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KINEMATICS, WORKING PARAMETERS AND MODES OF SWING-TYPE DIGGING SHARE OF ELEVATOR-TYPE POTATO COMBINE

Abstract

The article presents an analysis of the kinematics, working parameters and modes of operation of swing-type digging share with elliptical profile cutting edge, and opportunities for rational operating regime adjustment of the working body under the conditions of operation. Expressions are derived and an analysis of kinematics, working and regime parameters of the swing-type share with elliptical cutting edge is given.

1. Introduction

The development of means of mechanization in agriculture has resulted in the creation of tractor units realizing new technological and design concepts, overlapping technological operations, provided with multipurpose hook-on machines of modular design for a set of certain regular applications of new active working bodies (AWB) (Furletow 1981, Opiejko 1968, Tanas 2001).

This trend is also realized in the development of a universal elevator-type potato combine, differing from those used so far in the use of the sideways swing design of the digging share. Application of such an AWB permitted improved functionality and reliability of the combine at work (Lisowski 1998a and 1998b, Zaltzman and Schmilovitch 1986).

As tests have shown, the efficiency of a combine depends on the correct choice of design and work regime parameters of the digging share. In connection with this, an analysis of various aspects of the working process of such a share is of interest, with the purpose of determining its laws and developing engineering recommendations for the choice of rational parameters of such an AWB (Abrams et al. 1980, Bujaszow and Tanas 2000, Hyde et al. 1983).

In this work, the features of kinematics of the sideways swing-type digging share have been considered, which allowed the formulation of some recommendations concerning the choice of the design and work regime parameters of such shares and identification of various possibilities of their practical selection and combination for optimum operational setting of the share drive.

2. Kinematics of swing-type share with elliptical cutting edge

Let us define the current coordinates of points on the share edge during combine movement on the working path.

In the $X_1O_1Y_1$ system of coordinates (see Fig. 1) the equation of an ellipse is:

$$\frac{X_1^{\,2}}{a^2} + \frac{Y_1^{\,2}}{b^2} = 1; \tag{1}$$

In the $X_1O_1Y_1$ system of coordinates (parallel axes) we have:

$$\begin{cases} X_2^* = X_1 - C_x; \qquad C_x = 0; \\ Y_2^* = Y_1 + C_y; \end{cases} \tag{2}$$

hence:

$$\begin{cases} X_1 = X_2^* - C_x; \\ Y_1 = Y_2^* - C_y; \end{cases} \tag{3}$$

Substituting (3) in (1)

$$\frac{(X_2^* - C_x)^2}{a^2} + \frac{(Y_2^* - C_y)^2}{b^2} = 1 \tag{4}$$

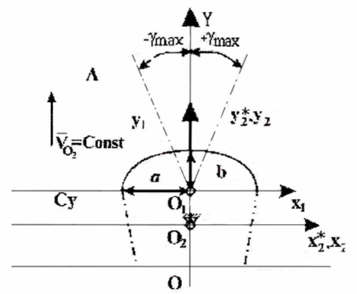

Fig. 1. Schematic diagram of movement of the swing-type share

As the share swings within system $X^*_2O_2Y^*_2$ relative to point O_2 (turn of axes) in the system $X_2O_2Y_2$ by an angle γ , we receive:

$$\left.\begin{aligned} X_2 &= X_2^* \cos\gamma_t - Y_2^* \sin\gamma_t; \\ Y_2 &= X_2^* \sin\gamma_t - Y_2^* \cos\gamma_t; \end{aligned}\right\} \quad \left.\begin{aligned} X_2^* &= X_2 \cos\gamma_t + Y_2 \sin\gamma_t; \\ Y_2^* &= X_2 \sin\gamma_t + Y_2 \cos\gamma_t; \end{aligned}\right\} \tag{5}$$

