Study of soil separation at a potato chain with a cross rotating agitator

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Abstract. The goal of the research was the theoretical justification and practical implementation of the device for improving the separation of potato impurities with the help of a transverse rotary agitator of a potato digger. The proposed technical solution is simple to construct, and when used, the technological process of soil separation is improved, not only on light soils, but also on heavy waterlogged soils.

1. Introduction
Potato production is associated with high labor and energy costs. At the same time, harvesting accounts for 60 to 70 % of all labor costs [1]. Considering the labor-intensive process of harvesting potatoes, it is clear that the use of productive potato harvesters at small enterprises is not effective in terms of financial relations. This problem forces to develop potato diggers, which can reduce financial costs.

To harvest potatoes with minimum expenditure of labor and funds, it is necessary to ensure:
1. yield growth;
2. production of less energy-intensive machines;
3. high level of seed production and breeding, favorable organization of work. The specific soil and climatic conditions and provisions of local farms are very effective with this technology [2].

The goal is to increase the efficiency of the technological procedure for harvesting potatoes by creating a method that is aimed at intensifying separation at a potato chain.

The objectives include analysis of the existing methods of harvesting potatoes and determining some promising areas to improve potato harvesting machines. Objectives also presuppose analysis of the designs of separating mechanisms and main separation intensifiers of the main potato chain of a potato harvester to identify the most significant research area.

2. Materials and methods
In order to improve the separating ability of the potato chain, various intensifiers and shakers: elliptical, cam, agitators, screws and other devices are used. Due to the intensive tossing of the material, a certain increase in soil separation is achieved, but the damage to the potato also increases. To increase the efficiency of cleaning in different conditions, different types of intensifiers are used. The goal of intensifiers is to improve soil separation. Consider the main types of intensifiers located above the elevator surface.
Borychev S.N., Uspenskiy I.A., Byshov N.V., Vereshchagin N.I., Petrov G.D., Kostenko M.Yu., Rembalovich G.K. and others were engaged in the tasks of increasing the separation efficiency of the potato harvester [1, 2, 3, 4].

Based on the works [11], it can be concluded that the width of the potato chain is subject to uneven distribution by the tuberous heap. Consequently, soil separation is deteriorating and the load on the working bodies is increasing. The solution to this problem was applied in the structural-technological scheme of the potato chain of the disk agitator [9].

The mechanism comes into effect as follows. Potato heap of the digging mechanism goes to the surface of the potato chain 1.

When moving together with the surface of the potato chain, the separation of impurities occurs, as well as their removal through gaps located between the teeth of the belt. This process is not always effective. When a potato heap comes in contact with a disk agitator, fingers, mounted cantilever on the lower portion of the agitator disk, gradually enter the heap.

Fingers are made up of rubber tubes mounted on metal rods. That is why there is a smooth entry of fingers into the layer. Since the fingers are designed with the function of changing the length of the extreme limit of the tube, a gentle effect is provided with any change in weather conditions and the risk of damage to potato tubers is reduced. Effective separation occurs when the stiffness of the fingers changes. It occurs due to the destruction of structural formations in the heap, as well as its movement throughout the potato chain [3].

A screw-elevator separator which consists of a potato chain and two screws on top is installed on the potato harvester (KPK-2-01). The potato chain is made in the form of closed rubberized belts with transverse rods. This potato chain is necessary for screening small impurities through the openings between the bars of the aprons. A separator with intensifiers in the form of elastic springs was developed at RSATU. The elastic springs are equipped with a screw for adjusting the vertical clearance between them and the elevator apron.

Soil-potato tuberous mass is fed to elastic springs, which distribute it on the surface of the potato chain and carry out intensive crumbling of soil lumps, which ensures improved soil separation [4].

Potato tubers in this case interact with both the helical surface of the springs and the surface of the potato chain. In this case, jamming of the potato tuber in the gap between the surfaces of the potato chain and the coil of the spring is possible, as well as damage to the tubers due to the high speed of collision of tubers with coils [4].

To reduce damage to tubers, an additional coil spring is installed, which acts as an overrunning clutch. A favorable effect on soil separation and soil lump destruction is ensured by the constant complex of movements of the potato heap relative to the potato chain. A reduction in potato losses happens due to eliminating the possibility of rolling tubers behind a potato harvester [10].

