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NUMERICAL INVESTIGATION OF KINEMATICAL FUNCTIONS OF SCYTHE DRIVING MECHANISMS APPLIED IN AGRICULTURAL MECHANICAL ENGINEERING

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ABSTRACT: Different types of scythe driving mechanisms are applied in grass cutters and combine harvesters. Obviously the kinematical functions of driven parts are different. The method of numerical derivation is a simple and useful tool to investigate the applied structures and the effect of modification of main dimensions on kinematical functions. Presented method can be easily to use in technical higher education and quite demonstrative.
KEYWORDS: Agricultural mechanical engineering, scythe driving mechanisms, transmission function

❖ INTRODUCTION

Position-time functions of most of scythe driving mechanisms can be described by simple trigonometric equations. Derivations of these equations are easily obtained too. In this way the velocity-time and acceleration-time functions of driven part (or angular velocity-time and angular acceleration-time functions in case of swinging part) can be obtained. In some cases in spite of simple structure (four-bar mechanisms, swing frame drives) the position-time functions are quite difficult. In consequence of this fact after twice derivation the kinematical functions become more difficult and additionally the chances of mistakes are not negligible. The crank is assumed to rotate at a constant angular velocity and the links are considered to be rigid. The functions are presented in case of concrete topologies and dimensions graphically plotted.

Applying the method of numerical derivation - by the aid of Excel - on the basis of position-time function the velocity-time and acceleration-time functions of driven part can be created. The effect of modification of main dimensions of mechanisms on kinematical functions of driven part can be investigated.

❖ SCYTHE DRIVING MECHANISMS OF AGRICULTURAL MACHINERY

The scythe driving mechanisms of mowing-machines (grass cutter, combine) constitute different field of mechanisms of agricultural machinery [2, 3]. In this study

- the crank drive (centric and eccentric),
- the fulcrum bearing drive, and
- the swing frame drive are mainly treated.

❖ TRANSMISSION FUNCTIONS OF MECHANISMS – THE ECCENTRIC CRANK DRIVE

The eccentric crank drive is the most frequently used mechanism of grass cutters. The rate r/l is usually 1/25, the eccentricity e=7..8r. The mechanism under study is shown in Fig. 1.

Taking into consideration the constraint conditions, the position of scythe in system of axes xy is defined with the position of point C in function of $\varphi=\omega t$ angular position of crank:

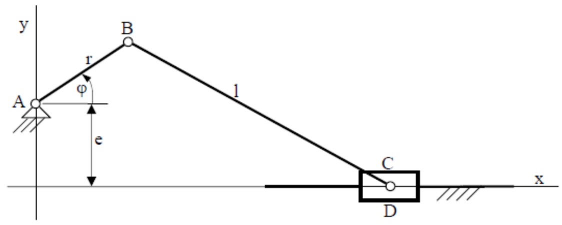

Fig. 1

$$x_c = r\cos\varphi + \sqrt{l^2 - (e + r\sin\varphi)^2} \tag{1}$$

The velocity and acceleration can be obtained by taking the first and second time derivatives of equation (1).

$$\dot{x}_c = -r\omega\left(\sin\varphi + \frac{(e + r\sin\varphi)\cos\varphi}{\sqrt{l^2 - (e + r\sin\varphi)^2}}\right) \tag{2}$$

and

$$\ddot{x}_c = -r\omega^2\left(\cos\varphi + \frac{r\cos 2\varphi - e\sin\varphi}{\sqrt{l^2 - (e + r\sin\varphi)^2}} + \frac{r(e + r\sin\varphi)^2\cos^2\varphi}{\left[l^2 - (e + r\sin\varphi)^2\right]^{\frac{3}{2}}}\right) \tag{3}$$

If e = 0, we can get the transmission functions of centric crank driver. With the aim of emphasizing particularities of crank drivers we can differ from the usual dimensions and rates of links. The transmission functions of crank drive are shown in Fig. 2-3. Data: $r=0,04$ m, $l=0,20$ m, $\omega=20\pi$ s^{-1}. (If $e=0$, Fig. 4)

