# CALCULUS OF THE WORK PARAMETERS OF THE SOIL DIGGING MACHINES

# CALCULUL PARAMETRILOR DE LUCRU LA MAŞINILE DE SĂPAT SOLUL

**BARBU GRECU, VICTOR MOISE, GEORGE ADIR, GHEORGHE VOICU**

*University POLITEHNICA of Bucharest, Romania*

***Abstract.*** *In this paper, the driving mechanism of the soil digging machine operating element is analyzed from the point of view of geometry and kinetics. It is an articulated quadrangle, of which leading element is the shaft crankpin. The paper determines the parameters specific to the plane parallel motion-paths, rates which ascertain the mode of operation of the mattock and of the soil digging machine with driving elements in plane motion.*

***Rezumat:*** *În lucrare, se analizează din punct de vedere geometric şi cinematic elementul de execuţie al mecanismului maşinii de săpat solul. Acesta se prezintă sub forma unui patrulater articulat, al cărui element conducător este arborele cotit. Lucrarea stabileşte parametrii specifici ai traiectoriilor mişcării plan-paralele, vitezele care determină modul de acţionare al sapei şi, respectiv, al maşinii de săpat solul cu elemente în mişcare plană.*

***Key words****: mechanism, kinetic, equation of the rod curve, skeleton diagram of the mattock.*
***Cuvinte cheie:*** *mecanism, cinematică, ecuaţiile curbei de bielă, diagrame de lucru.*

## MATERIALS, METHODS AND EXPERIMENTAL PROCEDURES

The skeleton diagram of the mattock driving mechanism is shown in figure 1. The driving element of the mechanism with articulated quadrangle is the crankpin 1 of the shaft, driven with a constant speed from the tractor power plug, by a conic gear transmission. All the machine mattocks, laid out on its working width, are driven from this shaft, by mechanisms which are similar from the point of view of their construction. The shaft bends are shifted adequately, in relation with the number of operating elements. The operating element - the mattock, of trapezoidal form, is fixed at the tip of rod 2.

### a. PATHS OF THE OPERATING ELEMENTS POINTS

The path of a point on the mattock, which belongs to rod 2 (fig. 1), that is the path of a point on the rod, is a rod curve of sixth degree, generally. The support curve equation may be expressed under the general form of the power polynom [3] or under the parametric form.

The equation of the rod curve for point T (fig. 1) - the mattock nib, under parametric form, is derived from the projection equations of the quadrangle mechanism outline:

$$\begin{aligned} AB\cos\varphi_1 + BC\cos\varphi_2 &= X_D + DC\cos\varphi_3 \\ AB\sin\varphi_1 + BC\sin\varphi_2 &= Y_D + DC\sin\varphi_3 \end{aligned} \qquad (1)$$