Let us substitute expressions (5) in (4) and we shall receive:

$$\frac{(X_2 \cos\gamma_t + Y_2 \sin\gamma_t - C_x)^2}{a^2} + \frac{(-X_2 \sin\gamma_t + Y_2 \cos\gamma_t - C_y)^2}{b^2} = 1 \tag{6}$$

At $V \neq 0$, at the moment of time t, coordinate $X_{2i} = X_i$, and coordinate $Y_i = Y_{2i} + V \cdot t$, then in the motionless system XOY we have:

$Y_2 = (Y - V \cdot t)$

$$\frac{\left[X \cos\gamma_t + (Y - V \cdot t) \cdot \sin\gamma_t - C_x\right]^2}{a^2} + \frac{\left[-X \sin\gamma_t + (Y - V \cdot t) \sin\gamma_t - C_y\right]^2}{b^2} = 1 \tag{7}$$

$X_{\max}(t) = a \cdot \cos\gamma_t;$

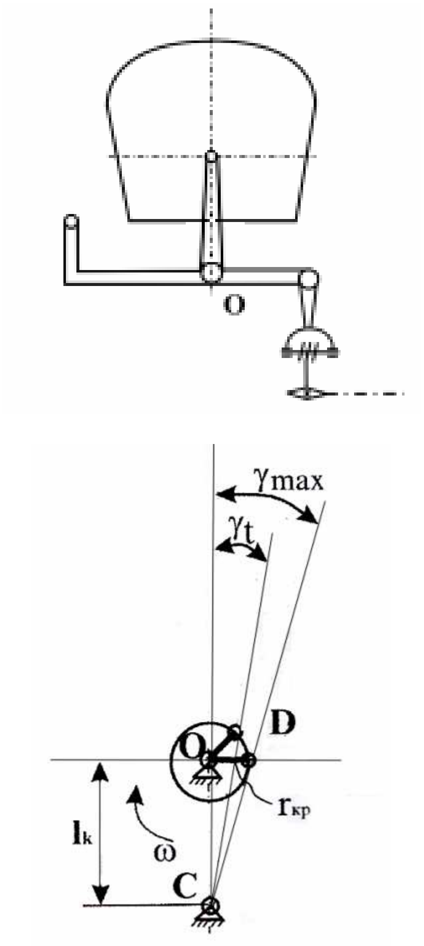

Fig. 2. Schematic diagram of a variant of the swing-type share drive

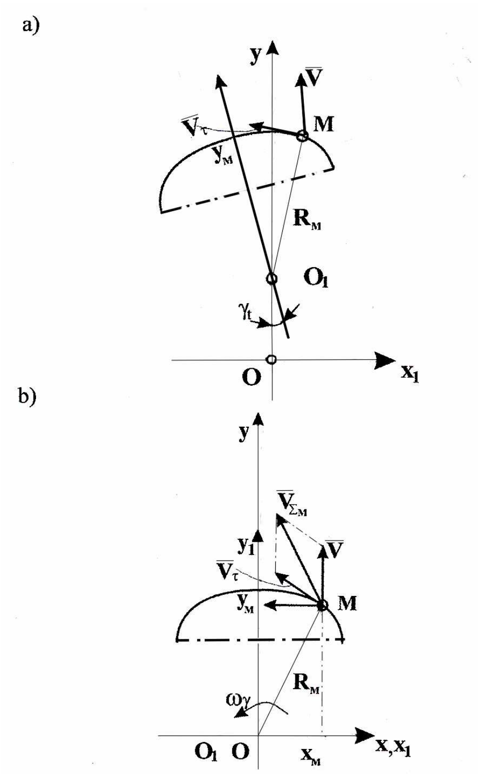

Fig. 3. Schematic diagrams of swing-type share movement

Angle γ_t at the moment of time t is defined by the parameters of the share drive and the frequency of swing motions (oscillations) ω of the share (see Fig. 2 b).