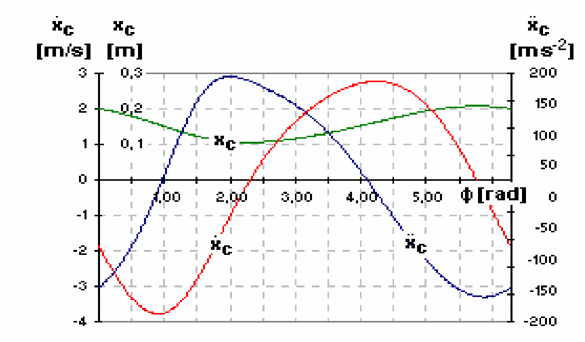

Fig. 2

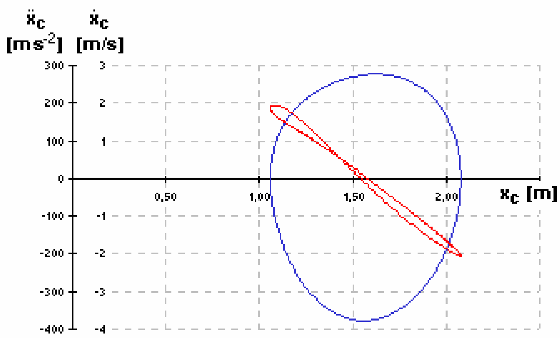

Fig. 3

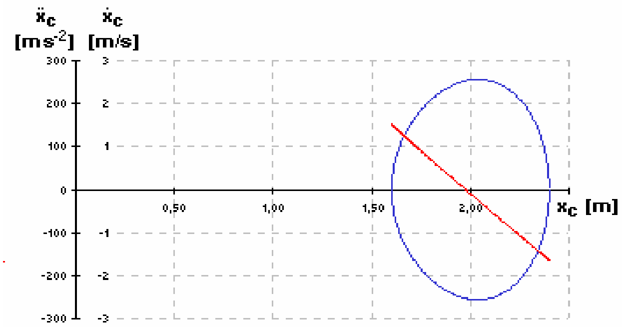

Fig. 4

On the basis of Fig. 2-4 we can study the consequences of eccentricity: the increase of the stroke length of the scythe in comparison with centric crank driver 28 per cent, moreover the maximum velocity and acceleration of the scythe has increased. It's easy to realize that the distortion of functions by the increase of eccentricity will appear to a greater extent.

The use of fulcrum bearing drive is mostly wide-spread in scythe driving mechanisms of combines [4]. The kinematical plot of the drive is shown in Fig. 5.

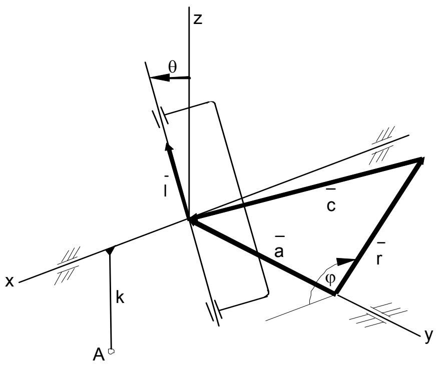

Fig. 5

On the basis of the construction of mechanism, the vectors c and l are always perpendicular to each other i.e. cl = 0, and

$$(\mathbf{a} - \mathbf{r})\mathbf{l} = 0 \tag{4}$$

The vectors r and l can be written as function of the driving side angular displacement $\varphi=\omega t$ and the driven side angular position θ, where i, j and k are unit vectors parallel to the x, y and z axes, respectively.

$$[-a\mathbf{j} - r(\cos\ \varphi\mathbf{i} + \sin\ \varphi\mathbf{k})][-l\sin\ \theta\mathbf{j} + l\cos\ \theta\mathbf{k}] = 0 \tag{5}$$

After multiplication $al\sin\theta - rl\sin\varphi\cos\theta = 0$. If $tg\alpha = r/a$, $\theta = arctg(tg\alpha\sin\varphi t)$, where α is the slant of bearing. If $\varphi=0$, the rod k is parallel with the axes z. For the y direction projection of point A $k\sin\theta$, from which

$$y = \frac{k\sin\alpha\sin\varphi}{\cos\alpha(1 + tg^2\alpha\sin^2\varphi)^{\frac{1}{2}}} \tag{6}$$

