8.4 Load balancing device of planetary gear train

Load balancing device of planetary gear train

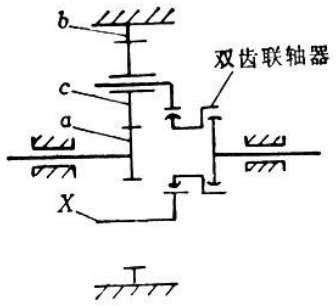
In planetary gear train, there are lots of planetary gears with the same geometrical parameter that can bear torque at the same time. Influenced by processing, installation, the elastic deformation of components, the load beard by different planetary gear is not even, which may affect the bearing capacity, life service, vibration and noise. Therefore, specific equipment must be set to reduce the uneven shared load and this equipment is called load balancing device.

Load balancing device can also compensate for processing and installation error and reduce vibration noise. It is an indispensable part in planetary gear train.

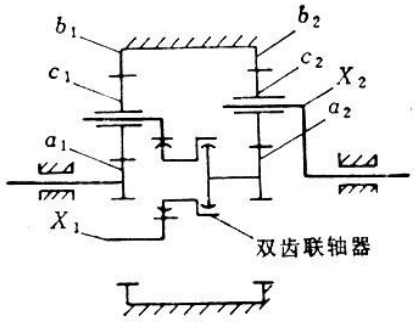
There are various kinds of load balancing devices. The main forms are: spring element load balancing device, basic element floating device and lever linkage load balancing device.

Floating device of planet carrier

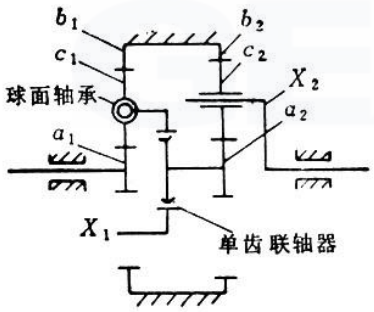
The floating of planet carrier is working by connecting directly the gear coupling with low speed axis (Figure 8-51).Bearing large force for planet carrier is good for floating. Planet carrier, without support, can simplify the mechanism, especially those multistage planet gear mechanism. But in high speed occasion, relative large centrifugal force may occur which has disadvantage for the stability and loading efficiency. Therefore, floating device of planet carrier is better used in low and medium speed occasion. Figure 8-51 shows several common floating structures.



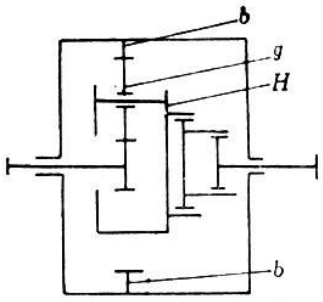
a）



b）



c）



d）

图 8-51

a）NGW型行星架浮动 b）二级NGW型行星架浮动 c）三级NGW型行星架浮动 d）行星架浮动示意图

Floating device of planetary gear

This is a commonly seen load balancing device. The common method of floating are listed as follows:

1. Elastic floating

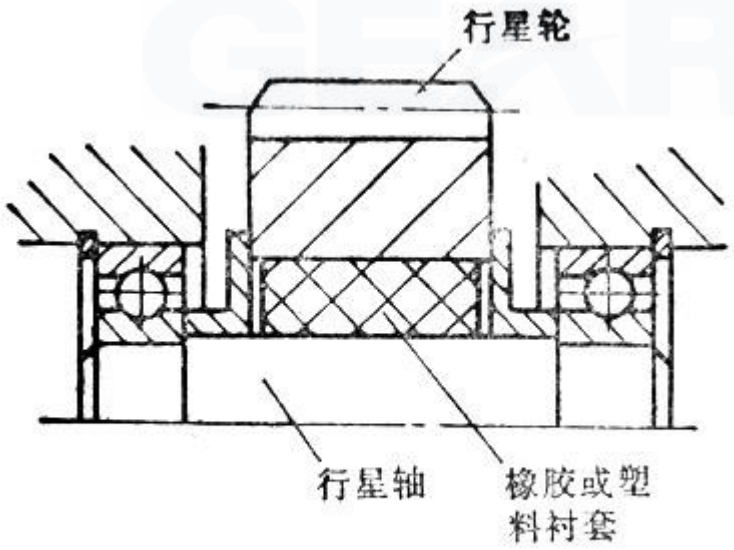
Elastic floating is a load balancing device installed on the elastic mandrel on planetary gear. Figure 8-52 a, b show devices that make radial floating depending on the elastic cover.

