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# DETERMINATION OF KINEMATIC PARAMETERS OF THE BISATELLITE POINT IN A BIPLANETARY MECHANISM

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**Abstract:**This study investigates the kinematic parameters of the bisatellite point in a biplanetary mechanism used in periodic dough mixing machines. Using the motion inversion method, we derive equations for angular velocities, trajectory, speed, and acceleration of the bisatellite point. Computational analysis in MathCAD 15 evaluates the influence of carrier rotation speed on extreme kinematic values, providing insights for optimizing biplanetary drive performance.

**Keywords:** biplanetary mechanism, kinematic parameters, bisatellite, dough mixing machine, motion inversion, angular velocity, trajectory optimization

One of the ways to improve the efficiency of periodic dough mixing machines is the use of a biplanetary mechanism as the drive for the working body. The biplanetary drive of the working body enables high-quality mixing of ingredients to produce the final dough. The work presents various designs of biplanetary drives for working bodies of periodic dough mixing machines. It has been established that the trajectory and kinematic parameters of the bisatellite points play a crucial role in achieving high-quality mixing.
To analyze the kinematics of the biplanetary mechanism, we use the motion inversion method.

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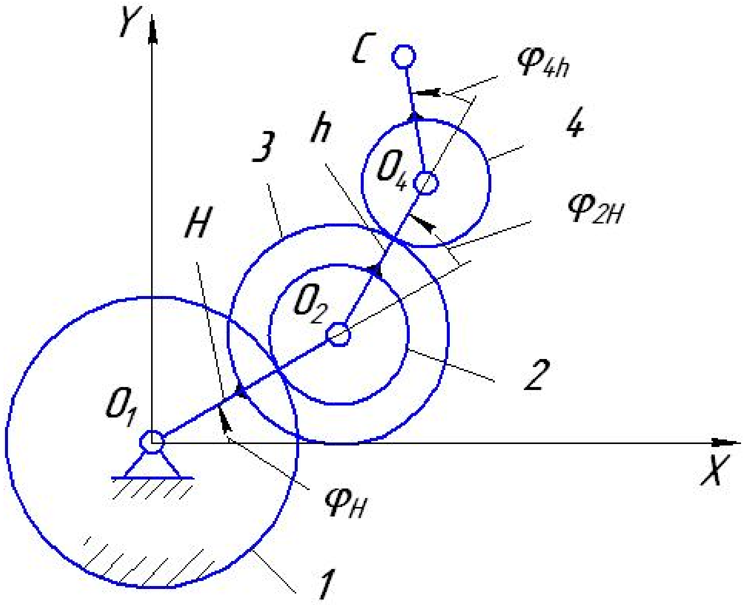


**Fig. 1.** Schematic for deriving of the kinematic equations biplanetary mechanism

For this mechanism (Fig. 1), the following relation can be written

$$u_{4H} = (1 - u_{41}^{(H)})$$

By imparting all links of the mechanism (Fig. 1) with an angular velocity $-\omega_H$, equal in magnitude and opposite in direction to the velocity of the main carrier H, the carrier H becomes stationary, while gear 1 acquires an angular velocity $-\omega_H$. This motion inversion results in a conventional planetary mechanism with two simple gear pairs (1 and 2). Its transmission ratio is:

$u_{41}^{(H)} = u_{21}(1 - u_{43}^{(h)})$ or $u_{41}^{(H)} =-\frac{z_1}{z_2}(1 - u_{43}^{(h)})$

where $(1 - u_{43}^{(h)})$ is the transmission ratio of the satellite planetary mechanism, which can be determined using a second motion inversion applied exclusively to this mechanism.

then $u_{43}^{(h)} =-\frac{z_3}{z_4}$ that $u_{41}^{(H)} =-\frac{z_1}{z_2}(1 + \frac{z_3}{z_4}) =-\frac{z_1}{z_2} - \frac{z_3 z_1}{z_4 z_2}$

Considering this, we can write

$$u_{4H} = (1 + \frac{z_1}{z_2} + \frac{z_1 z_3}{z_2 z_4})$$

Thus, the absolute rotation angle of the bisatellite relative to $O_H$is:

$$\phi_4 = \phi_H \left(1 + \frac{z_1}{z_2} + \frac{z_3}{z_4}\frac{z_1}{z_2}\right)$$

The absolute angular velocity of the bisatellite is $\omega_4 = \omega_H \left(1 + \frac{z_1}{z_2} + \frac{z_1}{z_2}\frac{z_3}{z_4}\right)$ the angular velocity of the bisatellite 4 relative to the bicarrier H is $\omega_{4h} = \omega_H \left(\frac{z_1}{z_2}\frac{z_3}{z_4}\right)$ the angular velocity of the bisatellite 4 relative to the carrier H is $\omega_{4H} = \omega_H \left(\frac{z_1}{z_2} + \frac{z_1}{z_2}\frac{z_3}{z_4}\right)$, and the absolute angular velocity of satellite 2 is $\omega_2 = \omega_H \left(1 + \frac{z_1}{z_2}\right)$.