In this case of the drive mechanism considered:

$$K_{np} = \frac{r_{kp}}{l_k};\ l_k = \frac{r_{kp}}{K_{np}};\quad \varphi_t = \omega \cdot t;$$

From ΔOBD: OB = $r_{\kappa p.}\cos\varphi_i$; BD = $r_{\kappa p.}\sin\varphi_i$; From ΔCBD:

$$\text{tg}\,\gamma_t = \gamma_{\max} = arc\sin K_{\kappa p.} = arc\sin\frac{r_{\kappa p.}}{l_{\kappa.}};$$

$$\text{tg}\,\gamma_t = \frac{BD}{BC} = \frac{BD}{BO+OC} = \frac{r_{kp}\sin\varphi_t}{r_{kp}\cos\varphi_t + k} = \frac{r_{kp}\sin\varpi\cdot t}{r_{kp}\cos\varpi\cdot t + l_k}; \quad (8)$$

$$\gamma_t = arc\,\text{ctg}\left(\frac{r_{kp}\sin\varpi\cdot t}{r_{kp}\cos\varphi_t + l_k}\right) \quad (9)$$

$$\gamma_{\max} = arc\sin K_{\kappa p.} = arc\sin\frac{r_{kp}}{l_k} \quad (10)$$

Let us consider the trajectory of a point M on the contour of the cutting edge. At t = 0 and γ_t = 0 we determine coordinates of point M: X_M and Y_M, fulfilling equation (8). We have point M which participates in two movements: 1) relative, around the centre O_1 of mobile system X_1OY_1 with frequency ω and amplitude $\gamma_{\max}$; 2) translatable, with centre O_1 in system XOY, with speed V = const along axis OY.

From Fig. 3 a) we have:

$$R_M = \sqrt{X_M^2 + Y_M^2};\quad \omega_\gamma = \frac{d\gamma_t}{dt} = \frac{d}{dt}\left(arc\,\text{ctg}\frac{r_{kp}\sin\omega t}{r_{kp}\cos\omega t + l_k}\right); \quad (11)$$

In Fig. 3 b) it is visible that $V_\tau = \omega_\gamma \cdot R_M$.
At any moment of time t, $\gamma = \gamma_t$, then

$$\left.\begin{aligned} X &= X_M\cos\gamma_t - Y_M\sin\gamma_t;\\ Y &= (X_M\sin\gamma_t + Y_M\cos\gamma_t) + Vt;\\ \gamma_t &= aarctg\left(\frac{r_{kp}\sin\omega t}{r_{kp}\cos\omega t + l_k}\right); \end{aligned}\right\} \quad (12)$$

Expression (12) is also the required equation of movement of point M during work of the swing-type share. Changing t, it is possible to construct diagrams of change of coordinates $X(t)$, $Y(t)$, $\gamma_t(t)$ of any point of the share cutting edge.

3. Results of calculations of kinematics of the swing-type share

For the start position before the beginning of movement of the digging unit the coordinates of i-points of the share edge are given in Table 1.

Changes of coordinates of some points of the share edge during the movement of the digging unit, obtained with the use of the MathCAD program, are presented in Figs. 4 - 6. At the initial data:

Coordinates of the point (0,26; 0,1) change as follows (see fig. 4):

v:= 1.8; r_k:=0.05; l_k:=0.12; w:= 15.0 x_m:= 0.26; y_m:= 0.1

At a change of frequency of share oscillations we shall receive the following picture of change of the coordinates of the same point on the share.

The qualitative character of the change of kinematic characteristics of movement of points of the swing-type share edge at the change of parities of the work regime parameters of the share (speed of the unit, frequency of oscillation, maximum angle of swing) can be seen in the diagrams in Fig. 6.

From the diagrams it follows that the longitudinal absolute speed of the chosen point of the edge of the swing-type share has periods of movement with negative speed.

With an increase in the speed of movement of the unit at constant frequency of share swing motion, or with constant speed of movement of the harvesting unit at reduced frequency of the share oscillations (see Fig. 6 a) it is possible to change the intensity of undercutting the ridge and weed roots by the share.