![Figure 1. Basic diagram of a potato harvester. 1, 3 - tusk; 4 - high-speed potato chain; 5 - main potato chain; 6 - cascade potato chain; 7 - running wheels; 2 - supporting wheels; 12 - drive shaft; 10, 14 - flange; 11, 13 - spiral spring; 9, 15 - bearing; 8 - sprocket](image-url)
The potato digger is equipped with tusks 1 and 3, high-speed 4, main 5 and cascaded 6 potato chains, running 7 and supporting 2 wheels. Potato chains 4, 5 and 6 are designed for grinding and moving the tuberous layer, separating the soil from tubers and screening the soil. They are located one after the other with some difference in height and are presented in the form of lattice aprons with a closed circuit. The upper parts, being workers, move from tusks 1 and 3 to the exit. The coil springs 11 and 13 are coiled with a gap between the loops. The coil springs 11 and 13 are made of round wire with right and left winding. The surface of the wire of the springs 11 and 13 is made of an elastic material, such as rubber.

The drive shaft 12 has a sprocket 8. The drive shaft 12 of the intensifier rotates in bearings 9 and 15 and is driven by a chain drive from the sprocket mounted on the shaft of the cascade potato chain 6. The chain drive and sprocket mounted on the shaft of the cascade potato chain 6 are not shown.

The potato digger works as follows. When the potato digger moves along the rows to be harvested, the tuberous layers dug up by tusks 1 and 3 enter the high-speed potato chain 4. Due to the fact that the speed of the bars of the high-speed potato chain 4 is greater than the speed of the potato harvester itself, the tuberous layer is divided into pieces and tuberous soil. The tuberous soil with soil lumps moves to the main potato chain 5. The depth of the tusks 1 and 3 is regulated by a screw mechanism to 25 cm by changing the position of the support wheel 2.

The tuberous layer, passing from the high-speed potato chain 4 to the main potato chain 5, and then to the cascade potato chain 6, is further crushed. Fine soil is sieved between bars.

Soil lumps and plant debris, which are not destroyed as well as stolons, go from the high-speed potato chain 4 to the main potato chain 5. The upper part of the main potato chain 5 is shaken by elliptical sprockets during movement. The soil lumps are crushed, and the soil is sieved through the separating surface of the main potato chain 5. Potato tubers and not destroyed soil lumps are moved to the cascade potato chain 6.

When moving soil lumps and potato tubers in the area of the intensifier, spiral springs 11 and 13, made with right and left windings with a gap between the coils, act on soil lumps and potatoes. The distance between the rods of the cascade potato chain 6 and spiral springs 11 and 13, mounted on the drive shaft 12 of the intensifier is changed by nuts.

Potato tubers and soil lumps under the influence of springs 11 and 13, rotating towards the elevator, move to the middle of the cascade potato chain 6. Spiral springs 11 and 13 destroy soil lumps, tear off stolons from tubers and as a result, intensive soil separation occurs on the cascade potato chain 6. Potato tubers are cleaned from the soil by spiral springs 11 and 13, move to the middle of the cascade potato chain 6, and then fall onto the soil without rolling behind the potato digger forming rolls.

When the potato harvester is working on light soils, as well as on heavy soils with a moisture content of up to 27 %, the intensifier is installed with the possibility of changing the distance between it and the rods of the cascade potato chain 6.

The use of a potato digger with the inventive intensifier, made with spiral springs allows grinding of soil lumps, separation of stolons from tubers and laying of potatoes in the roll behind the potato digger [5].

At the same time, the use of the intensifier with spiral springs can lead to increased energy costs. It is necessary to clarify the power to drive an additional working body and evaluate its effect on the total energy consumption of the unit.

3. Theoretical investigation
The authors consider the movement of the components of a potato pile during the transition from one potato chain to another one.

The following assumptions are introduced:
- the components of the potato heap have the speed of the potato chain apron;
- the number of components of the potato chain is negligible, that is, the components are not in one layer and do not affect each other.

Let us determine the angle of descent of the components of the drive drum and potato chain, since the components of the potato heap move at a constant speed together with the potato chain apron and are in equilibrium.