2. Oil film elastic floating device

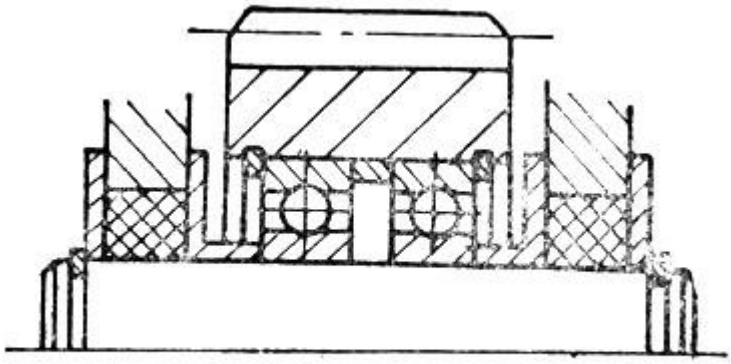
Put a floating device between planetary gear and planetary gear shaft, there need to leave some space between the floating device and the inner hole of planetary gear to form oil film. In fact, oil film elastic floating device is a sliding bearing, which realize floating relying on the elasticity of dynamic pressure oil film so as to achieve the purpose of load sharing. Detail can be seen from the Figure 8-52.

3. Elastic axis floating device

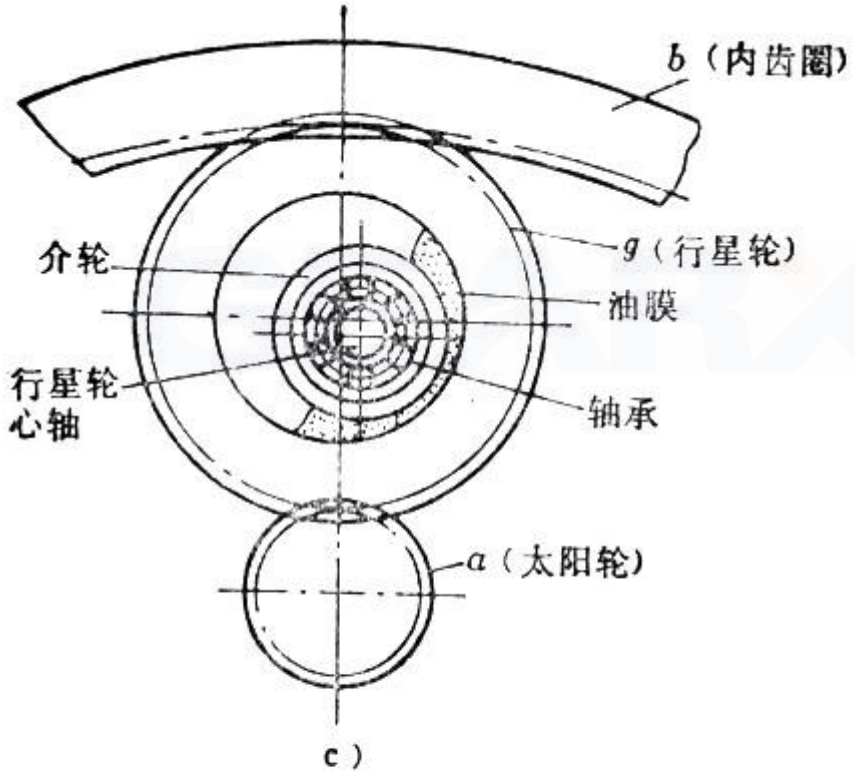
Install the planetary gear on axis with good elastic performance, and then load sharing purpose can be realized by the elastic deformation of the axis.



