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KOŁA PLANETARNE W PRZEKŁADNI TOROIDALNEJ

Streszczenie: Warunkiem montażu przekładni toroidalnej jest precyzja ustawienia kół planetarnych (satelitów) w ich przestrzeni konfiguracji. Położenie satelitów zależy od ich liczby, liczby zwojów ślimaka i liczby zwojów stojana.

Słowa kluczowe: globoidalny ślimak, planeta (koło planetarne), przełożenie przekładni

PLANETS IN TOROIDAL DRIVE

Summary: The condition for assembly of the toroidal gear is precision of space set-up of the planets. The position of the planets depends on the number of planets, on the number of worm groves and on the number groves of stator.

Keywords: globoid worm, stator, planet, gear ratio

1. Principle of drive operation

The toroidal drive (Figure 1) combines the principle of operation of the worm and planetary gearing, with the gearing being replaced on the worm *1* and the stator *3* by the grooves and in the planets are rolling elements *2*. The input and output of the toroidal drive is coaxial. This type of drive is kinematic accurate. It allows larger gear ratios of up to *150* in one stage at relatively high efficiency with outputs up to *20 kW*. These characteristics make it suitable for use in equipment requiring high gear ratios or kinematic accuracy

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The toroidal drive (Fig. 1) is made up of the following basic members: a globoid worm *1*, planets including the rolling elements *2*, a split stator *3* and a carrier *4* (index s). The planet rolling elements must engage the grooves of the worm and the stator. The drive can be in two versions, where the rolling elements are balls or rollers. The rollers have axes positioned radially to the planet.

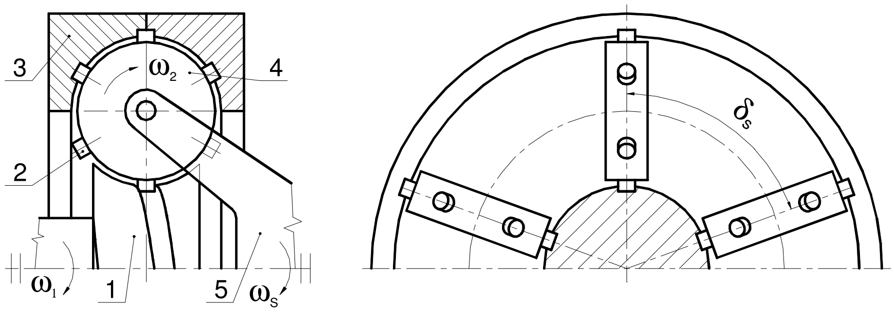


Figure 1. Toroidal drive 1-worm, 2-rollers, 3-stator, 4-planets, 5-carrier

Total gear ratio:

$$i = \frac{z_2}{z_1} \cdot \frac{z_3}{z_2} \pm 1 = \frac{z_3}{z_1} \pm 1 \tag{1}$$

The plus sign applies to the same direction of the screw grooves in the worm and the stator.

1.1. Lead angle of worm and stator

In Fig. 2, the point in the groove of the worm is defined by the angles φ_1 and υ_1. Lead angle α_{1i} is variable. Similarly in Figure 3, the point in the groove of stator.

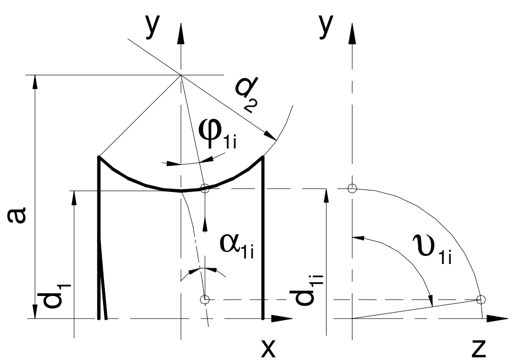


Figure 2. Define lead angle in worm for general engagement point

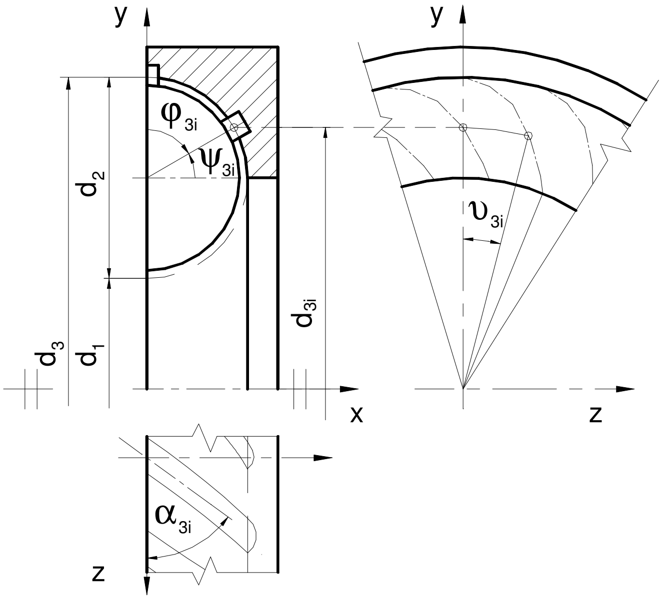


Figure 3. Defining lead angles in stator for general engagement point

Defining variable lead angles α_{1i} in worm and α_{3i} stator:

$$tg\,\alpha_{1i} = \frac{z_1 \cdot d_2}{z_2 \cdot d_{1i}} \tag{2}$$

$$tg\,\alpha_{3i} = \frac{z_3 \cdot d_2}{z_2 \cdot d_{3i}} \tag{3}$$

1.2. Planets

The rolling elements roll in the groove of the worm and the stator. The planets must be positioned so that this condition is met. The lead angles on the worm and in the stator significantly affect the drive efficiency. The position of the planets is shown in Fig. 4. for $z_1 = 1$, $z_3 = 24$, so total gear ratio is $i = 25$ (Fig. 4a) or i = *23* (Fig. 4b). The figure shows the positions of the planets that are generated by turning the worm by one revolution. For the co-ordinate direction of the grooves of the worm and the stator (Fig. 4a), the worm and the carrier rotate in the same direction (clockwise). For the same direction of the grooves, the worm rotates *25* times and the carrier rotates once, i.e. *360* °. Planet positions are highlighted in the figure. The figure shows the first, the third and the twenty-fifth position of the planet.

