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MECHANIZMY NAPĘDOWE O WYSOKIEJ PRECYZJI W MASZYNACH

Streszczenie: Zastosowanie i wykorzystanie mechanizmów przekładniowych w maszynach jest obecnie szeroko rozpowszechnione we wszystkich obszarach przemysłowych. W odniesieniu do maszyn, ciągle rosną wymagania dotyczące parametrów dokładności kół zębatych, zwłaszcza takich jak sztywność skrętna, luz, luz poprzeczny. Określenie przekładnie precyzyjne pochodzi głównie od ich producentów, zwłaszcza japońskich firm takich jak Teijin Seiki, Sumitomo Cyclo, Harmonic Drive, a swoimi parametrami do nich należy również słowacka firma Spinea.

Słowa kluczowe: przekładnia bezluzowa, przekładnia, przekładnia cykloidalna, reduktor,

HIGH-PRECISION GEAR MECHANISMS IN MACHINERY

Summary: The application and use of transmission mechanisms in machinery is now widespread in all industrial areas. In machinery, the requirements for the accuracy parameters of gears are increasing, especially such as torsional rigidity, backlash, lateral play. The term high-precision gears comes mainly from their manufacturers, especially Japanese companies such as Teijin Seiki, Sumitomo Cyclo, Harmonic Drive, and the Slovak company Spinea also belongs to them achieving high parameters of own products.

Keywords: zero backlash gearbox, gearing, cycloid gearbox, reducer

1. Zero backlash

High-precision gears are characterized as backlash-free gears. There are several ways in which it is possible to provide a gearbox with zero backlash, thus enabling high precision motion control.
There is a wide range of modification techniques, but the most commonly used are as follows:

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Decreasing the width between centers. Smaller between-center distances are achieved either by securing a gearwheel in place with preset spacing or by inserting a spring. Rigid bolted assembly is typical of bidirectional gearboxes of the bevel, spur, worm or helical type in heavy-duty applications. Spring loading is a better choice to keep lash at acceptable values in low-torque solution.

Splitting - the split arrangement implies mounting two halves of a gearwheel onto a shaft side by side with a spring in between. One half is secured in place, while the other is forced to turn slightly by the spring. The technique is commonly used in systems where speeds and loads are low

Preloading - to eliminate the clearance between the interfacing teeth, a torsion spring or a load is coupled to the last driven gearwheel. The technique proves especially efficient in multi-stage applications, where play is a cumulative magnitude. Those are typically low-torque engines rotating in one direction only. The biggest issues with the configuration is that the preloading impairs free spinning. To eliminate the problem, it is advisable to replace them with an auxiliary motor.

Dual-path configuration. In the configuration, two identical gearing sets are mounted in a parallel arrangement and gyrate in opposite directions. Additionally, the arrangement is preloaded: a motor shaft is inserted together with a pinion into the gearhead. The downsides are doubled quantity of components and extended assembly time.

2. TwinSpin bearing reducer

There is a difference between harmonic and cycloid gearboxes (reducers). Cycloid gearboxes have antifriction bearing with die cam on driven shaft. This is in engagement with the rollers (needles) that co-engage with the cupboard. The number of rollers is always one more than the teeth on the curve disc.

There is contrarotating movement caused during the rotation of driven shaft. One rotation causes countermovement of one tooth. This movement is transferred to driven shaft by arm. The transmission ratio is derived from the number of curved disk teeth and the number of rollers. This principle was created by L. Braren, who pioneered in the construction of ratios. The primary system worked on the principle of *pin & bushing* (roller and bushing), the system TWINSPIN works with needles, teeth and cross [4]. In (Fig. 1, 2) there are particular constructions of cyclic gearboxes.

The original principle is based on meshing of cycloid wheel with openings for the rollers which are in boxes. The wheel is supported by a roller bearing connected with the transmission input shaft. The torque is transferred by the movement of the rollers in boxes, openings of the wheel and needles that are on the girt of the cycloid wheel (Fig.1a)). Usually it uses three cycloid wheels which are gradually rotating, securing even layout of stress.