a)



b）



c）

图 8-52

a）弹性套装在行星齿轮孔内 b）弹性套装在行星架上 c）油膜弹性均载装置

Simultaneous floating of sun gear and planet carrier

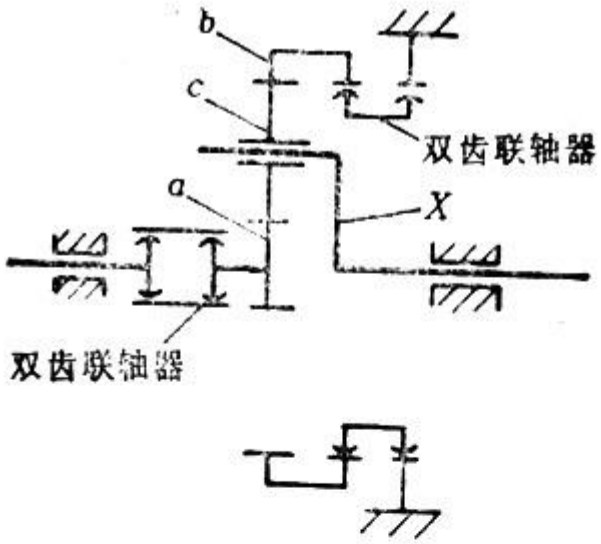
Better load balancing performance can be true when the two basic structural units floating at the same time. This is usually seen in multi-tier planetary gear train. The

uneven coefficient of load distribution K^{β} =1.15~1.2.

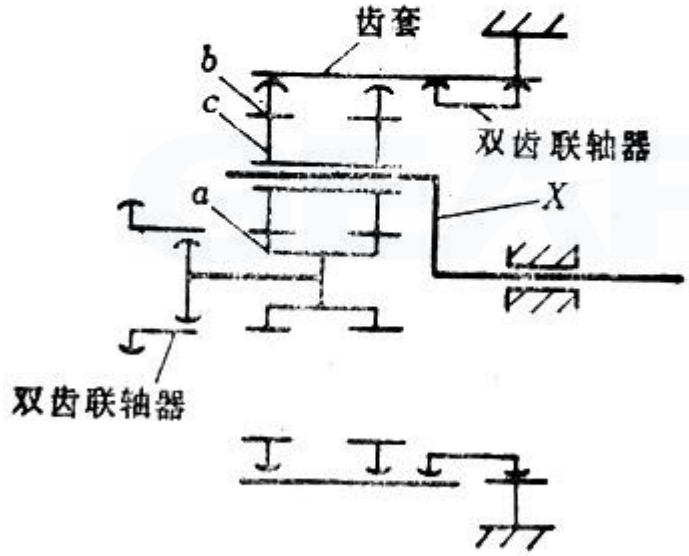
Simultaneous floating of sun gear and ring gear

When sun gear and internal ring gear float at the same time, good load sharing performance can be realized. This is adaptable in high velocity planetary gear driving.

The merits are: good floating performance, K^{β} =1.05~1.15, low noise and reliable work performance. Figure 8-53 shows two forms of floating device.



a)



b)

图 8-53

a）用于直齿NGW型传动 b）用于人字齿NGW型传动

Floating device of sun gear

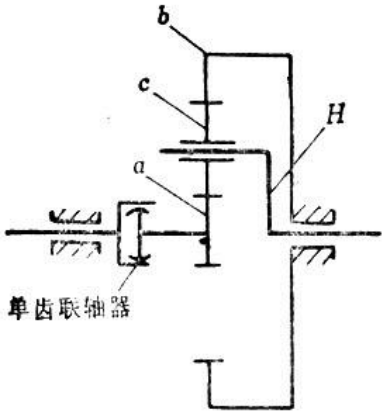
In planetary gear train, sun gear floating is a commonly seen basic unit of floating device (Figure 8-45). The commonly seen floating devices are:

