# THE DESIGN AND THEORETICAL JUSTIFICATION OF A VIBRATORY DIGGER SHOVEL

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**Abstract:** *In order to improve the technological process of potato harvester during operation in hard soil-climatic condition, vibratory digger shovel was created and mounted on exiting potato harvester produced by Grimme (RL 1700), Further laboratory and field experiments. Theoretically established mutual dependence between technology and design parameters of the vibratory digger shovel of potato harvester. Optimization of the parameters have been occurred by processing of the influencing factors using the theory of Similarity and dimensions.*

***KEY WORDS: POTATO DIGGER, VIBRATE DIGGER BLAEDE, PATATO HARVESTING TECHNOLOGY***

## *1.Introduction*

Among world's food products, potato after wheat, rice, and corn is the fourth well-known product. The annual production of potato is about 385 million tones around the world [1]. Potato crops has a key role to play in feeding the world's growing population. Harvesting potatoes is the most important process in the manufacture of its entire technology. For potato harvesting is spent 70% labor and 40-60% energy costs of the total costs of potato production [2]. Technological process of operation harvester involves cutting a potato rows, separation of tubers from the soil and placement them on the soil surface or gathering in a bunker, in case of combines. Cutting of potato ridges is the most important in operation of harvester, which largely determines performance of the following operations perfectly. Cutting of soil is the most energy-intensive process because requires considerable traction by the prime mover to pull plowshares throught the soil. In many cases, over-sized tractors which are heavier and more powerful than necessary are often used - resulting is unnecessary soil compaction. One way alleviate this problem is to use vibrating digger blades which reduce draft and transfer some of the power requirements to the power take off. Another advantage of vibrating digger blade is the increased break-up of the soil which facilitate soil/potato separation and reduce damage to potatoes caused by soil clods.

Studies over the past 50 years have revealed that oscillation of a tillage tool can be very effective in decreasing draft force and improving the transfer of engine power to soil loosening [3,4].
The works has highlighted that the performance of oscillatory tillage depends upon the amplitude, frequency and oscillation angle. The effect of amplitude, frequency and oscillation angle b can be combined in a velocity ratio:

$$\lambda = \frac{\alpha\omega\cos\beta}{\upsilon} \tag{1}$$

Where, a - amplitude (m); ω - 2πf (angular velocity (rad/s); f = frequency (Hz); β = oscillation angle (deg); υ-tractor velocity (m/s).

At the same time, due to climate change impacts harvesting tuber crops by machines is complicated, especially during work in heavy physical and mechanical composition soil. At harvesting time due to non-optimal conditions of soil increased traction resistance forces, not being sufficient break up of cut layer of soil, It significantly determines the reduction of quality indicators of harvesting technology. Digger blades of the existing harvesting machinery can not manage sufficient break up of soil, to compensate of this, it is made by increasing vibration Frequency and amplitude of the separators. Because of this increases mechanical damage of tubers by machine working body and also increases required power of the machine [5].

## *2. Precondition and means for resolving problems*

In order to solve the current problems was developed design of a vibratory digger blade, which was mounted on exiting potato harvester produced by Grimme (RL 1700). The prototype has independent oscillatory input, which vibrate the hole "curve shape" blades horizontally. The oscillatory input is made of the eccentric shaft, with an attached digger blades. The direction of vibration and tilt angle of the blades can be changed from a special regulatory mechanism. It will be used in late field experiments to determine the effect of vibration on the dependent variables of draft, torque and soil break-up. Laboratory examination of mechanism is being at this time and field test is scheduled for later.

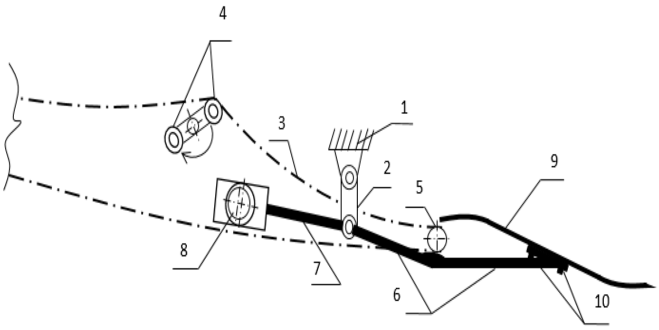


Fig. 1. Vibratory Digger Shovel

*1-Cassis of Machine, 2-Link, 3-Elevator, 4-Shaker of Elevator, 5-Sprocket of Elevator, 6-Beam, 7-Beam of Vibration, 8-Eccentric Shaft, 9-"S"-Shape shovel, 10-Shovel Holders*

Geometrical parameters of "S-shape" shovel defined in such a way that using of working surface of the concave-convex shape cut soil layer is suffering a compression deformation on concave section, while during transition to the convex section – stretch deformation. Thus soil deformation will be implemented in the opposite direction during the movement on the concave-convex surface.

