.

Internal gear with rolling ball or roller oscillating-tooth gear and with similar circular arc internal gear can compose oscillating-tooth internal gear pair with few

tooth difference.

Rod pin oscillating-tooth gear and ring internal gear can compose oscillating-tooth internal gear pair with few tooth difference.

Oscillating-tooth gear pair with few tooth difference is the main part of oscillating-tooth planetary gear drive mechanism with few teeth difference.

Oscillating tooth carrier

Oscillating tooth carrier refers to that carrier whose oscillating-tooth is evenly distributed in radial hole (or groove) and makes rotational or rolling movement inside the hole. It is the wheel body of oscillating-tooth gear. Generally, it integrates with input or output shaft.

Oscillating tooth

The gear teeth of oscillating-tooth gear can be classified into rolling ball, roller and rod pin type, but it cannot engage with conjugate internal gear (rolling ball or roller oscillating-tooth) or pin gear internal gear (rod pin oscillating-tooth). It can also make rotational movement or advance-and-return movement in the holes (or grooves) of oscillating-tooth.

Oscillating-tooth gear

In oscillating-tooth gear, the gear teeth are combined gear of active links. Generally, it is composed of oscillating tooth and oscillating-tooth carrier. Oscillating-tooth can be classified into three types: rolling ball oscillating-tooth gear, roller oscillating-tooth gear and rod pin oscillating-tooth gear. Oscillating-tooth gear can also be classified into internal gear and external gear. Generally, oscillating-tooth gear, together with its conjugate internal gear or pin gear internal gear, forms gear pair, which is always used to compose oscillating-tooth planetary gear drive with few tooth difference.

Roller and ball oscillating-tooth gear

It refers to gear taking roller and ball as oscillating-tooth. It is composed of roller (or ball), oscillating tooth carrier and eccentric wheel. When the eccentric wheel is rotating, orderly advancing roller (or ball) to make movement along the radial hole of oscillating tooth carrier and make the roller (or ball) getting out of engagement. When oscillating tooth carrier planetary gear drive mechanism with few teeth difference is composed, the eccentric wheel is always seen as planetary carrier, as an input shaft and the oscillating tooth gear is planetary gear. Roller oscillating-tooth gear presents line contact while ball oscillating-tooth gear pair presents point contact. The engagement condition can be seen from Figure 8-43a, b.

Conjugate profile of ball and roller oscillating tooth

It refers to internal engagement gear pair formed by the meshing of ball or roller oscillating tooth and internal gear that has conjugate profile. Two conditions need to be considered when choosing this kind of internal gear profile, one is conjugation and

the other is processing technology.

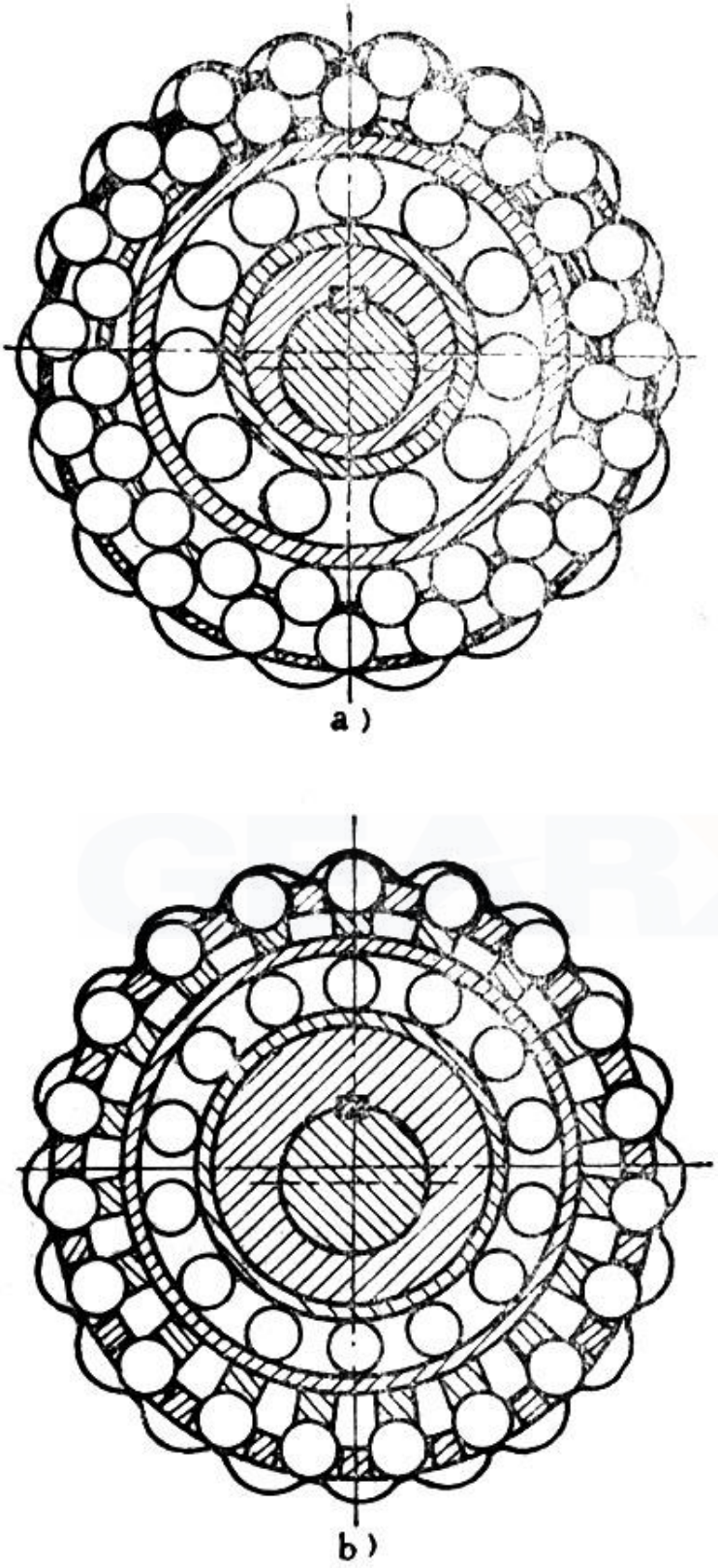


图 8-43

a）径向双排滚柱结构　b）隔块滚柱结构

Conjugate line, which is a complicated line and a line with poor processing facility, is the envelop curve of roller or ball oscillating tooth. In order to reduce the difficulties in the production, conjugate line can be replaced by the osculating circle of roller or ball oscillating-tooth profile. The radius of osculating circle is close to the diameter of roller. This osculating circle is the profile of the engaged gear of ball or roller osculating tooth.