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Stability of the Motion of the Plow for a Smooth Flash with a Class 0.9 Tractor

Mamatov F.M., Ravshanov H.A., Babajanov L.K., Kurbanov Sh.B., Chorieva D.N.

Professor, Karshi Engineering-Economics Institute (KIEI), Karshi, Uzbekistan
Senior Researcher, Karshi Engineering-Economics Institute (KIEI), Karshi, Uzbekistan
Senior Researcher, Tashkent Institute of Irrigation and Mechanization Engineers, Tashkent, Uzbekistan
PhD researcher, Karshi Engineering-Economics Institute (KIEI), Karshi, Uzbekistan
Master student, Karshi Engineering-Economics Institute (KIEI), Karshi, Uzbekistan

ABSTRACT. The single-body plow carries out smooth plowing with reversal of the formation within its furrow. The aim of the study is to study the stability of the movement of the plow with a tractor of class 0.9. For the analysis of the straight-line movement of the unit consisting of a single-body plow and a tractor, the equation of the plow angular oscillations relative to the tractor has been compiled and solved. It is revealed that the oscillation of the plow in the horizontal plane consists of its own and forced. Forced oscillations are sustained harmonic oscillations with a frequency equal to the frequency of the disturbing force. With a longitudinal distance between the body ploughshare and the frame 0-20 m and the installation of the support wheel in front of the plow body, the required horizontal stability of the unit movement is ensured.

KEYWORDS. Plow, body, tractor, smooth plowing, motion stability, angular oscillation, rectilinear motion.

I. INTRODUCTION

In recent years, in the Republic of Uzbekistan, class 0.9 tractors have been widely used in horticulture and farms with small-contour plots. In this regard, research work is underway to create a set of agricultural machines, including plows for these tractors.

II. SIGNIFICANCE OF THE SYSTEM

The article presents the results of studies on the stability of the movement of a single-body plow for smooth plowing with a tractor of class 0,9. The study of literature survey is presented in section III, methodology is explained in section IV, section V covers the experimental results of the study, and section VI discusses the future study and conclusion.

III. LITERATURE SURVEY

It is known that in order to stabilize the process of plowing, the force effect of the plow on the tractor should not lead to the appearance of a moment deflecting it from straight-line movement. [1, 2, 3].

When the machine is working, the plow in the horizontal plane simultaneously with the translational movement makes angular oscillations (due to the inconstancy of the acting forces) relative to the tractor around the instantaneous center of rotation, which contributes to the violation of the straightness of the movement of the arable farm and the deterioration of the uniformity of travel across the width [2, 3]. In this case, the smaller the deviation of the plow from the equilibrium state, the better the stability of the rectilinear movement of the unit and the uniformity of the width of the plow, and vice versa.

IV. METHODOLOGY

In the studies applied methods of theoretical mechanics and agricultural mechanics.
To analyze the straight-line movement of an aggregate consisting of a single-body plow for smooth plowing and a tractor, we compose and solve the equation of angular oscillations of the plow relative to the tractor. In this case, the

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point *B*, located at the end of the field board of the plow body, makes forced oscillations relative to the instantaneous center of rotation (point *O*) of the unit (Fig. 1).

V. EXPERIMENTAL RESULTS

Let in the current position the line OA_1 is deflected at an angle φ from the line OA and has an angular velocity $\omega_{OA} = \dot{\varphi}$. As a generalized coordinate of the plow, we take the angle φ and compose the differential equation of its oscillations relative to the instantaneous center of rotation (ICR) in the *XOY* plane in the form of the Lagrange second-order equation [1]

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{\varphi}}\right) - \frac{\partial T}{\partial \varphi} = Q_{\varphi}, \quad (1)$$

where T – is the kinetic energy of the plow during rotational motion; Q_{φ} – is the generalized resistance force of the working bodies.

The generalized force Q_{φ} is defined as the sum of the moments of forces relative to a single-body plow for smooth plowing (ICR), i.e. $Q_{\varphi}=\sum M_o$.

The kinetic energy of the plow is defined as [1]

$$T = \frac{1}{2} J_n \dot{\varphi}^2, \quad (2)$$

where J_n –is the moment of inertia of the plow relative to the ICR;

When differentiating, equation (2) will take the following form

$$J_n \ddot{\varphi} = Q_{\varphi}. \quad (3)$$

The generalized force Q_{φ} of resistance of the working bodies of the plow is equal to the sum of moments relative to the ICR. All forces acting on the hull, arrester and support wheel are assumed to be constant, and we consider the reaction of the furrow wall to the field board as elastic-viscous [1, 2, 3].