The velocity and acceleration can be written by taking the first and second time derivatives of equation (6).

$$\dot{y} = \frac{\omega k\sin\alpha\cos\varphi}{\cos\alpha(1 + tg^2\alpha\sin^2\varphi)^{\frac{3}{2}}} \tag{7}$$

and

$$\ddot{y} = -\omega^2 k\sin\alpha\sin\varphi\frac{1 + 3tg^2\alpha - 2tg^2\sin\varphi}{\cos\alpha(1 + tg^2\alpha\sin^2\varphi)^{\frac{5}{2}}} \tag{8}$$

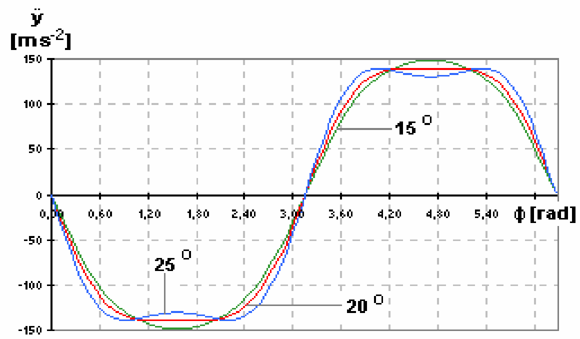

Fig. 6

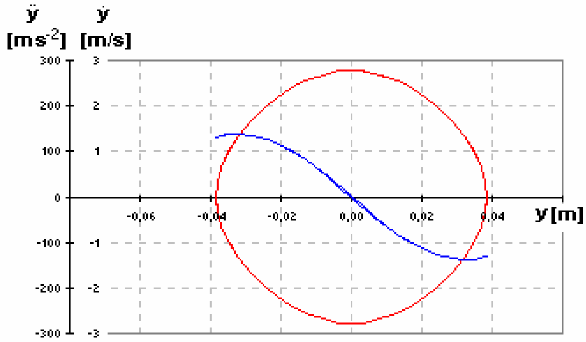

Fig. 7

The plots for different α angles in Fig. 6-7 indicate that this mechanism produces symmetrical motion, and when the angle α is near 25 deg., the maximum angular acceleration produced by a fulcrum bearing drive is lower than that of a sinusoidal oscillator.

❖ TRANSMISSION FUNCTIONS OF MECHANISMS – THE SWING FRAME DRIVE

The swing frame drive was used first time by firm HESSTON in a grass cutter of its own. The plot of mechanism is shown in Fig. 8. The angular position of swing frame is determined by the type $F(\theta,\varphi)=0$ equation (9). It was assumed, that either it was neared from the four-bar mechanism OAFC or OAED, the link EF is straight, i.e.

$$\sigma=\gamma+\delta-\pi=\delta©-\gamma© \qquad (9)$$

where

$$\gamma=\arccos\frac{m^2+k^2-d^2}{2mk},\quad \delta=\arccos\frac{m}{2a},\quad \delta=\arccos\frac{n}{2a},$$

$$\gamma=\arccos\frac{n^2+k^2-c^2}{2nk},$$

$$m=\sqrt{k^2+d^2-2kd\cos x},$$

$$n=\sqrt{k^2+c^2-2kc\cos(\beta-x)},$$

$$k=\sqrt{r^2+l^2-2rl\sin\varphi}.$$

$$r=\overline{OA},\quad l=\overline{OB},\quad k=\overline{AB},$$

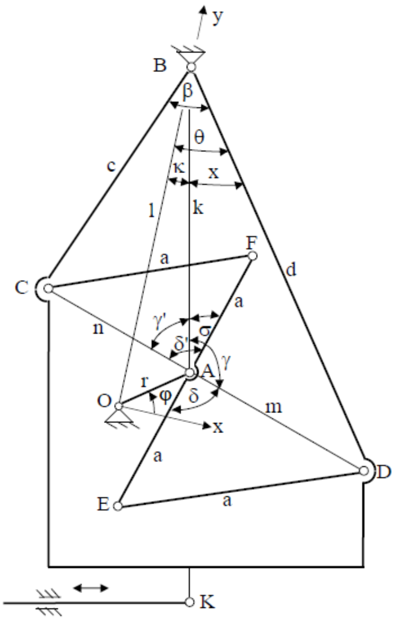

Fig. 8

After substitution the equation (9) will take a new form (10).

