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Eccentric device for varying the gear ratio

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Abstract. In the paper is presented the working principle of the device as well as the constructive-functional scheme for its realization. The use of such a device allows variable gear ratios to be obtained in a very wide range. It has the advantage of a compact construction relative to other mechanisms with varying transmission ratios, such as the crank mechanism. The device contains a worm gear that allows for the eccentricity of a toothed wheel in relation to the cone wheel. The worm gear mechanism also ensures that it is self-locking while it is in operation without the need for other insurance items. The device can be used in the control of actuators in the field of machining or packaging in an automated process.

1. General considerations regarding wheel drive with eccentric wheels

Practice demonstrates that there are many situations where a variable gearing ratio is required for ordering assembly or machining processes. Variable gear ratios can be the basis for rotational motion transformation in linear or oscillating displacements with variable speeds,[8].

The realization of these variable or variable gear ratios can also be implemented with camshafts, non-circular wheels (figure 1 and figure 2), but also with eccentric circular wheels. The use of non-circular wheels involves special problems both in design and especially in manufacturing,[1].

Figure 1. Logarithmic non-circular gears.

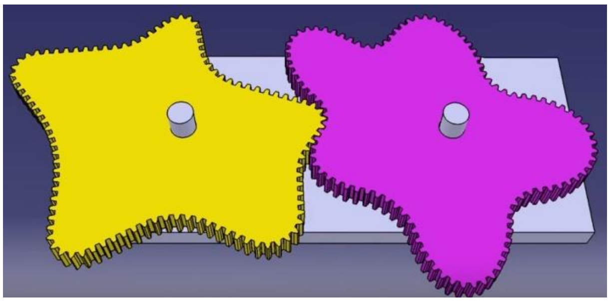

Figure 2. Complex non-circular roots.

The concave non-circular wheels can only be made by copying, a technological process that gives low precision.

The eccentric circular wheels can be run by rolling and centric but also eccentric. In the use of eccentric wheels we studied: circular rings with identical eccentrics, with constant axis spacing

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(figure 3); circular, eccentric, both eccentric or one non-eccentric; the center of rotation of the eccentric wheel moving in a fixed direction (figure 4); circular, non-eccentric and the other eccentric; the center of rotation of the eccentric wheel moving on a trajectory in a circular arc (figure 5),[3].

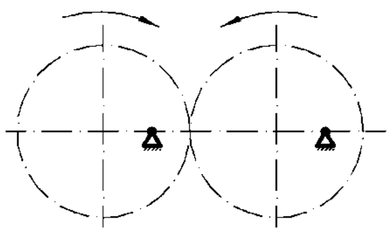

Figure 3. Non-eccentric wheel and eccentric wheel with fixed center of rotation.

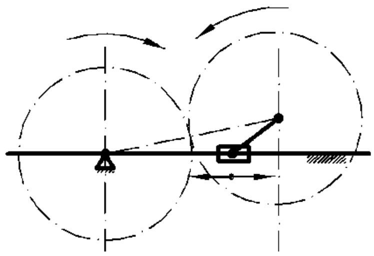

Figure 4.Identical identical eccentric circles with constant axis spacing.

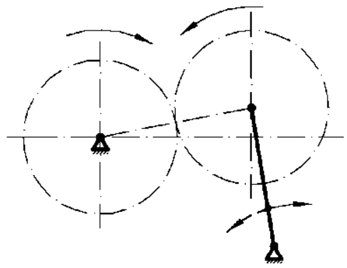

Figure 5. Non-eccentric wheel and eccentric wheel with oscillating center.

2. Determining the mathematical expression of the gear ratio

In order to establish thematic expression of the ratio of gearing, it is considered the case of the engagement between two toothed wheels, one centered and the other one eccentric.

It is also necessary, as a condition of operation, to keep the center of rotation of the eccentric wheel on a fixed line as presented in figure 6,[7].

