INVESTIGATION OF PICKING DEVICE OSCILLATING MOTION IN FLAX HARVESTING ASSEMBLY

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Let us study only the vertical reciprocating (jumping) oscillating motion. Then the equivalent dynamic model will look like that depicted in Fig. 1. It is a mechanical system with one degree of freedom. Vertical displacement *Z* of sprung mass over rear wheels (there are no front ones) is accepted as generalized co-ordinate. The generalized co-ordinate will be calculated from the position of the static system equilibrium. Then the motion of the given mechanic system is described by a II-d mode Lagranghe equation [1, 2]

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot z}\right)-\frac{\partial T}{\partial z}=Q_z \qquad (1)$$

where:

$$T=\frac{1}{2}m\dot z^2$$
$$P=\frac{1}{2}C(z-h)$$
$$h=h(t)$$
$$\Phi=\frac{1}{2}\mu(\dot z-\dot h)^2$$

where:

$m=\frac{Ml}{1}$ – mass of the combine-harvester's part performing rotary oscillation.

$$Q_z=Q_z^{(P)}+Q_z^{(F)}+Q_z^{(Fr)}$$
$$Q_z^{(P)}=-\frac{\partial P}{\partial z}=-c(z-h)$$
$$Q_z^{(F)}=-\frac{\partial F}{\partial \dot z}=-\mu(\dot z-\dot h), \qquad (2)$$
$$Q_z^{(Fr)}=0,$$
$$Q_z=-c(z-h)-\mu(\dot z-\dot h),$$

$$\frac{\partial T}{\partial \dot{z}} = m\dot{z},$$
$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{z}}\right) = m\ddot{z},$$
$$\frac{\partial T}{\partial z} = 0,$$

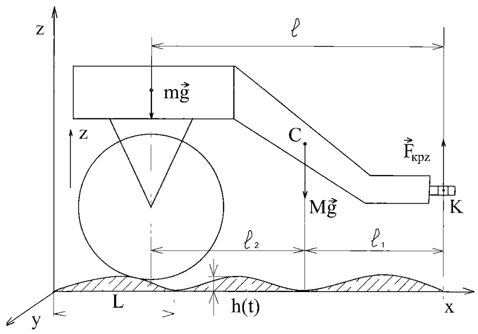

Fig. 1. Oscillating mechanical system with one degree of freedom

Substituting (2) in (1), we obtain

$$m\ddot{z} = -c(z-h) - \mu(\dot{z} - \dot{h}),$$
$$\ddot{z} = -\frac{c}{m}(z-h) - \frac{\mu}{m}(\dot{z} - \dot{h}),$$
$$\ddot{z} + \frac{\mu}{m}\dot{z} + \frac{c}{m}z = \frac{ch}{m} + \frac{\mu}{m}\dot{h}, \tag{3}$$

Let

$$\frac{c}{m} = k^2,$$
$$\frac{\mu}{2m} = n,$$

Then

$$\ddot{z} + 2n\dot{z} + k^2 z = \frac{ch(t)}{m} + \frac{\mu}{m}\dot{h}(t),$$
$$\ddot{z} + 2n\dot{z} + k^2 z = k^2 h(t) + 2n\dot{h}(t),$$
$$z = z_1 + z_2,$$
$$\ddot{z}_1 + 2n\dot{z}_1 + kz_1 = 0,$$

In accordance with the theory of differential equations [3] the general solution of this equation looks like

$$1.\left[\begin{array}{l} z_1(t) = e^{-nt}(C_1\cos(k_1 t) + C_2\sin(k_1 t)), \text{ if resistance is low } n < k;\ k_1 = \sqrt{k^2 - n^2} \\ \text{or } z_1(t) = ae^{-nt}\sin(k_1 t + \beta), \end{array}\right.$$

2. $\left[\begin{array}{l} z_1(t) = C_1 e^{\lambda_1 t} + C_2 e^{\lambda_2 t}, \text{ where } \lambda_1 = -n + \sqrt{n^2 - k^2};\ \lambda_2 = -n - \sqrt{n^2 - k^2} \\ z_1(t) = e^{-nt}(C_1 e^{k_2 t} + C_2 e^{-k_2 t}) \text{ high resistance } (n > k)\ k_2 = \sqrt{n^2 - k^2}, \end{array}\right.$

3. $z_1(t) = e^{-nt}(C_1 + C_2 t)$ $n = k$- critical resistance.

Cases (2) (3) are damping not oscillating motions. Case (1) – damping oscillating motions.

Structure $z_2(t)$ – of partial solution of the differential equation depends on road shape, that is on $h(t)$.