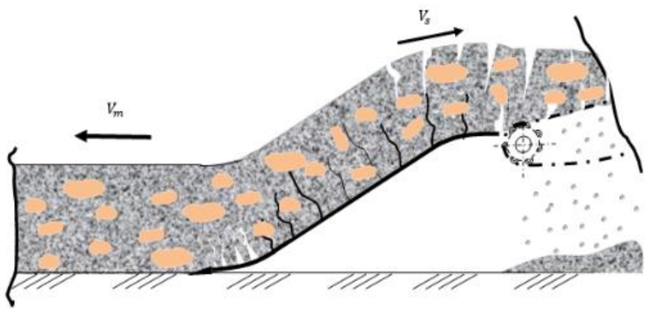


Fig. 2. Operation of S-Shape Shovel

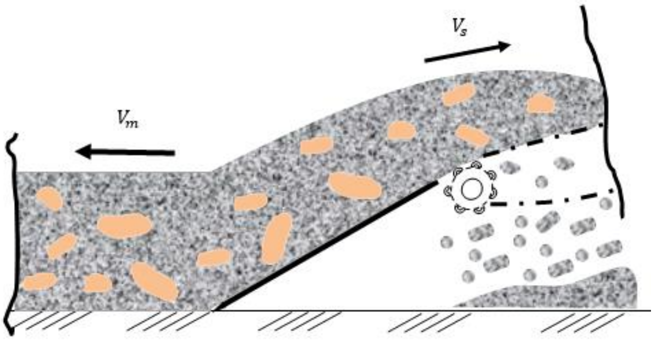


Fig. 3. Operation of Flat Shovel

Therefore, in addition to the effect of reducing energy intensity by chopping reduce the strain rate, this form allows to realize the effect “Baushinger”, thus achieving additional energy savings. Due to complexity of analytical modeling of the current processes in soil, defining of the concave-convex shapes for using potato digging should be experimentally.

To get the potato harvester work effectively geometrical parameters and working regimes of digger shovel would be selected correctly. In accordance with this determined equations of motion of the tip of the shovel [6]:

Displacement

$$x_x = ut + r(1 - \cos \omega t) \quad (2)$$
$$x_y = -r \sin \omega t \quad (3)$$

Velocity

$$v_x = u + r\omega \sin \omega t, \quad (4)$$
$$v_y = -r\omega \cos \omega t; \quad (5)$$

Acceleration

$$a_x = r\omega^2 \cos \omega t\ , \quad (6)$$
$$a_y = r\omega^2 \sin \omega t; \quad (7)$$

Where,

u – speed of machine, t – time, r – amplitude of vibration, ω – angular velocity of vibration.

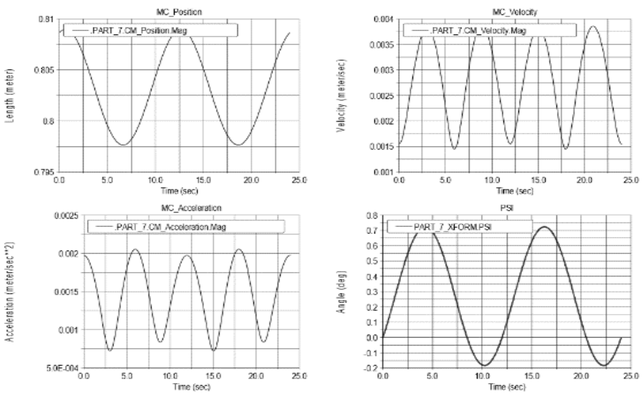


Fig. 4. Graphs of tip movement of the shovel

Investigation of similarity criterias were carried out for planning of experimental studies. The purpose of processing of the mathematical model was identifying such optimal values of regulatory factors, whereby the traction resistance force of harvester would be minimal.

| Title | Symbol | Dimension | Dimension by LMT |
|---|---|---|---|
| Length of digger | L | M | L |
| Width of digger | B | M | L |
| Tilt angle of digger | θ | Rad | - |
| Frequency of oscillation | ω | $Sec^{-1}$ | $T^{-1}$ |
| Amplitude of oscillation | Q | MM | L |
| Soil density | ρ | $Kg/m^3$ | $ML^{-3}$ |
| Draft | F | N | $MLT^{-2}$ |
| Moisture content of soil | W | - | - |
| Operational depth of digger | h | M | L |
| Acceleration of gravity | g | $M/sec^2$ | $LT^{-2}$ |
| Velocity of machine | $V_m$ | M/sec | $LT^{-1}$ |
| Velocity of elevator | $V_e$ | M/sec | $LT^{-1}$ |

The functional relationship between the parameter of optimization and influencing factors looks like:

$$F = f(L, h, B, \omega, Q, \rho, W, g, V_m, V_e, \theta) \quad (8)$$

Basic values have been chosen - V, ρ and g, which dimensions can be represented as follows:

$$[\rho] = ML^{-3};$$

$$[g] = LT^{-2};$$

$$[B] = L;`$$

Determinant indicators of the degrees of these variables is equal:

$$\Delta = \begin{vmatrix} 1 & -3 & 0 \\ 0 & 1 & -2 \\ 0 & 1 & 0 \end{vmatrix} = -2 \neq 0$$