The number of planets is n. Planets must be positioned at an angle of δ_s, provided that:

$$\delta_s \cdot (z_3 + z_1) = \frac{360°}{n} \cdot z_3 \tag{4}$$

After adjustment:

$$\delta_s = \frac{360°}{n} \cdot \left(\frac{z_3}{z_3 + z_1} \right) \tag{5}$$

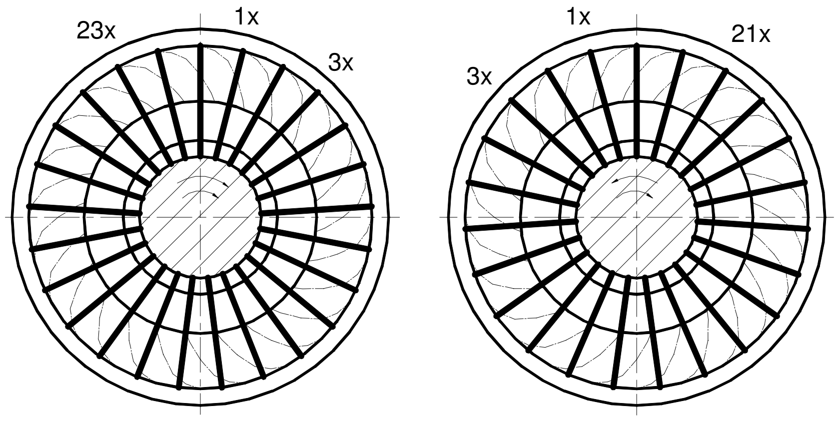


Figure 4. Planet positions: a) same direction of rotation of worm and carrier, b) opposite direction of rotation of the worm and the carrier

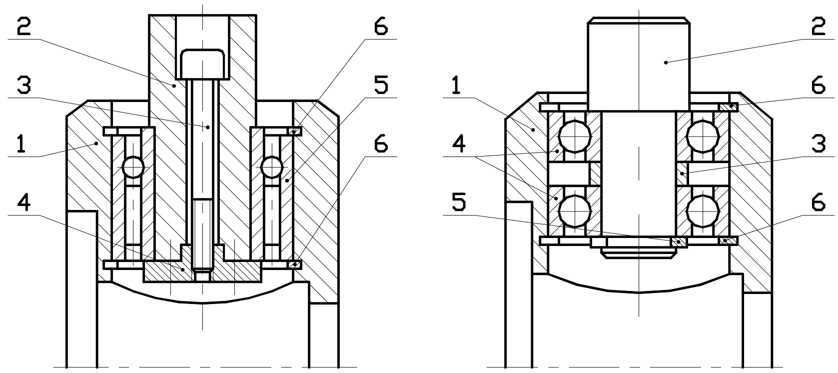
The angle at which the planets are located is a function of the number of planets *n*, the number of grooves of the worm z_1 and the number of grooves of the stator z_3.

Table 1 shows the calculated values of the positioning angles of the planets and their complementary values depending on the number of planets, the number of grooves in the stator for a single-groove worm.

Table 1. Dependence on the positioning angles of the number of planets

Number of planets n	z_3=24		z_3=29		z_3=36	
	δs[°]	360°-(n-1)δs	δs[°]	360°-(n-1)δs	δS[°]	360°-(n-1)δs
3	11, 52	129,6	116	128	116,8	126,5
4	86,4	100,8	87	99	87,6	97,3
5	69,1	83,5	69,6	81,6	70,1	79,8
6	57,6	72	58	70	58,4	68,1
Number of planets n	z_3=54		z_3=74		z_3=93	
	δs[°]	360°-(n-1)δs	δs[°]	360°-(n-1)δs	δs[°]	360°-(n-1)δs
3	117,8	124,4	118,4	123,2	118,7	122,6
4	88,4	94,9	88,8	93,6	89	92,9
5	70,7	77,2	71	75,9	71,2	75,1
6	58,9	65,5	59,2	64	59,4	63,2

Figure 5 shows various solutions of the planet. In Figure 5a, the rolling element-roller *2* is hollow with a graded diameter, loosely fitted on the screw *3*. The bearing *5* is secured by retaining rings *6* and the retainer *4*. In Figure 3b, the rolling element of the roller is full, supported in two ball bearings *4*, secured by retaining rings *6* of the hole, on the retaining ring *5* on the roller. Bearings *4* are delimited by ring *3*.



a) *b)*

Figure 5. Design of the planet with rolling elements by rollers

Conclusion

The condition of the drive assembly is the correct positioning of the planets, which depends on the number of planets, the number of grooves of the worm and the number of grooves of the stator. The planets set-up is independent of the number of rolling elements in the planet. The values given in Table 1 show that with increasing number of grooves of the stator, the unevenness of the circumference distribution of the planets decreases.

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VEGA 1/0473/17: „*Research and development of technology for homogeneous charge self-ignition using compression in order to increase engine efficiency and to reduce vehicle emissions*".

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