1. Single tooth or double tooth gear coupling floating device

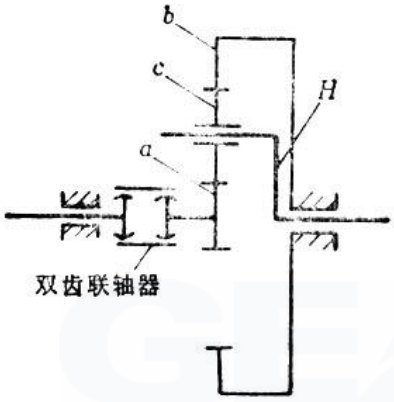
Sun gear shaft is formed by connecting directly the single-tooth or double tooth gear coupling with high speed axis without adding support so as to realize sun gear floating and realize load sharing purpose. This method is very flexible with simple structure. Its processing and installation technology are all good and the cost is low. Planetary gear can also be applied independently when the number is n_p=3 and in the condition of low and medium speed. But when n_p>3 with high speed, the performance is not so good because the load distribution is not even. The coefficient is generally being K^{β}=1.1～1.15 (Figure 8-54a and b).

2. The floating device of elastic element

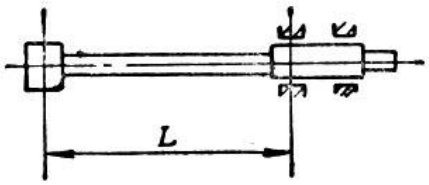
Sun gear is stalled on the long and thin elastic shaft or serving directly as shaft gear with good elastic performance. Simple beam type would be relatively good. When the load is unevenly distributed, shared loading can be realized by the elastic deformation of long and thin shaft. This kind of load sharing device has simple structure, good technical performance and its vibration reduction capacity is excellent. But the axial size is relatively big which requires high processing precision. Detail can be seen from the Figure 8-54c, d.



a)



b)



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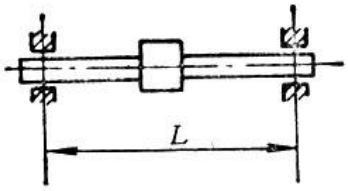


d)

图 8 54

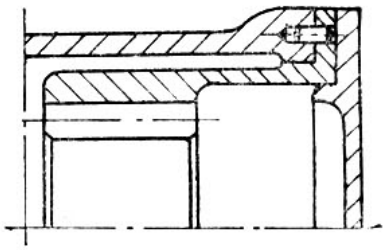
a) 单齿联轴器浮动 b) 双齿联轴器浮动
c) 悬臂梁式 d) 简支梁式

Floating device of ring gear

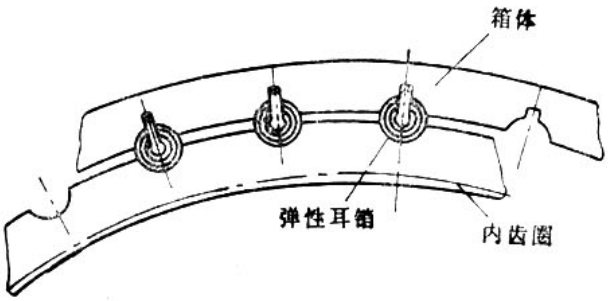
Floating device of ring gear is a device that takes advantage of the internal ring floating in central gear to realize load balancing. The common methods of floating are listed as follows:

1. Thin-wall internal gear ring device

This device helps realize load balancing by putting the ring gear on the thin-wall cylinder and taking advantages of the elastic deformation of thin-wall cylinder. It performs well when n_p>3. See Figure 8-55a.



a)