Let

$$h(t) = h_0 \sin\left(\frac{Vt}{L}\right),$$

where:

$h(t)$ – the height of the road hill,
L – length of the road hill,
V – constant speed of the combine-harvester movement.

Let's designate

$$\frac{V}{L} = k_3,$$

$$h(t) = h_0 \sin(k_3 t).$$

Then

$$h(t) = h_0 \sin(k_3 t),$$

$$\dot{h}(t) = h_0 k_3 \cos(k_3 t),$$

$$k^2 h(t) + 2n\dot{h}(t) = k^2 h_0 \sin(k_3 t) + 2n h_0 k_3 \cos(k_3 t) = A_0 \sin(k_3 t) + B_0 \cos(k_3 t),$$

$$\ddot{z} + 2n\dot{z} + k^2 z = A_0 \sin(k_3 t) + B_0 \cos(k_3 t),$$

where:

$k^2 = \frac{C}{m}$

$n = \frac{\mu}{2m}$

$k_3 = \frac{V}{L}$

$A_0 = k^2 h_0$

$B_0 = 2n k_3 h_0$.

$$z_2(t) = A\sin(k_3 t) + B\cos(k_3 t), \text{ if } k_3 \neq k,$$

that is,

$$\sqrt{\frac{C}{m}} \neq \frac{V}{L}.$$

If $\sqrt{\frac{C}{m}} = \frac{V}{L}$, then resonance will occur.

$$\dot{z}_2(t) = Ak_3\cos(k_3 t) + Bk_3\sin(k_3 t),$$

$$\ddot{z}_2(t) = -Ak_3^2\sin(k_3 t) + Bk_3^2\cos(k_3 t),$$

$$-Ak_3^2\sin(k_3t) - Bk_3^2\cos(k_3t) + 2n(Ak_3\cos(k_3t) + Bk_3\sin(k_3t)) +$$
$$+k^2(A\sin(k_3t) + B\cos(k_3t)) \equiv A_0\sin(k_3t) + B_0\cos(k_3t),$$

$$\left.\begin{array}{l}\sin(k_3t)\left[-Ak_3^2 - 2nk_3 + Ak^2 - A_0\right] + \cos(k_3t)\times \\ \times\left[-Bk_3^2 + 2nk_3A + k^2B - B_0\right] \equiv 0,\end{array}\right| \Rightarrow$$

$$\left\{\begin{array}{l}A(k^2 - k_3^2) - 2nk_3B = A_0 \\ B(k^2 - k_3^2) + 2nk_3A = B_0\end{array}\right| \Rightarrow \quad A = \frac{A_0 + 2nk_3B}{k^2 - k_3^2},$$

$$B(k^2 - k_3^2) + 2nk_3\frac{A_0 + 2nk_3B}{k^2 - k_3^2} = B_0,$$

$$B\left[k^2 - k_3^2 + \frac{4n^2k_3^2}{k^2 - k_3^2}\right] = B_0 - \frac{2nk_3A_0}{k^2 - k_3^2},$$

$$B\frac{(k^2 - k_3^2)^2 + 4n^2k_3^2}{k^2 - k_3^2} = \frac{B_0(k^2 - k_3^2) - 2nk_3A_0}{k^2 - k_3^2},$$

$$B = \frac{2nk_3h_0(k^2 - k_3^2) - 2nk_3k^2h_0}{(k^2 - k_3^2)^2 + 4n^2k_3^2} = -\frac{2nk_3^3h_0}{(k^2 - k_3^2)^2 + 4n^2k_3^2},$$

$$B = -\frac{2nk_3^3h_0}{(k^2 - k_3^2)^2 + 4n^2k_3^2},$$

$$A = \left(A_0 + 2nk_3\frac{-2nk_3^3h_0}{(k^2 - k_3^2)^2 + 4n^2k_3^2}\right)\Big/(k^2 - k_3^2) = \left(A_0 - \frac{4n^2k_3^4h_0}{(k^2 - k_3^2)^2 + 4n^2k_3^2}\right)\Big/(k^2 - k_3^2) =$$

$$= \left(k^2h_0 - \frac{4n^2k_3^4h_0}{(k^2 - k_3^2)^2 + 4n^2k_3^2}\right)\Big/(k^2 - k_3^2) = \frac{(k^2 - k_3^2)^2k^2h_0 + 4n^2k_3^2k^2h_0 - 4n^2k_3^4h_0}{\left[(k^2 - k_3^2)^2 + 4n^2k_3^2\right](k^2 - k_3^2)} =$$

$$= \frac{(k^2 - k_3^2)k^2h_0 + 4n^2k_3^2h_0}{(k^2 - k_3^2)^2 + 4n^2k_3^2} = \frac{h_0(k^2(k^2 - k_3^2) + 4n^2k_3^2}{(k^2 - k_3^2)^2 + 4n^2k_3^2}.$$