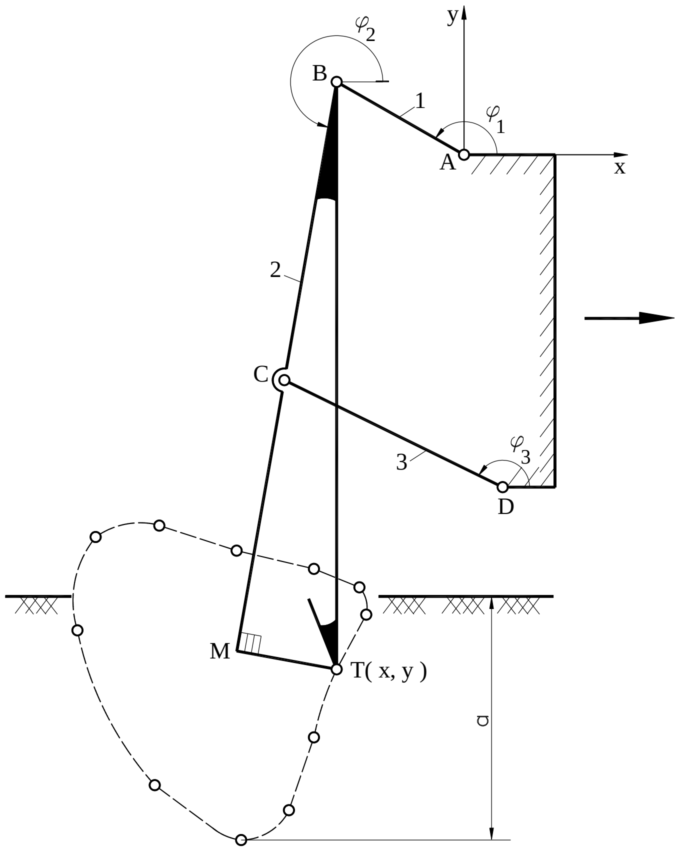

Figure 1. Scheme of mattock mechanism

and from the coordinates of point T(x,y):

$$x = AB\cos\varphi_1 + BM\cos\varphi_2 - MT\sin\varphi_2$$
$$y = AB\sin\varphi_1 + BM\sin\varphi_2 + MT\cos\varphi_2 \tag{2}$$

From relations (1), by eliminating the $\varphi_3$ parameter, an equation in $\varphi_2$ is obtained, that is:

$$(AB\cos\varphi_1 - X_D)^2 + 2(AB\cos\varphi_1 - X_D)BC\cos\varphi_2 + BC^2 +$$
$$+ (AB\sin\varphi_1 - Y_D)^2 + 2(AB\sin\varphi_1 - Y_D)BC\sin\varphi_2 = DC^2 \tag{3}$$

By arrangement, equation (3) becomes:

$$K_1\cos\varphi_2 + K_2\sin\varphi_2 = K_3 \tag{4}$$

where:

$$K_1(\varphi_1) = 2(AB\cos\varphi_1 - X_D)BC$$
$$K_2(\varphi_1) = 2(AB\sin\varphi_1 - Y_D)BC$$
$$K_3(\varphi_1) = -(AB\cos\varphi_1 - X_D)^2 - BC^2 - (AB\sin\varphi_1 - Y_D)^2 + DC^2$$

Solutions of equation (4) are:

$$\sin\varphi_2 = \frac{K_2K_3 \pm K_1\sqrt{K_1^2 + K_2^2 - K_3^2}}{K_1^2 + K_2^2} \tag{5}$$

or

$$\cos\varphi_2 = \frac{K_1K_3 \pm K_2\sqrt{K_1^2 + K_2^2 - K_3^2}}{K_1^2 + K_2^2} \tag{6}$$

By substitution of angle $\varphi_2$, one obtains the rod curve given by the parametric equations $x(\varphi_1)$ and $y(\varphi_1)$ - relation (2).

During the machine moving $(v_m \neq 0)$, the path of point T is given by the equations:

$$X = v_m \frac{\varphi_1}{\omega_1} + x; Y = y \tag{7}$$

The thickness of the furrow displaced by every mattock represents:

$$s = v_m t = v_m \frac{2\pi}{\omega_1} \tag{8}$$

where $v_m$ is the machine moving rate;

$\omega_1$ - the angular velocity of mattocks operating shaft.

b. **Cutting rate**

Point T (mattock nib) rate is determined by its components on the coordinate axes:

$$\begin{aligned} v_T^x &= -AB\omega_1 \sin\varphi_1 - \omega_2(BM\sin\varphi_2 + TM\cos\varphi_2) \\ v_T^y &= AB\omega_1 \cos\varphi_1 + \omega_2(BM\cos\varphi_2 - TM\sin\varphi_2) \end{aligned} \tag{9}$$

Absolute velocity support is represented by the tangential rod curve, velocity $v_T$ being given by the relation:

$$v_T = \sqrt{(v_T^x)^2 + (v_T^y)^2} \tag{10}$$

The angular velocity $\omega_2$ results from the relation:

$$\omega_2 = -\frac{AB}{BC}\frac{\sin(\varphi_1 - \varphi_3)}{\sin(\varphi_2 - \varphi_3)}\omega_1 \tag{11}$$

The components of velocity $v_T^x(\varphi_1)$ and $v_T^y(\varphi_1)$ are obtained by substitution of angular velocity $\omega_2$ and of angles $\varphi_2$, $\varphi_3$.