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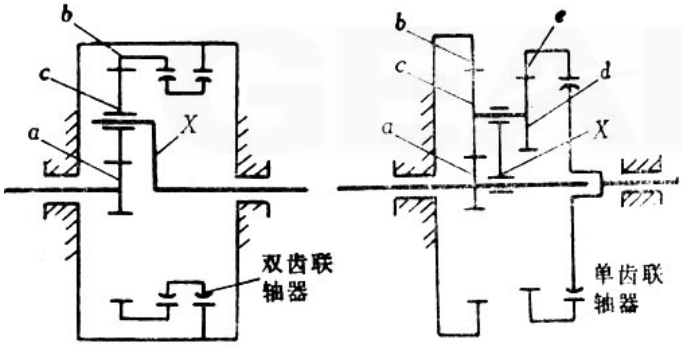
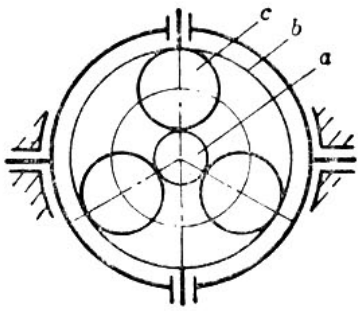


c)



d)

图 8-55

a）薄壁内齿圈 b）弹性套销均载装置 c）齿轮联轴器均载装置 d）十字滑销均载装置

2. Gudgeon pin spring balancing device

There is gudgeon pin installed between ring gear and housing and there are lots tiers of ringent spring outside the gudgeon. The spring gradually becomes thick from inside to outside and it allows radial and tangential free floating and it can also move axially. Load balance can be realized when it is working, taking advantage from elastic deformation of course. Detail can be seen from the Figure 8-55b.

3. Gear coupling and oldham coupling floating device

Ring gear connects with housing or output shaft through single or double toothed gear coupling to realize load balancing, utilizing the floating allowed by the coupling. This method sees small axial size and compact structure. But the disadvantages are large size and of floating units with heavy amount which reduce the flexibility. So NG-WN typed gear train often uses this floating method. See Figure 8-55c.

4. Crossed sliding pin floating device

There are four sliding pins on ring gear connecting the housing. Radial floating can be realized when it is working so as to make true the load balancing. Detail can be seen from the Figure 8-55d.

5. Nonmetal elastic unit floating used in ring gear

That means to add nonmetal elastic material (such as rubber and plastics etc) in the ring gear and housing so as to realize loading balancing. But it is unacceptable when the material that is too soft and when the equipment is working in a low speed. Detailed can be seen from the Figure 8-56.