Table 1. Coordinates of points of the initial position of the share edge

№ i- point	1	2	3	4	5	6	7	8	9	10	11
X,м	0.3	0.29	0.294	0.286	0.275	0.260	0.240	0.214	0.168	0.110	0.0
Y,м	0	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20

$$x = xm\cdot\cos\left[a\tan\left(\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}\right)\right] - ym\cdot\sin\left[a\tan\left(\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}\right)\right]$$

$$y = xm\cdot\sin\left[a\tan\left(\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}\right)\right] + ym\cdot\cos\left[a\tan\left(\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}\right)\right] + v\cdot t$$

$$\gamma = a\tan\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}$$

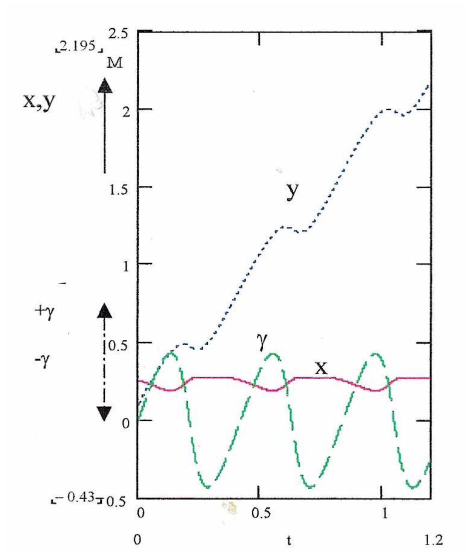

Fig. 4. Change of coordinates of some points on the share edge during movement of the harvest unit

$$x = xm\cdot\cos\left[a\tan\left(\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}\right)\right] - ym\cdot\sin\left[a\tan\left(\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}\right)\right]$$

$$y = xm\cdot\sin\left[a\tan\left(\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}\right)\right] + ym\cdot\cos\left[a\tan\left(\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}\right)\right] + v\cdot t$$

$$\gamma = a\tan\frac{rk\cdot\sin(w\cdot t)}{rk\cdot\cos(w\cdot t)+lk}$$

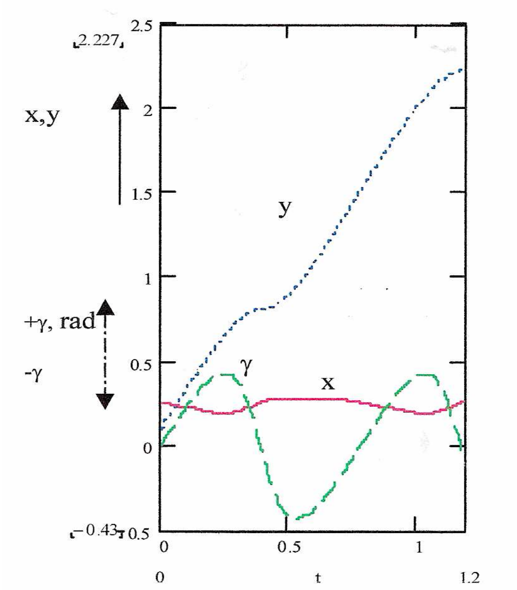

Fig. 5. Change of coordinates of points on the share edge during movement of the harvest unit