Consider the movement of a tuber after a fall.

\[
\begin{align*}
& \frac{d^2x}{dt^2} = 0 \\
& \frac{d^2x}{dt^2} = -mg \\
\end{align*}
\]  

From the potato chain, the following assumption is applied:

1) the flow resistance force is not taken into account since the speed of moving potatoes do not exceed 2 m / s;

2) the initial speed of the potato tuber is determined by the speed of the potato chain taking into account separation angle $\beta$.

\[
\begin{align*}
& \frac{d^2x}{dt^2} = c_1 \\
& \frac{d^2x}{dt^2} = -gt + c_2 \\
\end{align*}
\]  

Replacing $\frac{d^2x}{dt^2}$ by $\frac{d^2x}{dt^2}$, where $\frac{d^2x}{dt^2}$ one gets:

\[
\frac{\theta x = c_1}{\theta y = gt + c_2} 
\]

Substituting the initial conditions for $t_0=0; x_0=0; y_0=\theta_0 \cos \beta; \theta y_0 \sin \beta$ one gets:

\[
\begin{align*}
& c_1 = \theta_0 x = \theta_0 \cos \beta \\
& c_2 = \theta_0 y = \theta_0 \sin \beta \\
\end{align*}
\]  

Taking into account the integration constants, expression (2.12) is replaced as follows;

\[
\begin{align*}
& \frac{dx}{dt} = \theta_0 \cos \beta \\
& \frac{dy}{dt} = gt + \theta_0 \sin \beta \\
\end{align*}
\]

Separate the variables and integrate again.

\[
\begin{align*}
& x = \theta_0 \cos \beta + c_3 \\
& y = -\frac{gt^2}{2} + \theta_0 t \sin \beta + c_4 \\
\end{align*}
\]

Given the initial conditions, the integration constants are:

\[
\begin{align*}
& c_3 = x_0 = 0, \ c_4 = y_0 = 0 \\
\end{align*}
\]

then the expression will be written as:

\[
\begin{align*}
& x = \theta_0 t \cos \beta \\
& y = -\frac{gt^2}{2} + \theta_0 t \sin \beta \\
\end{align*}
\]

Using the obtained equation, the MathCAD program verified the simulation of the process of moving the components of a potato heap. Figure 2 shows the trajectory of the components of the potato heap depending on the initial separation angle.

Simulating the trajectory, the movement of the component of the potato heap when moving from one potato chain to another, the trajectory depends on the initial separation and determines the range of the component when superimposing the flight path on the relative position of the potato digger chains, it was found that the maximum range of the component is not more than 0.7 m. In addition, on
the basis of the simulation, the angle of incidence of the components on the potato chain was established and it was 35-40 °.

The analysis of the graph of the speed of the components during their transition from one potato chain to another showed that the maximum collision speed on the potato chain did not exceed 2.5 m / s. It should be borne in mind that the potato chain moves in the direction of the fall of the components, so the absolute collision speed will be determined minus the velocity of the potato chain. Moreover, the ratio of the impact speed before and after, as well as the direction, depends on the recovery coefficient.

Based on the change in momentum theorem, one gets:

$$ M(\vec{U} - \vec{\vartheta}) = \vec{S} \tag{9} $$

where:
- $M$ - tuber mass;
- $U$ - speed before the tuber hits the potato chain;
- $\vartheta$ - tuber speed after impact;
- $S$ - power impulse.

We project expression (9) on the coordinate axis:
Since the friction force of the tuber against the potato chain is not taken into account, the velocity along the axis before the impact and after the impact will be equal.

Therefore, we consider the impact with respect to the $y_1$ axis, taking into account the signs of the projection:

$$U_{y_1} = -k \theta_{y_1}$$

Taking into account expression (2.22), we transform expression (22) and determine the momentum of force:

$$S = M(U_{y_1})(1 + k)$$

Thus, we determine the magnitude of the vertical and horizontal shock pulses of the potato tuber. We determine the direction of speed after impact:

$$\tan \beta = \frac{\theta_{x_1}}{U_{y_1}}$$

On the other hand, the angle of incidence is

$$\tan \alpha = \frac{U_{x_1}}{\theta_{y_1}}$$

Then the ratio of the angle of incidence and the angle of reflection can be written as:

$$\tan \alpha \tan \beta = \frac{U_{x_1}}{\theta_{y_1}} = k$$

Using the obtained equation, the MathCAD program verified the modeling of the fall process and constructed the trajectory of the movement of the components of the potato heap during the transition from one potato chain to another.