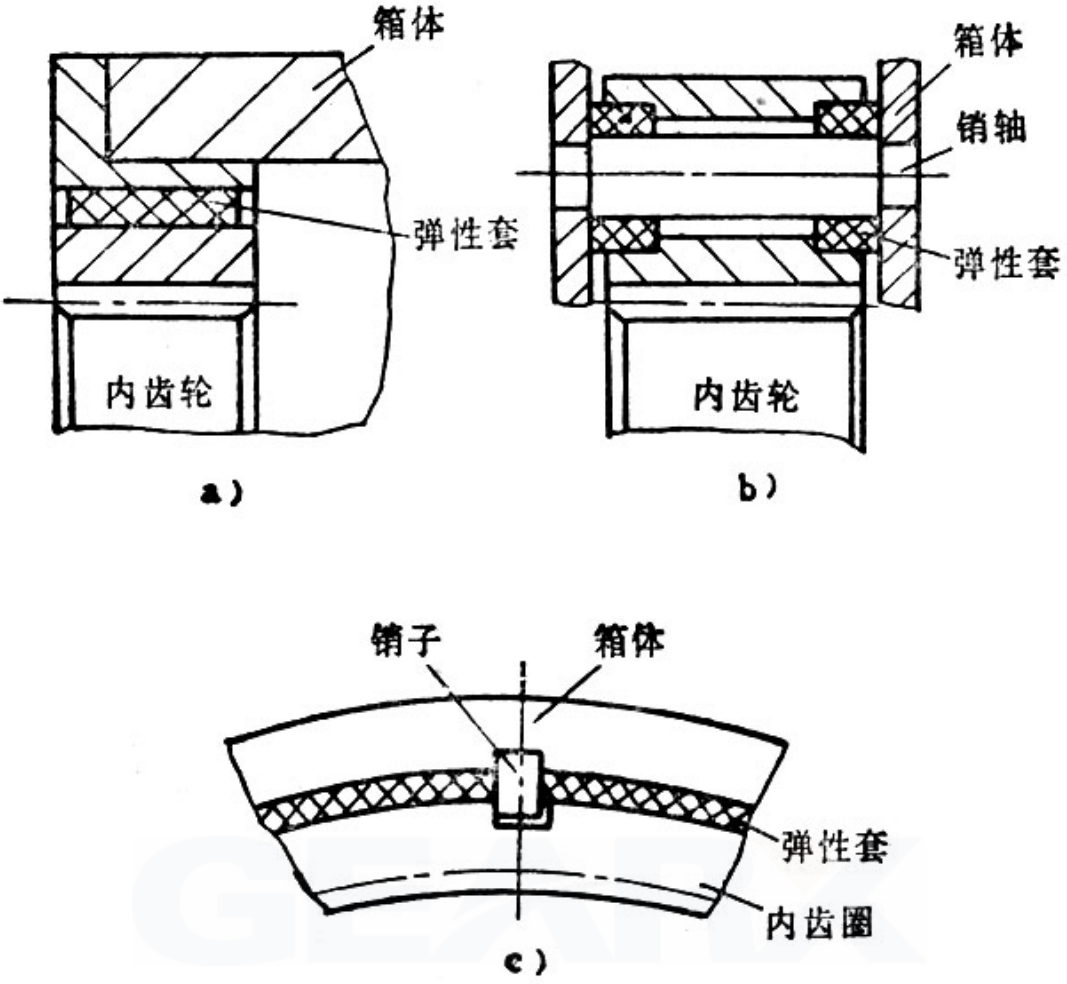


图 8-56

Load balancing device of basic structure unit floating

It means not adding radial support unit for the basic unit and allows it making radial or bias placement. The nature is that to eradicate or reduce unnecessary constraint by floating some unit to make it move more freely. That would help it realize load balancing when bearing heavy load.

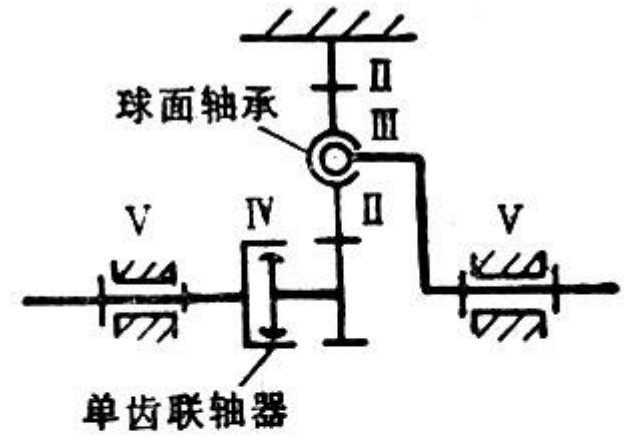
The common method for load balancing device of basic structure unit floating is using double (or single) toothed coupling. One of the three basic structural unit floats can realize load balancing. If two of them float at the same time, better results can be achieved.

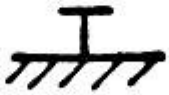
Common floating basic structural unit are: sun gear floating, ring gear floating, planet carrier floating, sun gear and planet carrier floats at the same time, sun gear and ring gear floats at the same time and the statically defined floating of gear train.