$$\arccos\frac{k-d\cos\left[\theta-(\operatorname{sgn}\sin\varphi)\arccos\dfrac{l-r\sin\varphi}{k}\right]}{\sqrt{k^2+d^2-2dk\cos\left[\theta-(\operatorname{sgn}\sin\varphi)\arccos\dfrac{l-r\sin\varphi}{k}\right]}}+$$

$$+\arccos\left[\frac{1}{2a}\sqrt{k^2+d^2-2dk\cos\left[\theta-(\operatorname{sgn}\sin\varphi)\arccos\frac{l-r\sin\varphi}{k}\right]}\right]-$$

$$-\arccos\left[\frac{1}{2a}\sqrt{k^2+c^2-2ck\cos\left[\beta-\theta+(\operatorname{sgn}\sin\varphi)\arccos\frac{l-r\sin\varphi}{k}\right]}\right]+$$

$$+\arccos\frac{k-c\cos\left[\beta-\theta+(\operatorname{sgn}\sin\varphi)\arccos\dfrac{l-r\sin\varphi}{k}\right]}{\sqrt{k^2+c^2-2ck\cos\left[\beta-\theta+(\operatorname{sgn}\sin\varphi)\arccos\dfrac{l-r\sin\varphi}{k}\right]}}-\pi=0 \qquad (10)$$

The angular velocity and angular acceleration functions of swing frame can be obtained by the aid of numerical differentiation. Data: r=0,1 m, a=0,25 m, l=0,5 m, c=0,354 m, d=0,791 m, β=1,1071 rad, $\omega=20\pi$ s^{-1}. For the sake of insistence of kinematical particularities of mechanism the data are different from the dimensions of HESSTON grass cutter. The drive is connected with the joint K to the scythe. In the case of using real dimensions the path of point K is hardly different from the straight-line. Knowing the dimensions, the kinematical parameters of point K can be calculated on the basis of above mentioned. The plots in Fig. 9-10 indicate really the particularities of swing frame drive.

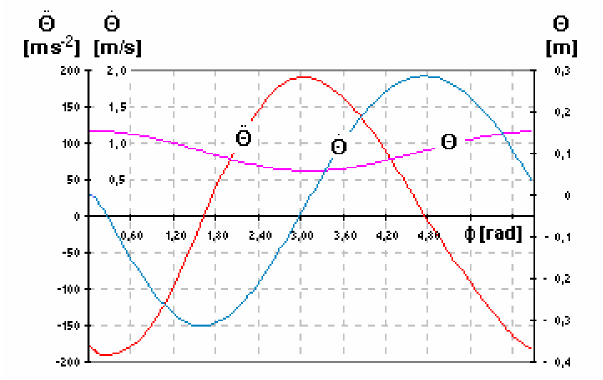

Fig. 9

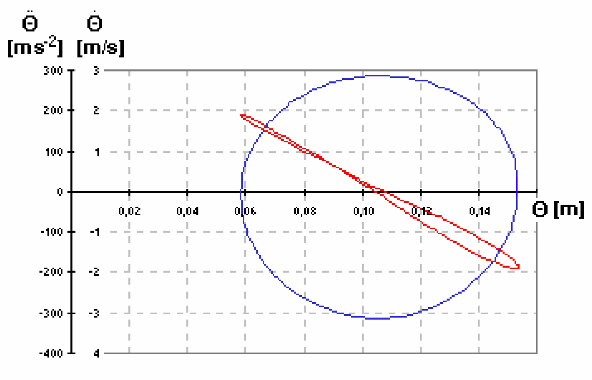

Fig. 10

❖ CONCLUSIONS

Three different types of scythe driving mechanisms were treated in this paper. By the aid of transmission functions we could study kinematical parameters of driven links of mechanisms. These mechanisms, in consequence of their different construction, comply different ways with the agricultural technical requirements of scythe.

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