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Based on Geometric and Kinematic Parameters of Worm Transmission

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Abstract: This article presents the types of worm gears, areas of use, formulas for calculating geometric and kinematic parameters, and types of materials.

Keywords: mechanical, bearing, thought, element, geometric, kinematic, parameter, length, diameter.

Introduction. Worm gears are very important in the production of mechanical engineering. The advantage of worm gears over other gears is smooth, noiseless operation, compactness; the disadvantage is the relative sliding of the connecting elements (worm winding and wheel tooth) on top of each other, the low coefficient of useful work, and the heating of parts. In order to reduce wear of worm wheels, they are made of antifriction materials (mainly bronze), structural materials (bronze-steel, bronze-cast iron) to save non-ferrous metals, and in weak transmissions, they are made of textolite, polyamide, etc.

Worm transmissions are used in moving machines, control devices (car steering wheel), metal cutting machines, hydraulic structures, lifting and transporting machines, etc.

Research method. Worm gears are used in cases where the axes of the shafts are located at the intersection. The value of the crossing angle can be different, but in practice it is mostly 90^0. Such a transmission consists of a worm wheel and a threaded shaft - a worm (pictures 1, 2) and its principle of operation is the same as that of a screw pair.

Figure 1. Worm reducer (Worm up).

Worm gears, depending on the structure of the worm body, cylindrical and globoid b) (Fig. 2); depending on the position of the worm relative to the wheel - the worm is located below, next to, or above; open and closed, depending on whether or not there is an enclosing body; depending on the task, it is divided into power and moment transmitting or kinematic types.

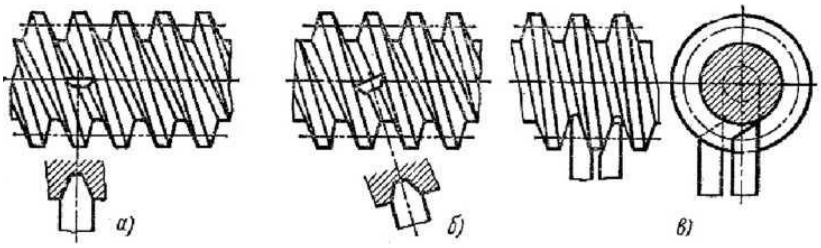

Figure 2. Types of worms. a) - Archimedes, b) - Involute, c) - Convolute worms.

The shape formed when cut by a plane perpendicular to the axis of the worm is a trapezoid. If the shape of the coils from the side resembles an Archimedean spiral, it is called an Archimedean worm, and if it resembles an involute, it is called an involute worm. If the shape resembles a shortened or elongated involute, such a worm is called a convoluted worm (Fig. 2).

Research results and discussions. Geometric parameters of the Archimedean worm (Fig. 3):

a = 20°- profile angle in the cross-section along the axis;

$d_1 = m*q$, where q is the diameter coefficient (relative diameter) of the worm and indicates the number of modules in the diameter of the partition, and its value is selected from the table depending on the module, or it is recommended to take q = 0.25 Z_1.

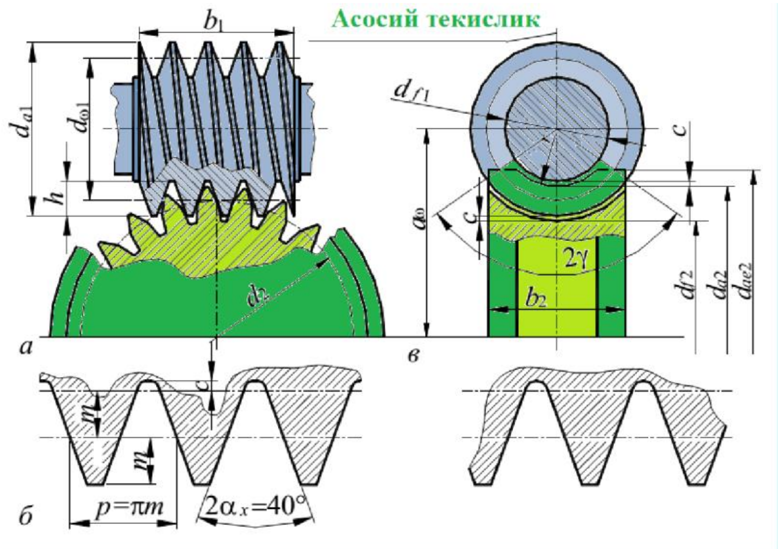

Figure 3. Geometry and kinematics of a worm gear.

$\boldsymbol{d_{a1} = d_1 + 2\,m}$, $\boldsymbol{d_{f1} = d_1 - 2{,}4\,m}$.

b_2 - the width and surface diameter of the wheel-D_H depends on the number of threads of the worm,

$\boldsymbol{Z_1}$ = 1 when, $D_H = d_{a2} + 2m$, $b_2 = 0{,}75\, d_{a1}$.

$\boldsymbol{Z_1}$ =2 when, $D_H = d_{a2} + 1{,}5m$, $b_2 = 0{,}75\, d_{a1}$.

$\boldsymbol{Z_1}$ = 4 when, $D_H = d_{a2} + m$, $b_2 = 0{,}67\, d_{a1}$.

b_1 is the length of the part of the worm where the coils are cut. Its value is determined depending on Z_1 and the displacement coefficient. The displacement coefficient is equal to zero, and

Z_1 =1 and Z_1 =2 when $b_1{}^3$ (11 + 0,06 Z_2) m

Z_1 = 4 when $b_1{}^3$ (12,5 + 0,09 Z_2) m.