Floating method of mechanism statically determinate

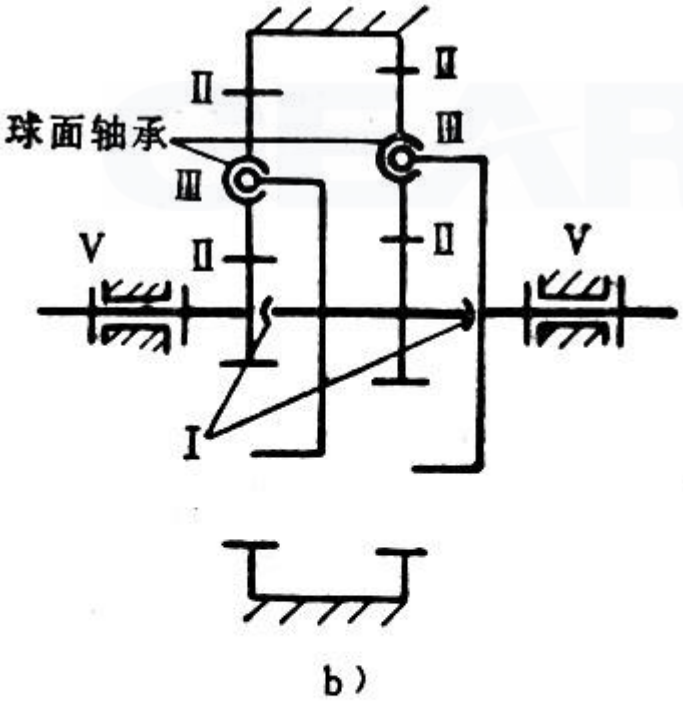
This method is also called floating method without redundant constraint. The gear train of multi-planetary gear is mechanism with virtual constraint. But if the precision

cannot meet technical requirements, virtual constraint may become real constraint and cause uneven distribution of load. In order to solve the uneven load distribution and tooth width direction distribution problems, the degree of freedom of mechanism and the real degree of freedom must be equal, that is, to realize a spatial statical occasion. Therefore, floating method shown in Figure 8-57 will always be adopted.





a）



b）

图 8-57

a）单级NGW型静定机构

b）二级NGW型静定机构

Load balancing device of lever link

It installs eccentric planetary gear shaft and lever. When planetary gear bears uneven force, the lever link system can automatically adjust it to a new balancing position so as to realize load balancing. This device is appropriate for NGW type gear train which has 2～4 planetary gears.

1. Two planetary gear linking mechanism

Install the two planetary gears asymmetrically and fix an engaged sector gear on both side of the offset shaft. When one offset shaft turns, the other will turn in an opposite way in equal speed, resulting from the lever effect of engaged sector gear.

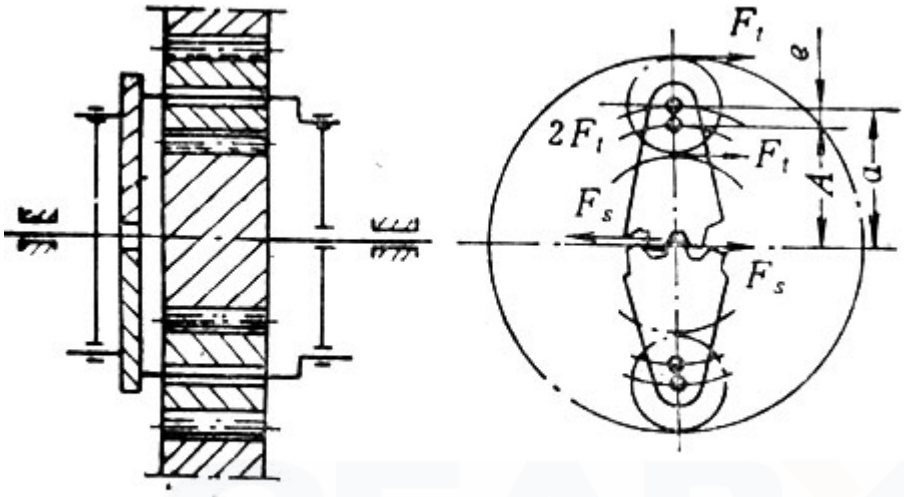


图 8-58

2. Three planetary gear linking mechanism

Three planetary gears are distributed in 120 degree. Every offset shaft is linking with the balanced lever. The other end of lever is supported by a floating ring that can make free movement within its own plane. When the load is uneven, three radial forces working on the floating ring is not equal so the floating ring will move or turn to realize load balancing (Figure 8-59).