Second construction principle of cycloid gearbox is based on planetary gearbox. The torque is transmitted by three crank satellites connected via bearings with cycloidal wheels, which are housed in roller bearings of eccentrics [4] (Fig. 1 b)). The difference between previous and this one is that sliding friction occurs here, but the bearing is made without backlash, that means that during motion reserving almost no backlash occurs here. Limited radial space for satellites and bearings is one of the disadvantages, resulting in reduction in size of the transferred torque M_k. The efficiencies are comparable to the previous ones.

a) b)

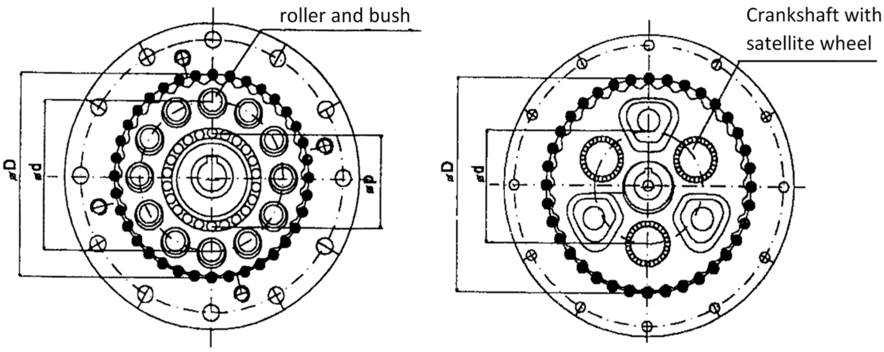

Figure 1. a) representation of rollers housed in bushings, wheel holes and needles on the circumference of the wheel cycloid, b) three crankshafts with satellite wheel connected via bearings with cycloidal wheels

The principle of reducer TWINSPIN (TS) by SPINEA Ltd., enables to eliminate the disadvantages of above mentioned constructions. It is protected by world´s patent from 1995 [4]. The principle of this transmission lies in the location of the driving cross between the cycloidal wheel and the output member, thereby ensuring the transmission of Mk (Fig.2). One pair of the cross is secured in the openings on cycloid wheel and the other pair is in the openings in output flange. The reducing mechanism is made up of pair of cycloid wheel partially rotated by 180°, pair of crosses and firmly joined output flanges. The pair of firmly joined output flanges is synchronously rotating like one common output element.

When the speed of oscillating movement is small (up to 0.1 m/s), we can classify the transfer element of M_k as a low-speed component. Graphic insight of the reducer TS is in the (Fig 3).

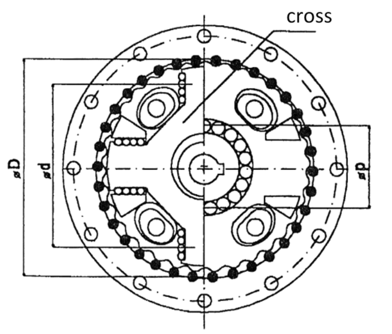

Figure 2. Placing the cross between the cycloidal ones wheel and output member

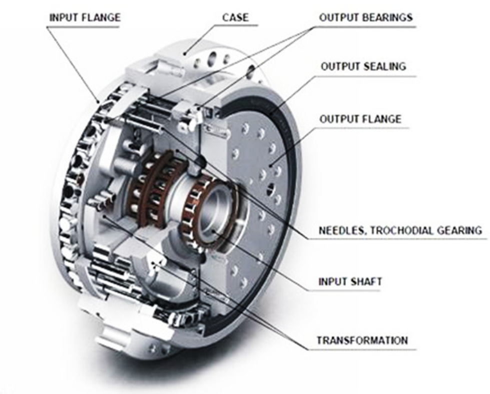

Figure 3. TwinSpin bearing reducer

3. Characteristics of Sumitomo fine cyclo

Sumitomo fine cyclo precision gears for robotics, Machine tool industry and automation are torsionally stiff, compact and cost effective. Zero backlash speed reduction assemblies for all applications which demand the highest precision and stiffnes.

- Cyclo system incorporating three disc and a single eccentric. Available in four mounting versions.
- Cyclo system incorporating two disc and a single eccentric for the highest transmission accuracy with minimum speed ripple and minimum vibration.