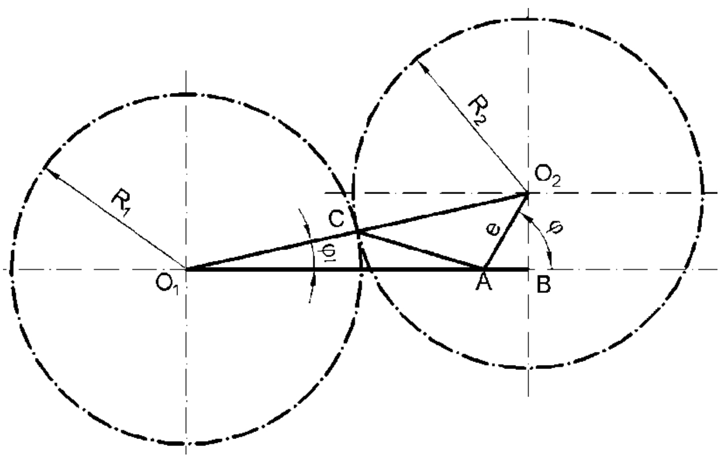

Figure 6. Calculation scheme of the gear ratio for the variant in figure 1.

- O_1A O_2 center wheel as steering wheel with angle;
- O_1 cent wheel as a driven wheel, normal center wheel;
- R_2 - is the radius of the driving wheel;
- R_1 - driven wheel radius;
- the guiding point A moves;
- e represents the wheel eccentricity

It has been admitted that the variable center of wheel 2 is the leading wheel for mathematical approach because the angle can go through the entire trigonometric circle compared to the angle that covers a range.

It can also be mentioned that the two wheels will be permanently in contact at point C located on the line of the O_1O_2 centers and the purpose of establishing the mathematical relationship of the gear ratio has as an intermediate element the determination of the length of the AC segment that will enter the gearing relation as follows,[6]:

Is considered ΔO_1O_2A in which it is noted $\angle O_2O_1A = \varphi_1$ and it results $\angle O_1O_2A=\varphi-\varphi_1$ angle φ_1 can be calculated from ΔO_1O_2B where $O_2B = e \cdot \sin\varphi$ It is obtained, [5]:
$\sin\varphi_1 = \dfrac{e \cdot \sin\varphi}{R_1 + R_2}$ with the particular solution $\varphi_1 = \arcsin\dfrac{e \cdot \sin\varphi}{R_1 + R_2}$ The sinus theorem is applied ΔO_1O_2A

$$\frac{e}{\sin\varphi_1} = \frac{O_1A}{\sin(\varphi - \varphi_1)} \tag{1}$$

$$O_1A = \frac{e \cdot \sin(\varphi - \varphi_1)}{\sin\varphi_1} \text{ getting} \tag{2}$$

$$AC = \sqrt{R_1^2 + O_1A^2 - 2 \cdot R_1 \cdot O_1A \cdot \cos\varphi_1} \tag{3}$$

Into the ΔO_1CA we apply the generalized Pythagoras theorem for calculating the AC segment that will enter the calculation ratio of the gear ratio:

For Mathcad representation of the gear ratio as a function of all the sizes used should be expressed as simple functions or composed of this angle. Thus, the expressions are used, [4]:

$$O_1A(\varphi) = \frac{e \times sin\,(\varphi - \varphi_1)}{sin\varphi_1(\varphi)} \tag{4}$$

$$\varphi\varphi_1(\varphi) = arcsin\frac{e \times sin\varphi}{R_1 + R_2} \tag{5}$$

The angle is the angle of the O_1O_2 center line with the direction of rotation of the center of rotation A. To determine the value range where the variation is located, the derivation of its expression will be made according to:

$$\varphi_1'(\varphi) = \left[\arcsin\frac{e \cdot \sin\varphi}{R_1 + R_2}\right]' = \frac{e}{R_1 + R_2} \cdot \frac{\cos\varphi}{\sqrt{1 - \left(\dfrac{e \cdot \sin\varphi}{R_1 + R_2}\right)^2}} \tag{6}$$

$$AC(\varphi) = \sqrt{R_1^2 + O_1A(\varphi)^2 - 2 \cdot R_1 \cdot O_1A(\varphi) \cdot \cos\varphi_1(\varphi)} \tag{7}$$

For: $e = 25$, $R_1 = R_2 = 50mm$, $\varphi \in \left[0^0, 360^0\right]$, $\varphi_1'(\varphi) = 0$ follows: $\varphi_{1\max} = 14^0 30'$; $\varphi_{1\min} = -14^0 30'$

The gear ratio function becomes: $u_{12}(\varphi) = \dfrac{\omega_1}{\omega_2} = \dfrac{AC(\varphi)}{R_1}$; $u_{21}(\varphi) = \dfrac{\omega_2}{\omega_1} = \dfrac{R_1}{AC(\varphi)}$

where, $u_{1,2}$ is the ratio of the angular speed; $\omega_{1,2}$ the angular speed of the wheels.