Thus

$$A = \frac{h_0\left[k^2(k^2 - k_3^2) + 4n^2k_3^2\right]}{(k^2 - k_3^2)^2 + 4n^2k_3^2},$$

$$B = -\frac{2nk_3^3h_0}{(k^2 - k_3^2)^2 + 4n^2k_3^2},$$

where:

$H = \sqrt{A^2 + B^2}$,

$\text{tg}\,\beta_3 = \frac{B}{A}$,

$$Z(t) = Z_1(t) + H\sin(k_3 t + \beta_3),$$

At $t>T$, where T – is some time;

$Z(t) \approx H\sin(k_3 t\beta_3)$ – forced oscillation.

If $n<k$ – low resistance, then we have

$$Z(t) = ae^{-nt}\sin(k_1 t + \beta) + H\sin(k_3 t + \beta_3).$$

Fig. 2 presents vertical oscillation of trailed assembly at the following meanings of the parameters:

$l = 3$ m; $l_1 = 2{,}975$ m; $l_2 = 0{,}025$ m; $L = 1$ m; $V = 1{,}5$ m/sec;

$M = 1800$ kg; $C = 250\,000$ N/m; $\mu = 1785$ kg/sec;

$h_0 = 0{,}03$ m; $Z_2(0) = 0$; $\dot{Z}_2(0) = 0$.

The graph is built using the package of applied programs Maple 7.

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VER : =proc (v, L, h0, M, l, l1, l2, c, MU, z0, zvo)
Local m, kk1, k1, k3, kk3, n, A0, B0, A, B, H, B3, AS, AKS, a, B1 ;
m : =M*l1/l ; kk1 : =c/m ; k1: =sqrt (kk1) ; k3 : =v/L ;
kk3 : =k3*k3 ; n :=MU/(2*m) ; A0 : =kk1*h0;  B0 : =2*n*k3*h0 ;
A : =h0*(kk1*(kk1- kk3)+4*n*n*kk3) / ( (kk1-kk3)**2+4*n*n*kk3) ;
B : =-2*n*k3*kk3*h0/((kk1 - kk3)**2+4*n*n*kk3) ;
H : =sqrt (A**2+B**2) ; B3 : =arctan (B/A) ;
AS : =z0-H*sin (B3) ; AKS :=zv0+n*AS-H*k3*cos(B3) ;
A : =sqrt (AS**2+AKS**2) ; B1 : =arctan (AS/AKS) ;
Plot (a*exp (-n*t)*sin (k1*t+B1)+H*sin (k3*t+B3) , t=0 . . 3*Pi , thickness =3) ;
end:
VER (1.5, 1.0, 0.03, 1800.0, 3.0, 2.975, 0.025, 250000, 2000, 0, 0);
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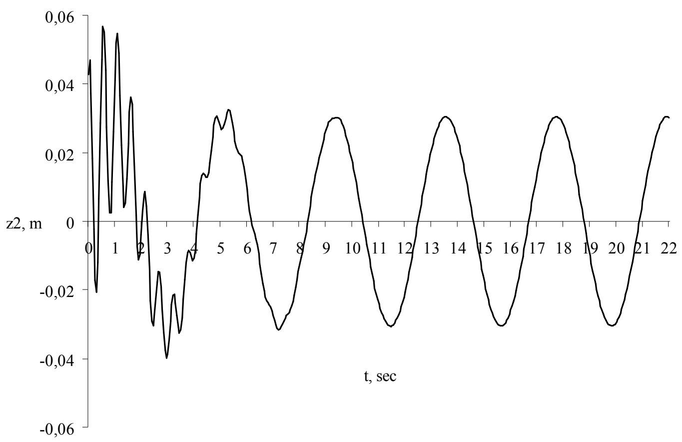

Fig. 2. Dependence of system deviation time on equilibrium position

The graph (Fig. 2) shows that during the initial period of time (0-9 sec) the influence of soil surface shape on cross oscillations of the assembly is marked and at (t > 9 sec) oscillations of the assembly are adjusted to the shape of the soil surface.

REFERENCES

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SUMMARY

Picking device oscillating motion in flax harvesting assembly is studied. Equivalent dynamic models of mechanical system with one and two degrees of freedom are developed.