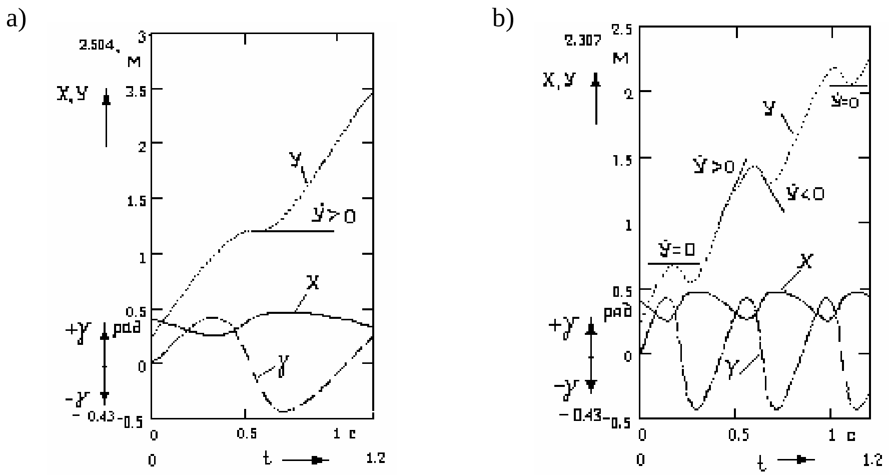

Fig. 6. Changes of kinematic characteristics of movement of the points on the share edge

By differentiating values of X, Y, γ_t in time we shall receive projections to coordinate axes of speeds and acceleration of point M and its angular acceleration in the function of time, which is necessary for the process of dynamic modelling of the swing-type share motion.

Trajectories of endpoints of diameters of the elliptic contour of the share edge have a harmonic character. At t = 0: for the median point on the share edge, designated with letter M: X_M =0; $Y_M = b$; for the extreme point T located on the end of the greater diameter of the ellipse of the edge of the share: $X_T = a$; Y_T = 0.

From relation (12), the changes of coordinates X of the points are defined by the expressions:

– point M: $x = -b \cdot \sin \gamma_t \pm X_{M\max} = \pm\, b \cdot r_{кр}/l_k$;
– point T: $x = a \cdot \cos\gamma_t$; $\pm X_{t\max} = \pm\, a \cdot \cos(\arcsin(r_{кр}/l_k))$;

The character of the movement of points on the contour line in the 1st plane, parallel to the vector of speed V of moving the unit, whose equation is X_i = const = d, shall be defined from the expressions (8) and (9), having substituted for X the value $X_i = d$.

The value of X_i varies from $-a$ to $+a$.

$$\left.\begin{aligned} &\frac{[d\cos\gamma_t + (y - Vt)\sin\gamma_t - C_x]^2}{a^2} + \frac{[(y - Vt)\cos\gamma_t - d\sin\gamma_t - C_y]^2}{b^2} = 1 \\ &\gamma_t = arctg(r_{кр} \cdot \sin wt)/(r_{кр} \cdot \cos wt + l_к) \end{aligned}\right\} \quad (13)$$

The periodic and non-linear dependence follows from the expressions (13) and causes a sign-variable acceleration of points on the share in the direction of the movement of the machine. Thus the amplitudes of this acceleration grow with increasing deflection from axis OY. Similar statement is true and typical for the contour of the share accelerations. It means that the intensity of shock of undercutting the ridge and roots and stalks of weeds by the edge of the share grows with the removal of the contour points from the axis of oscillation and from the plane of its symmetry, and also with increase in the frequency and amplitude $\gamma_{\max}$ of the swing motions.

Rational combinations of the design (a, b, c_x, c_y) and work regime parameters (V, w, $\gamma_{\max}$) of the swing-type share operation are determined by the following conditions: 1 – maintenance of constant width and straightness of the soil strip shifted by the share; 2 – maintenance of swing mode of cutting at all the points of the share; 3 – maintenance of the necessary amplitude and sign of accelerations at any point on the width of strip covered by the share in longitudinal plane for the achievement of cleanliness of cutting and to avoid cut fragments of plants being dragged by the share.

4. Conclusions

The developed approach to the definition of the kinematic characteristics of swing-type share is suitable for any configuration of share edge and coordinates of the poles of its angular swing motion.

On the basis of the received results, drive systems of the developed shares, permitting in-operation adjustments or continuous regulation of the work regime parameters in the function of speed of movement and parameters of conditions of harvest which characterize the condition of the soil, its fertility and contamination with weeds, were developed and tested under natural conditions.

5. References

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