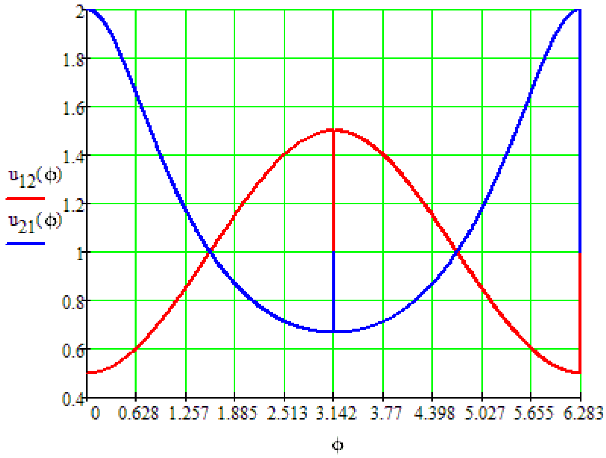

Figure 7. Engagement reports between the two wheels.

The graphs in figure 7 were obtained in the case of driven wheel radius, $R_1 = 50$ mm, the radius of the driving wheel, $R_2 = 50$ mm and wheel eccentricity $e = 25$ mm.

Curves have critical points for $\varphi = \pi$ or $\varphi = 2 \cdot \pi$ points from which the mechanism exits through the action of the motor or as the effect of inertia. The mechanism achieved in practice demonstrates this, in the case of $u_{12} > 1$ and as the speed multiplier on the interval where $u_{12} < 1$. Analog can be concluded for the other expression of the gear ratio. It can also be seen that the mechanism works with the reduction of the angular velocity, on the interval in which the variation of the gear ratio for different eccentricity values (figure 6) and for different values of the radius of the circular wheel without eccentricity (figure 7) is shown below.

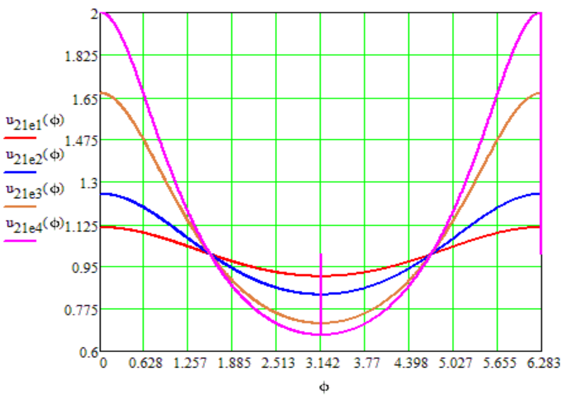

Figure 8. Variation of gear ratio according to eccentricity.

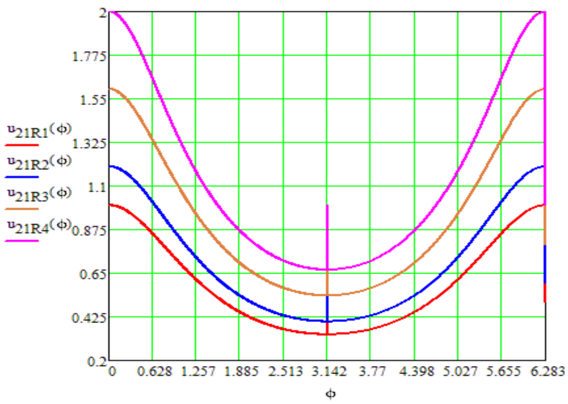

Figure 9. Variation of gear ratio according to centric wheel radius variation.