Having superimposed the trajectory of the movement of the potato heap on the drawing of the potato harvester, you can determine the place where the components fell and calculate the flight time.

**Figure 4.** Trajectory of potato components after impact with the potato chain

The analysis of the graph showed that the maximum flight range can be about 0.6 m, but the most probable is a range of about 0.4 m.

We determine the magnitude of the speed at this point. To do it, based on equation (14), we construct a graph of the change in absolute speed depending on the flight time.
Figure 5. Rate of fall of the components of the potato heap after impact with the potato chain

Theoretical substantiation of the parameters of a spiral agitator

When moving from one potato chain to another, the components of the potato heap will move relative to the potato chain with the speed obtained from the previous fall and the speed of the potato chain, that is, the absolute speed of the component will be equal to the sum of these speeds. When the components interact with the agitator in the form of a spring rotating in the direction of movement, the components will receive an additional impulse, and accelerate when interacting with the coil of the spring changing the motion path, to study the motion path, we will choose a coordinate system attached to the bottom of the spring, which is shown in Figure 5.

Figure 6. Scheme of interaction of the potato tuber with the potato chain working surfaces and the transverse agitator. 1, 2 – tusk; 3 – high-speed potato chain; 4 - main potato chain; 5 - cascade potato chain; 6 - running wheels; 7 - supporting wheels; 12 - drive shaft; 13 - 16 - flange; 17, 18 - spiral spring; 21, 22 - bearing; 23 - sprocket; 11 - transverse agitator

In order to determine the projection of gravity we write the differential equation of the component motion in the selected coordinate system in the following form:

\[
\begin{align*}
    m \frac{d^2 x}{dt^2} &= -kV \cos \theta - mg(f \cos \alpha - \sin \alpha) \\
    m \frac{d^2 y}{dt^2} &= -fmg \cos \alpha - kV \sin \theta
\end{align*}
\]  (17)

where

\( m \) - the mass of the potato heap component, kg;
The coefficient of resistance to the component movement along the apron, N / m / s;

V — the speed of the component of the potato heap on the potato chain apron m / s;

θ — the angle of motion of the component after its impact with the agitator;

g — acceleration of gravity m / s²;

f — friction coefficient of the component of the potato heap on the potato chain apron;

α — the potato chain elevation angle.

We rewrite the first equation of the system as follows:

\[ V' + \frac{k \cos \theta}{m} V = g(f \cos \alpha - \sin \alpha) \] (18)

We solve the linear non-ordinary differential equation of the first order by the Bernoulli method, for this we denote:

\[ a b' + a' b = M N L + MN' \] (19)

Then equation 18 is written as:

\[ ab' + a' b + a \frac{k \cos \theta}{m} = -g(f \cos \alpha - \sin \alpha) \] (20)

or:

\[ a'b + a \left( b' + b \frac{k \cos \theta}{m} \right) = -g(f \cos \alpha - \sin \alpha) \] (21)

Consider a system of variables of input equations 22:

\[ \begin{cases} 
  b' + b \frac{k \cos \theta}{m} = 0 \\
  a'b = -g(f \cos \alpha - \sin \alpha)
\end{cases} \] (22)

Transforming the first equation of the system \( b' = -b \frac{k \cos \theta}{m} \), we obtain:

\[ \frac{db}{dt} = -b \frac{k \cos \theta}{m} \] (23)

or:

\[ \int \frac{db}{b} = - \int \frac{k \cos \theta}{m} dt \] (24)

As a result of integration, we obtain expression 24:

\[ \ln |b| = - \frac{k \cos \theta}{m} t \] (25)

Potentiating expression 25, we obtain:

\[ b = e^{-\frac{k \cos \theta}{m} t} \] (26)

Given expression 26, we get the second variable system 22, substitute the values and write in the form:

\[ \frac{da}{dt} e^{-\frac{k \cos \theta}{m} t} = -g(f \cos \alpha - \sin \alpha) \] (27)