The main dimensions of the worm wheel (Fig. 3):

$d_2 = m\,Z_2$; $d_{a2} = d_2 + 2m$; $d_{f2} = d_2 - 2{,}4m$;

$h_a = m$; $h_f = 1{,}2m$ - height of tooth head and peduncle.

The pitch angle of the g-worm winding can be selected from the table or determined as follows:

$$tg\ g = l / \pi d_1 = P_t z_1 / \pi m q = m z_1 / m q = z_1 / q .$$

The tooth of the worm wheel covers the worm body along the arc at an angle of g »100°. It is recommended to make the number of teeth Z_2 ³ 28.

Distance between centers:

$$a_w = 0{,}5\ m\ (q + Z_2).$$

The remaining dimensions of the wheel remain unchanged. Usually, the correction (correction) coefficient is taken as x = ±1. The rotation speeds of the worm wheel and the worm starting circle are different and form an angle of 90^0 with each other. Therefore, the number of transmissions in worm gears cannot be expressed by the diameters of the starting circles, i.e.:

$$U \neq d_2 / d_1.$$

If the worm is made of one worm, when it rotates once, the wheel will turn an angle corresponding to one tooth around its axis. So, for one complete rotation of the wheel, the worm must rotate as many times as the number of teeth of the wheel. In other words, the number of transmissions of a worm gear is equal to the number of teeth on the wheel. When working with a two-worm worm, the number of transmissions is twice as small as the number of wheel teeth.

Thus, the number of transmissions in worm gears is as follows:

$$U = n_1 / n_2 = z_2 / z_1.$$

here n_1 – the number of revolutions of the wheel, s^{-1};

n_2 – the number of revolutions of the worm, s^{-1};

z_1 – the number of entries of the worm;

z_2 – the number of teeth of the wheel.

The windings of the moving worm slide on the side surface of the wheel teeth. The sliding velocity-V_s is tentatively directed to the screw line of the worm. Its value can be determined using the values of the worm and wheel rotational speeds (Fig. 4).

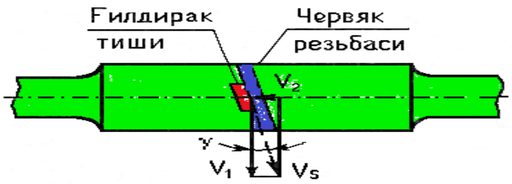

Figure 4. Slip in worm gear.

$$V_S = \sqrt{(V_1^2 + V_2^2)} = V_1 / \cos\gamma$$

where: g is the elevation angle of the worm screw line.

Usually, since g< 30°, V_2 is always smaller than V_1 and V_1 is smaller than V_s. Because of this, the teeth wear out quickly, and the useful work coefficient of the gear is relatively small.

The approximate value of the sliding speed in the design of the extension can be determined as follows:

$$V_S \approx 4{,}3\ n_1\ \sqrt[3]{T_2}\ 10^{-3}\ m/s$$

here: n_1 – the number of revolutions of the worm, s^{-1};

T_2 – torque on the worm wheel shaft, Nm.

The useful work coefficient (f.i.k) of the worm gear is determined as follows:

tgγ / tg(γ+ρ)

So, the f.i.k. of the worm gear can be increased by increasing the pitch angle g of the screw line or decreasing the friction angle r. Usually the worm is the lead, but it is also possible to transmit the movement from the wheel to the worm. In such cases η = *tg*(*γ* +*ρ*) / *tgγ*. It can be seen that if g £ r is taken as h<0. So, in such cases, the movement cannot be transmitted from the wheel to the worm, that is, the transmission becomes a self-braking pair. This feature of the worm gear is used in lifting machines. Since naturally self-braking worm gears have g < r, according to the expression, their f.i.k. it can be at most 0.5.

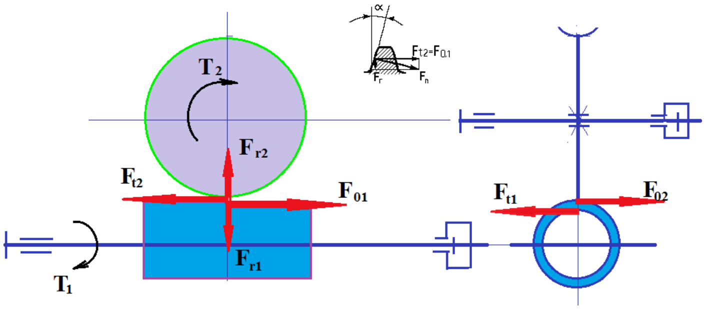

Figure 5. Forces affecting the worm gear.

On the worm and wheel of the working gear, rotational - F_t, radial - F_r and axial forces - F_a appear (Fig. 5).

Circumferential force on the worm: $F_{t1} = 2T_1 / d_1 = F_{a2}$.

Circumferential force on the wheel: $F_{t2} = 2T_2 / d_2 = F_{a1}$.

Radial force in extension: $F_{r2} = F_{t2} \odot tg\,\alpha$.

The torques on the worm and the wheel are interconnected as follows: $T_2 = T_1 \odot U \odot \eta$.

Conclusion. Worm gears are used in many areas of production. When using extensions, it is necessary to pay serious attention to working conditions, prepared materials and the forces applied to the extension. For this reason, it is important to theoretically justify the geometric parameters of the transmission and calculate its kinematic parameters accordingly.

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