Assuming a linear relationship between the movement of the field board y and the generalized coordinate φ, the furrow wall reaction can be represented as $N_y = (c\dot{\varphi} + \delta\varphi)$ [1, 2, 3], where c and δ – are the reduced viscosity and elasticity coefficients characterizing the resistance of the soil deformation.
When a disturbance of the $\sin\omega t$ type occurs, the generalized resistance force of the plow takes the following form (Fig. 1):

$$\begin{aligned} Q_{\varphi} = &-(c\ddot{\varphi} + \delta\varphi)(L_p + l_p + l_K - fY_K) + [R_X(Y_k + l_p) + R_Y(L_n + l_K + l_R ctg\gamma) + \\ &+ S_X(Y_K + b_K - \rho) - S_Y(L_n + l_K + l_Z) + Q_X(Y_Q - Y_K)]\sin\omega t \end{aligned} \quad (4)$$

where R_x, R_y, S_Y and S_X – are the horizontal components of the forces of the reaction of the soil to the body and backlit plow, H; b_K – width of the body grip, m; Y_Q – is the transverse coordinate of the support wheel relative to the field edge of the hull, m; γ – is the angle of the blade of a plowshare with the furrow wall; Q_x – wheel rolling resistance force, N.

Denoting $(L_n+l_p+l_Л-fY_K)=l$ formula (4) we bring to the simplest form

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$$Q_{\varphi} = -[(c\dot{\varphi} + \delta\varphi)l - M\sin\omega t]. \qquad (5)$$

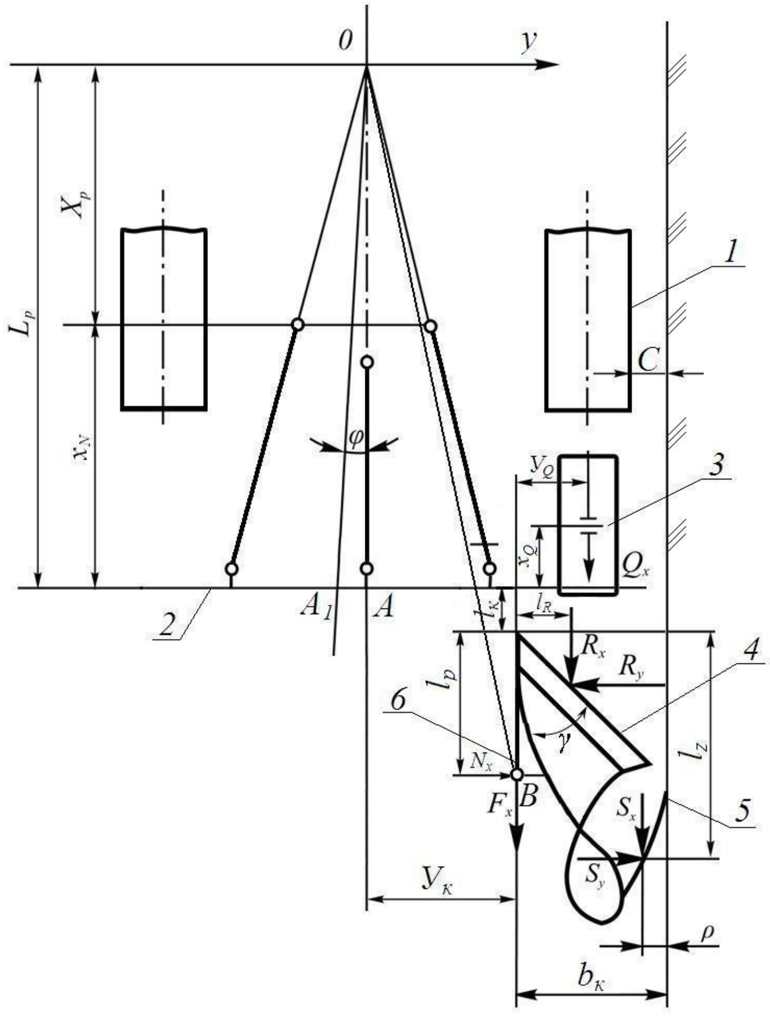

Fig.1. The design scheme of a single-body plow with a tractor in a horizontal plane:

1 - a tractor; 2 - plow frame; 3 - support wheel; 4 - case; 5 - the hedgehog; 6 - field board