In figure 8 it is the variation of the drive ratio between two circular wheels with eccentric:

$$R_1 = 50\,\text{mm}; \qquad R_2 = 50\,\text{mm}; \quad e \in \{5; 10; 20; 25\}$$

In figure 9 is the variation of the drive ratio between two circular wheels with eccentric having

$$R_2 = 50\text{mm}; \qquad e = 25\text{mm}; \quad R_1 \in \{5; 10; 20; 25\}$$

The paper presents the working principle of a device as well as its functional scheme. The device allows a variable gear ratio. It consists of two circular gears with eccentric gear, with the possibility to change the eccentricity and the distance between the axes, given the variation of the transmission ratio.

The construction contains a worn gear allowing a fine variation of the eccentricities and implicitly of the transmission ratio. The device can be used in the control drive devices in the process of processing and packaging in an automated process, [9].

3. Construction and operation of the eccentric device

For the practical embodiment of the device, the embodiment of figure 3 it is adopted in which the wheel 2 performs a pivotal movement around a fixed point 1 the center of rotation of the wheel moving after a trajectory in the arch arc,[11].

Wheel 3 it is an eccentric wheel. Its eccentricity is achieved by means of the worm gear consisting of the auger 4 and the worm gear 5. By rotation of the screw fixed on the wheel 3 and the eccentric piece 6, the eccentricity of the wheel is changed. Changing the eccentricity can be done in a continuous range of values.

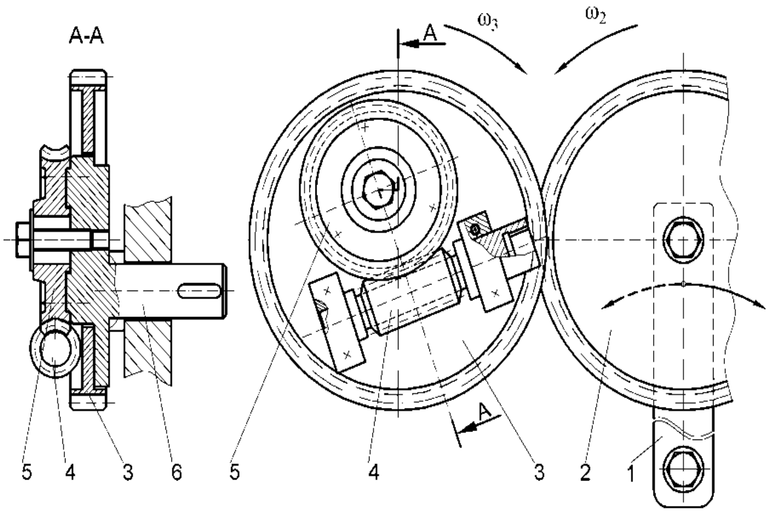

Figure 10. The eccentric wheel drive.

Devices designed to obtain a variable gear ratio can also be used to multiply torque; the reduction of the angular velocity is achieved with torque amplification, [10].

It is well known that the moments are established with the relation:

$$M_t \times \eta \frac{P}{n} \tag{8}$$

where: M_t represents the moment of torsion transmitted by the gear [$N \cdot m$]
P = driving power [kW] and n = speed of rotation [rpm]
η = efficiency (is the friction losses according to the type of gear and the material working conditions. In the case of the device presented in the paper we considered the value of η = 0.98).

It can be seen that the speed reduction with $u_{1,2}$ = 2 leads to the twisting torque multiplying twice. In this assumption, the device can be used both for cinematic purposes and for dynamic purposes, [9].

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4. Conclusions

The use of eccentric cylindrical wheels is a solution for making variable gear ratios used in various areas of machine building or automation of technological processes.

The eccentric cylindrical wheels have the advantage that they can be machined by rolling to produce high productivity and precision. The cost of manufacturing them is reduced compared to that of non-circular wheels or different mechanisms that can perform similar functions.

The physically created device is an original idea of the authors and its practical realization confirms the theoretical support.

The different wear of the tooth surface is due to the variation of speeds, moments, contact forces and bending as well as to the variation of the distance between axes leading to the different wear of the teeth on the same wheel.

With the built model we aim to accelerate some types of degradation such as pinching, exfoliation, grip, cracking and breaking of teeth with and without lubricant.

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