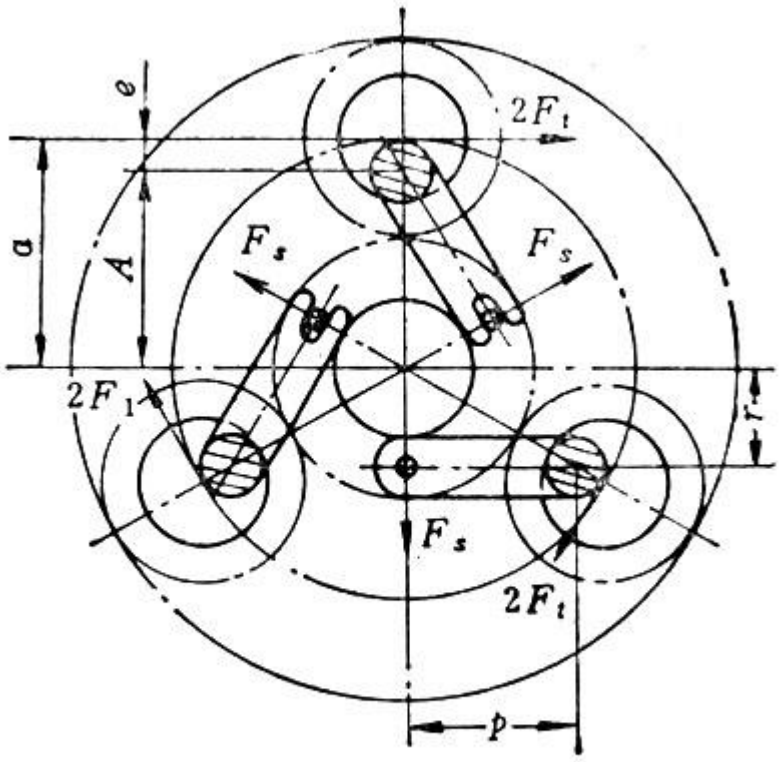


图 8-59

3. Four planetary gear linking mechanism

Its load balancing principle is the same as that of three planetary gear linking mechanism (Figure 8-60).

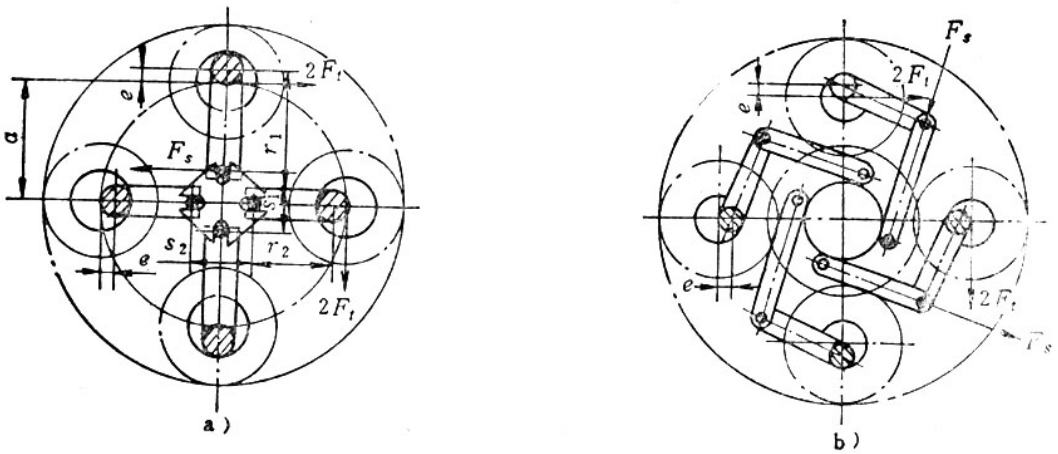


图 8-60