Proceeding to the kinematics of the biplanetary mechanism, based on, the kinematic equations for point "C" of the bisatellite in the biplanetary mechanism can be written as:

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$$x_c(t) = A\cos(\omega_H t) + B\cos(k_1\omega_H t) + D\cos(k_2\omega_H t);$$
$$y_c(t) = A\sin(\omega_H t) + B\sin(k_1\omega_H t) + D\sin(k_2\omega_H t),$$

where $k_1 = u_{2H} = \left(1 - u_{21}^{(H)}\right)$ or $k_1 = \left(1 + \frac{z_1}{z_2}\right)$

$$k_2 = u_{4H} = \left(1 - u_{21}^{(H)} - u_{43}^{(h)}\right) = \left(1 + \frac{z_1}{z_2} + \frac{z_1}{z_2}\frac{z_3}{z_4}\right)$$

$r_1, r_2, r_3, r_4$ - are the pitch circle radii of gears 1, 2, 3, 4.

The velocities $v_C$ of point "C" of bisatellite 4 are determined by:

$$v_{cx} = -A\omega_H \sin(\omega_H t) - Bk_1\omega_H \sin(k_1\omega_H t) - Dk_2\omega_H \sin(k_2\omega_H t);$$
$$v_{cy} = A\omega_H \cos(\omega_H t) + Bk_1\omega_H \cos(k_1\omega_H t) + D\omega_H k_2 \cos(k_2\omega_H t).$$

The absolute velocity of point "C" of bisatellite 4 is:

$$v_c = \sqrt{\left(\frac{dy_c}{dt}\right)^2 + \left(\frac{dx_c}{dt}\right)^2} = \sqrt{v_{cx}^2 + v_{cy}^2}$$

Similarly, the acceleration of point "C" of bisatellite 4 is determined by:

$$a_{cx} = -A\omega_H^2 \cos(\omega_H t) - Bk_1^2\omega_H^2 \cos(k_1\omega_H t) - Dk_2^2\omega_H^2 \cos(k_2\omega_H t);$$
$$a_{cy} = -A\omega_H^2 \sin(\omega_H t) - Bk_1^2\omega_H^2 \sin(k_1\omega_H t) - D\omega_H^2 k_2^2 \sin(k_2\omega_H t),$$

and the absolute acceleration of point "C" of bisatellite 4 is:

$$a_c = \sqrt{\left(\frac{d^2x_c}{dt^2}\right)^2 + \left(\frac{d^2y_c}{dt^2}\right)^2} = \sqrt{a_{cx}^2 + a_{cy}^2}$$

The equations describing the kinematic characteristics of the biplanetary mechanism for the drive of a periodic dough mixing machine were implemented on a computer using MathCAD 15.

To study the influence of carrier rotation speed on the kinematic parameters of the bisatellite point, we determined the extreme values of velocities and accelerations $v_{max}, v_{min}, a_{max}, a_{min}$, and the oscillation ranges $H_v = v_{max} - v_{min}$, $H_a = a_{max} - a_{min}$ as shown in Table 1.

**Table 1.**

Kinematic characteristics of the bisatellite point "C"

| №/n | Variation of the carrier rotation speed for point "C" of the bisatellite. | | | | | | |
|---|---|---|---|---|---|---|---|
| | $n_H$, (rpm) | $v_{max}$ (m/s) | $v_{min}$ (m/s) | $H_v$ (m/s) | $a_{max}$ (m/s²) | $a_{min}$ (m/s²) | $H_a$ (m/s²) |
| 1 | 20 | 3,11 | 0,34 | 2,77 | 49,15 | 18,49 | 30,66 |
| 2 | 30 | 4,67 | 0,51 | 4,16 | 110,6 | 41,6 | 69 |
| 3 | 40 | 6,22 | 0,68 | 5,54 | 196,6 | 73,6 | 123 |

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|---|---|---|---|---|---|---|---|
| 4 | 50 | 7,78 | 0,85 | 6,93 | 307,2 | 115,5 | 191,7 |
| 5 | 60 | 9,33 | 1,02 | 8,31 | 442,4 | 166,4 | 276 |

he obtained results are currently used to determine rational parameters for the biplanetary drive of working bodies in periodic dough mixing machines.

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