**RESULTS AND THEIR INTERPRETATION**

In order to determine the rod curve, the following values have be used: AB=0.154 m ; BC=0.325 m ; DC=0.265 m ; BM=0.629 m ; MT=0.133 m. Using these values, the numerical values of parametric coordinates $x(\varphi_1)$ and $y(\varphi_1)$ for point of the mattock cutting edge have been obtained. In figure 2, the curves described by the mattock nib for $v_m = 0$ (a) and $v_m = 0.4 m/s$ (b) are presented. Curve segments AB, A'B' and A"B" correspond to mattock penetration in soil, curve segments BC, B'C' and B"C" correspond to furrow displacement and throwing and segments CA, C'A' and C"A" correspond to the phase of mattock removing in initial position, in order to start the furrow digging. It results that the mattock penetration in soil is realized by beginning with point A (A',A",...), the active zone of cutting being on section AB (A'B', A"B", etc). Within the data taken into consideration, the depth of penetration is a=0.75-0.5=0.25 m.

The graphic of function $v_T^x(y_1)$ is presented in figure 3 and the graphic of function $v_T^y(y_1)$ for $v_m$=0.4 m/s is shown in figure 4. According to operation stages, different variations of rates are obtained, such as: A'B' for the stage of mattock penetration in soil (on section AB - figure 2.b); B'C' for the stage of furrow displacement and throwing and C'A' for the stage of mattock removing in the initial position.

Figure 5 shows the absolute velocity variation $v_T$ of mattock nib, for $v_m$=0.4 m/s, points A',B' and C' marking the beginning of phases AB, BC and CA, that is the beginning of mattock penetration in soil and of detachment and throwing of furrow and mattock removing in the initial position.

The value of the work parameters in the characteristic points A, B, C given in the table 1 and comprises:

- the T point parameters of the mattock cutting (coordinates, velocities, accelerations, absolute velocity);
- the mattock parameters (inclined angle, angular velocity, angular acceleration);
- the position angle of the driven element.

*Table 1*

| Point | $x_T$ [m] | $y_T$ [m] | $v_x$ [ms$^{-1}$] | $v_y$ [ms$^{-1}$] | $a_x$ [ms$^{-2}$] | $a_y$ [ms$^{-2}$] | $v_T$ [ms$^{-1}$] | $\psi$ [deg | $\omega$ [s$^{-1}$] |
|---|---|---|---|---|---|---|---|---|---|
| A | -0.107 | -0.504 | 0.0 | -1.074 | -47.89 | -28.78 | 1.074 | 96.8 | 3.73 |
| B | -0.240 | -0.745 | -2.511 | 0.0 | -68.28 | 104.4 | 2.511 | 86.8 | -7.66 |
| C | -0.415 | -0.517 | 0.0 | 4.174 | 110.0 | -107.3 | 4.174 | 49.8 | -4.3 |