There are essentially four major components in the cyclo gearbox:

a - High speed shaft with eccentric bearing.
b - Cycloid disc.
c - Ring gear housing with pins and rollers.
d -Slow speed shaft and flange wits pins and rollers

As the eccentric rotates, it rolls one or more cycloid disc around the internal circumference of the ring gear housing. The resulting action is similar to that of a disc rolling around the inside of a ring. As the cycloid disc travel in a clockwise path around the ring gear, the discs themselves turn in a counter-clockwise direction around their own axes. The teeth of the cycloid discs engage successively with the pins of the fixed ring gear, thus producing a reverse rotation at reduced speed. The reduction ratio is determined by the number of cycloid teeth on the cycloid disc. There is at least 1 lass tooth per cycloid disc than there are rollers in the ring gear housing which results in the reduction ratio being numerically equal to the number of teeth on the cycloid disc. Therefore for each complete revolution of the high speed shaft the cycloid disc move in the opposite direction by one tooth (Fig. 4).

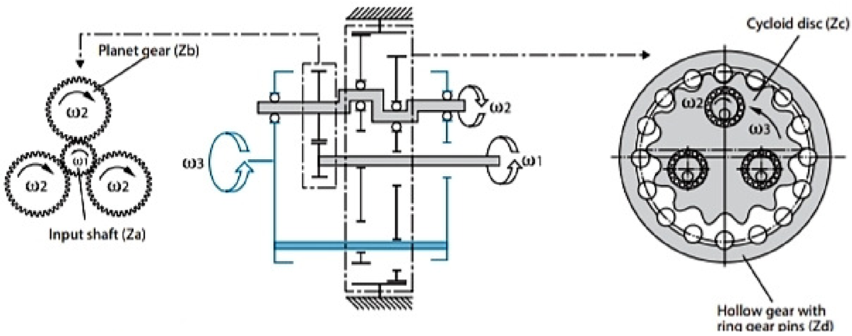

Figure 4. Construction principle of Sumitomo CYCLO gearboxes

The rotation of the cycloid disc is transmitted to the slow speed shaft via the pins and rollers projecting through holes in the cycloid discs.

The pins of the slow speed shaft and sometimes the pins of the ring gear, too are equipped with rollers so that the torque transmitting parts of the Cyclo gearbox toll smoothly.

4. Characteristics of TEIJIN SEIKI reducers

The products of this company are included among high-precision gears. They work similarly to TWIN SPIN reducers on the principle of cycloidal engagement of gear teeth with internal gear teeth of the housing, which represent needle-shaped rollers evenly distributed on the inner side of the gearbox body.
TEIJIN SEIKI manufactures reducers (Fig. 5) in three basic types "RV", "RD", and "RH".
The RV is a 2 - stage precision reduction gear.
- An input gear engages with and rotates spur gears that are coupled to crankshafts. Several overall gear ratios can be provided by selecting various first stage ratios.
Epicyclic gear reduction:
- Crankshafts driven by the spur gears cause an eccentric motion of two epicyclic gears called RV gears that are offset 180 degrees from one another to provide a balanced load.
-The eccentric motion of the RV gears causes engagement of the cycloidal shaped gear teeth with cylindrically shaped pins located around the inside edge of the case.
- In the course of one revolution of the crankshafts the teeth of the RV gear move the distance of one pin in the opposite direction of the rotating cranks. The motion of the RV gear is such that the teeth remain in close contact with the pins and multiple teeth share the load simultaneously.
The output can be either the shaft or the case. If the case is fixed, the shaft is the output. If the shaft is fixed the case is the output.