Substituting (5) into (3), we get

$$J_n\ddot{\varphi} + c\dot{\varphi}l + \delta\varphi l = M\sin\omega t. \qquad (6)$$

Dividing both sides of formula (6) by J_n, we find:

$$\ddot{\varphi} + 2b\dot{\varphi} + k^2\varphi = M_0\sin\omega t, \qquad (7)$$

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where $2b = cl / J_n;\ k^2 = \delta l / J_n;\ M_0 = M / J_n.$

It is known that the differential equation (7) has a general solution in the form $\varphi = \varphi_1 + \varphi_2$, where φ_1 – is the general solution of equation (7) without the right side; φ_2 – is a particular solution of the equation.

The particular solution is represented as [1, 2, 3]

$$\varphi_2 = A\sin(\omega t - \beta),$$

where A and β – are constant.

From this equation, by deriving the time derivative and substituting the values of the derivatives in equation (7) after some transformations, you can determine [2, 3]

$$A = \frac{M_0}{\sqrt{(k^2 - \omega^2)^2 + 4b^2\omega^2}};\ tg\beta = \frac{2b\omega}{k^2 - \omega^2}. \quad (8)$$

Since $\varphi = \varphi_1 + \varphi_2$, a value φ_1 (when $k > b$) is determined by equality $\varphi = de^{-bt}\sin(k_1 t + \alpha)$, then finally the solution of equation (7) has the following form

$$\varphi = de^{-bt}\sin(k_1 t + \alpha) + A\sin(\omega t - \beta), \quad (9)$$

where d, α – are the integration constants determined by the initial conditions ($k_1 = \sqrt{k^2 - b^2}$).

The oscillation of a single-body plow in the horizontal plane is complex and consists of its own (the first term of equality (9)) and the forced one (the second term of equality (9)). Own oscillations of the plow die out rather quickly and can practically be neglected. Forced oscillations are undamped harmonic oscillations with amplitude A and frequency ω, equal to the frequency of the disturbing force. The value of β characterizes the shift of forced oscillations with respect to the phase of the disturbing force.

According to the formula obtained, an algorithm and a computer program were compiled. Analysis of the calculation results shows (Fig. 2) that with a longitudinal distance between the body ploughshare and the frame, equal to 0,10 m, and an initial amplitude of 0,055 m, the maximum angle of oscillation of the plow is 1°05′, and within 4 seconds they fade away, for this the time the unit will be 4,5-5,5 m.

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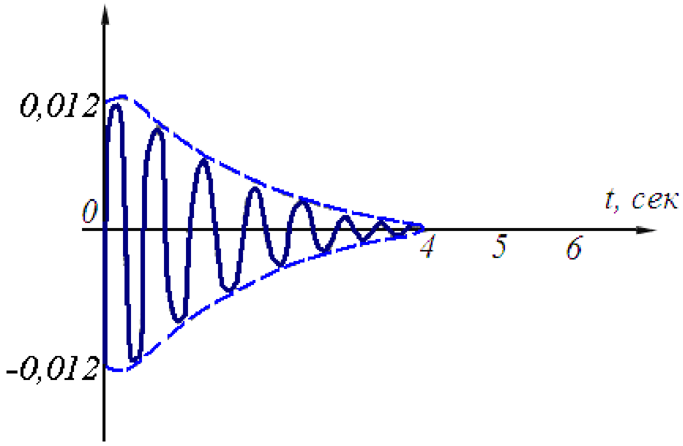

Fig.2. Attenuation of the plow during the time

Thus, as the calculations show, in the case when the longitudinal distance between the body ploughshare and the frame is 0-20 m and the support wheel is installed in front of the plow body, the magnitude of the generalized force M_c will be minimal. In this case, the amplitude of oscillations A will also be minimal. Therefore, the horizontal stability of the movement of the aggregate is improved. With a longitudinal distance between the frame and the body of more than 0,20 m, the straightness of the movement of the unit is violated. This is due to the increase in the amplitude of oscillations A.

V. CONCLUSION AND FUTURE WORK

It has been established that the oscillation of a single-body plow in the horizontal plane consists of its own and forced one. Forced vibrations of the plow are undamped harmonic oscillations with a frequency equal to the frequency of the disturbing force. With a longitudinal distance between the body ploughshare and the frame 0-20 m and the installation of the support wheel in front of the plow body, the required horizontal stability of the unit movement is ensured.

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