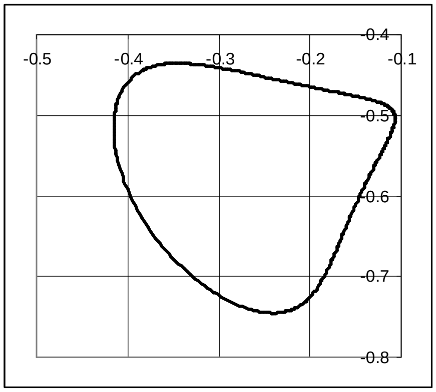

Figure 2a. Curve described for $v_m = 0$

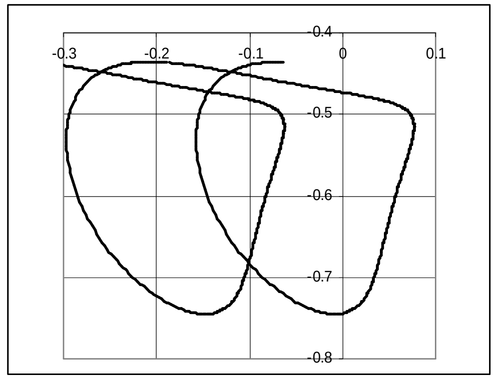

Figure 2b. Curve described for $v_m = 0{,}4$ m/s

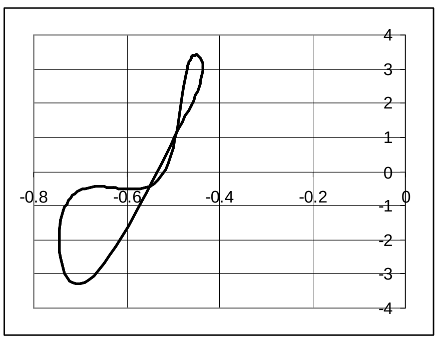

Figure 3. Graphic of function $v_T^x(y)$

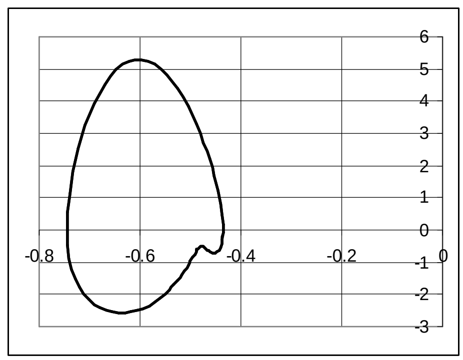

Figure 4. Graphic of function $v_T^y(y)$

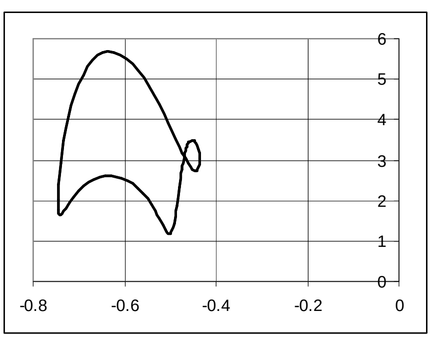

Figure 5. Graphic of function $v_T^a(y)$

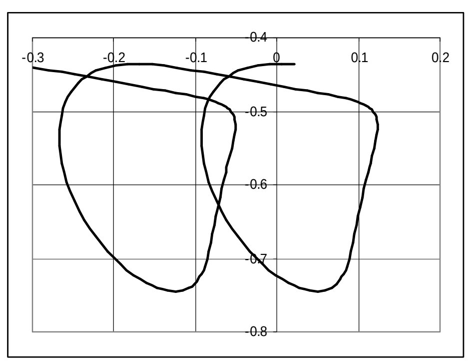

Figure 6. Curve described for $v_m = 0.5$ m/s

## CONCLUSIONS

The process of furrows detachment is realized in good conditions if the curve rate of the path described by the mattock nib is this one, which on segment AB has the form shown in figure 2. The machine operating rate, for a given driving gear, with certain constructive and functional parameters is especially limited by the operating conditions and by the necessity of obtaining furrows of such a growth able to assure a good crumbling and a homogeneous processing of soil on the working depth. At rate $v_m = 0.5$ m/s, the height h (fig. 6) of banks is approx. 0.5a. Taking into consideration the admissible $h<0.3\ a$, machine driving speed will be $v_m < 0.5$ m/s.

The possible maximum working depth of mattock which assures a normal running corresponds to the active zone between points A and B (fig. 2). Under the conditions of a normal running, modifications of the mechanism geometrical elements are necessary, in order to increase the working depth.

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