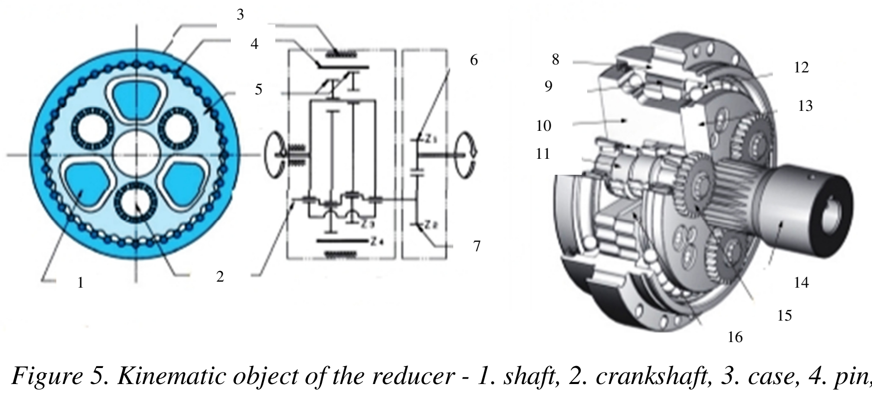

Figure 5. Kinematic object of the reducer - 1. shaft, 2. crankshaft, 3. case, 4. pin, 5. RV gear, 6. input gear, 7. spur gear, 8. case, 9. pin, 10. shaft, 11. crank shaft, 12. main bearing, 13. hold flange, 14. input gear, 15. spur gear, 16. RV gear

5. Harmonic drive

Ever since they were invented, Harmonic Drive (Fog. 6) strain wave gears have remained of great interest in a variety of industries, thanks to the constant innovation, improvements and modifications that they are still undergoing. Today they represent the first choice for applications that require a high level of positioning and repeat precision. Whether enclosed in a housing, employed as an actuator with motor and encoder, or as components in customer-specified configurations with specific materials or design elements, the flexibility of strain wave gears makes them suitable for a wide range of applications. Basically, the Harmonic Drive was developed to take advantage of the elastic dynamics of metal. The greatest benefits are the zero-backlash characteristics and the weight and space savings compared to other gears because our gear mechanism consists of only three basic parts. Flexible wheel 1 has external teeth; solid wheel 2 has internal gearing. Both bikes have the same module and diagonal. Flexible wheel has fewer teeth than the solid wheel. Under the effect of the wave generator the flexible wheel deforms and the teeth of the flexible wheel merge with the tooth gaps on the rigid wheel – they mesh.

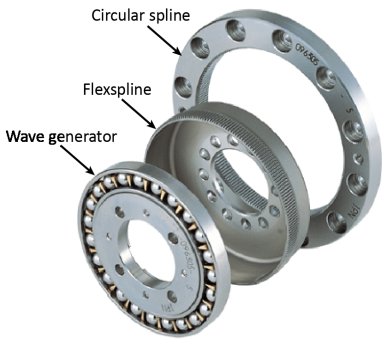

Figure 6. Harmonic drive.

The Wave Generator is an assembly of a thin-raced ball bearing fitted onto the periphery of an elliptical cam. The inner ring of the bearing is fixed around the cam causing the outer ring of the bearing to conform to the same elliptical shape of the assembly. The Wave Generator is usually attached to the input shaft.

The Flexspline is a thin-walled steel cup with gear teeth machined into the outer surface near the open end of the cup. The bottom of the Flexspline (cup bottom) is called the diaphragm. The diaphragm is usually fitted to the output shaft.

The Circular Spline is a rigid steel ring with teeth on the inside diameter. The Circular Spline has two teeth more than the Flexspline. The Circular Spline is usually fixed to a casing.

This simple three element construction combined with the unique operating principle allows extremely high reduction ratio in a very compact and lightweight package. Neither the size nor weight of the gear vary with the reduction ratio. The high performance attributes of this gearing technology including zero backlash, high torque, compact size, excellent positional accuracy and repeatability are all a direct result of the unique operating principle.

6. Utilizing inherently precise gear sets

Building an ultra-precise gearbox requires taking measures to avoid workmanship defects and ensuring close-tolerance alignment of components in a mechanism. Possible measures include custom machining techniques and enhanced dimensional control prior to and during assembly. Manufacturers also introduce safe handling and packaging practices to exclude post-production damages, such as chips, or dirt contamination. In addition, speed reducers with high precision are typically produced in small batching, which enables thorough quality testing.

7. Conclusion

With the development of science and technology, especially in the field of management and control of movements of executive members of technological and handling equipment, the requirements for the parameters of the accuracy of transmissions in the drives of machinery are increasing. The application of these requirements is very topical in the production and development of precision machining technology, in the technology of production and positioning associated with automation and robotics, as well as in other machines and equipment. The term high-precision transmissions comes mainly from their manufacturers, who named them due to the accuracy parameters they promoted.

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