When defining parameters are known from the basic selected values, similarity criteria can be expressed so:

$$\frac{F}{\rho^\alpha g^\beta B^\gamma} = f\left(\frac{\omega}{\rho^\alpha g^\beta B^\gamma}, \frac{V_m}{\rho^\alpha g^\beta B^\gamma}, \frac{V_e}{\rho^\alpha g^\beta B^\gamma}, \frac{L}{\rho^\alpha g^\beta B^\gamma}, \frac{h}{\rho^\alpha g^\beta B^\gamma}, \frac{Q}{\rho^\alpha g^\beta B^\gamma}, W, \theta\right) \quad (9)$$

Degree indicators of values of the equitation (9) should be chosen so that, if inserting of dimensions instead of their values received complex should be remained dimensionless.

$$\frac{F}{\rho^\alpha g^\beta B^\gamma} = \frac{MLT^{-2}}{[ML^{-3}]^\alpha [LT^{-2}]^\beta [L]^\gamma} = M^{1-\alpha}\, L^{1+3\alpha-\beta-\gamma}\ T^{-2+2\beta} = $$
$$= L^0\, M^0\, T^0 = 1 \quad (10)$$

By the degree indicators of dimensions getting tree algebraic equations:

Degree indicators for - M

$$1 - \alpha = 0\ ;$$

Degree indicators for - L

$$1 + 3\alpha - \beta - \gamma = 0\ ;$$

Degree indicators for - T

$$-2 + 2\beta = 0\ ;$$

Solve these equations:

$$\begin{cases} 1-\alpha=0 \\ 1+3\alpha-\beta-\gamma=0 \\ -2+2\beta=0 \end{cases} \quad \begin{cases} \alpha=1 \\ \gamma=3 \\ \beta=1 \end{cases}$$

Putting of these values of the degrees to appropriate complex of equation (9), getting the following similarity criteria:

$$\pi_1=\frac{F}{\rho\, g\, B^3} \qquad (8)$$

In the same way:

$$\frac{\omega}{\rho^\alpha g^\beta B^\gamma}=\frac{T^{-1}}{[ML^{-3}]^\alpha[LT^{-2}]^\beta[L]^\gamma}=M^{-\alpha}\,L^{3\alpha-\beta-\gamma}\,T^{-1+2\beta}=L^0\,M^0\,T^0==1 \qquad (11)$$

$$\begin{cases} -\alpha=0 \\ 3\alpha-\beta-\gamma=0 \\ -1+2\beta=0 \end{cases} \quad \begin{cases} \alpha=0 \\ \gamma=-\frac{1}{2} \\ \beta=\frac{1}{2} \end{cases}$$

$$\pi_2=\omega\sqrt{\frac{B}{g}};$$

Also,

$$\frac{V_m}{\rho^\alpha g^\beta B^\gamma}=\frac{LT^{-1}}{[ML^{-3}]^\alpha[LT^{-2}]^\beta[L]^\gamma}=M^\alpha\,L^{1+3\alpha-\beta-\gamma}\,T^{-1+2\beta}==L^0\,M^0\,T^0=1 \qquad (12)$$

$$\begin{cases} \alpha=0 \\ 1+3\alpha-\beta-\gamma=0 \\ -1+2\beta=0 \end{cases} \quad \begin{cases} \alpha=0 \\ \gamma=\frac{1}{2} \\ \beta=\frac{1}{2} \end{cases}$$

$$\pi_3=\frac{V_m}{\sqrt{gB}}$$

Similarity criteria composed of the rest of the factors will be likewise:

$$\pi_4=\frac{V_e}{\sqrt{gB}};\quad \pi_5=\frac{L}{B};\quad \pi_6=\frac{Q}{B};\quad \pi_7=\frac{h}{B};$$
$$\pi_8=W;\quad \pi_9=\theta;$$

$$\frac{F}{\rho\, g\, B^3}=f\left(\omega\sqrt{\frac{B}{g}};\frac{V_m}{\sqrt{gB}};\frac{V_e}{\sqrt{gB}};\frac{L}{B};\frac{Q}{B};\frac{h}{B};W;\theta\right) \qquad (13)$$

$$F=\rho\, g\, B^3 f\left(\omega\sqrt{\frac{B}{g}};\frac{V_m}{\sqrt{gB}};\frac{V_e}{\sqrt{gB}};\frac{L}{B};\frac{Q}{B};\frac{h}{B};W;\theta\right) \qquad (14)$$

The resulting overall view of criterion equation is the scientific basis of the pre-planned experiments to find the optimal conditions and modes of designed vibratory digger shovel.

## 3. Conclusion

● "S-shape" vibratory digger shovel was created and mounted on exiting potato harvester produced by Grimme (RL 1700), Further laboratory and field experiments.
● Theoretically established bilateral relations between technological and constructive parameters of the vibratory digging shovel.
● Influential factors analysis of traction resistance force was done by the theory of similarity and dimensions and composed criterial equations

## 4. Literature

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