Dividing the variables, we get:
\[ da = -e^{-\frac{k\cos\theta}{m}}g(f\cos\alpha - \sin\alpha)dt \quad (28) \]

Integrate expression 28:

\[ a = -g(f\cos\alpha - \sin\alpha)\int e^{-\frac{k\cos\theta}{m}}dt \quad (29) \]

As a result of integration, we obtain:

\[ a = -\frac{gm(f\cos\alpha - \sin\alpha)}{k\cos\theta} e^{-\frac{k\cos\theta}{m}} + C_1 \quad (30) \]

where \( C_1 \) is the constant of integration taking into account expressions 26 and 30. We write the equation of the projection of velocity on the abscissa.

\[ \theta_x = e^{-\frac{k\cos\theta}{m}} \left( \frac{gm(f\sin\alpha - \cos\alpha)}{k\cos\theta} e^{-\frac{k\cos\theta}{m}} + C_1 \right) \quad (31) \]

We transform expression 31 in the following form:

\[ \theta_x = \frac{gm(f\sin\alpha - \cos\alpha)}{k\cos\theta} e^{-\frac{k\cos\theta}{m}} + e^{-\frac{k\cos\theta}{m}} * C_1 \quad (32) \]

Given \( \theta_x = \frac{dx}{dt} \), we rewrite equation 32, separate the variables, and integrate:

\[ x = \int \left( \frac{gm(f\sin\alpha - \cos\alpha)}{k\cos\theta} e^{-\frac{k\cos\theta}{m}} + e^{-\frac{k\cos\theta}{m}} * C_1 \right) dt \quad (33) \]

Then the final expression of the law of motion of the component of the potato heap is written as:

\[ x = \frac{gm(f\sin\alpha - \cos\alpha)}{k\cos\theta} t - \frac{m}{k\cos\theta} e^{-\frac{k\cos\theta}{m}} * C_1 + C_2 \quad (34) \]

Similarly, by the Bernoulli method, we solve the second expression of system 17:

\[ V' + \frac{k}{m} V \sin \theta = -gf \sin \alpha \quad (35) \]

\[ V' = ab' + ab' \quad (36) \]

where ab – some time-dependent functions

\[ a = a(t) \]

\[ b = b(t) \]

Then equation 35 is written as:

\[ ab' + ab' + a \frac{k}{m} \sin \theta = -gf \sin \alpha \quad (37) \]

or:

\[ a'b + a \left( b' + b \frac{k}{m} \sin \theta \right) = -gf \cos \alpha - \sin \alpha \quad (38) \]

Consider a system of variables of input equation 38:

\[
\begin{aligned}
&b' + b \frac{k}{m} \sin \theta = 0 \\
&a'b = -gf \cos \alpha - \sin \alpha
\end{aligned}
\quad (39)
\]

Transforming the first equation of the system \( b' = -b \frac{k}{m} \), we obtain:

\[ b' = -b \frac{k}{m} \sin \theta \quad (40) \]
\[
\frac{db}{dt} = -b \frac{k}{m} \sin \theta 
\]  
(41)

or:

\[
\int \frac{db}{b} = - \int \frac{k}{m} \sin \theta \, dt 
\]  
(42)

As a result of integration, we obtain expression 53:

\[
|b| = -\frac{k}{m} \sin \theta \, t 
\]  
(43)

\[
b = e^{-\frac{k \sin \theta}{m} t} 
\]  
(44)

Given expression 44, we define the second variable system 39, substitute the values and write in the form:

\[
\frac{da}{dt} e^{-\frac{k \sin \theta}{m} t} = -gf \cos \alpha - \sin \alpha 
\]  
(45)

Dividing the variables, we get:

\[
da = -e^{-\frac{k \sin \theta}{m} t} f \sin \alpha \, dt 
\]  
(46)

Integrate expression 46:

\[
e^{-\frac{k \sin \theta}{m} t} = \frac{1}{e^{-\frac{k \sin \theta}{m} t}} 
\]  
(47)

As a result of integration, we obtain:

\[
a = -gf \sin \alpha \int e^{-\frac{k \sin \theta}{m} t} \, dt 
\]  
(48)

where \(C_3\) - constant integration taking into account expressions (44) and (48). We write the equation of the projection of the velocity on the abscissa.

\[
a = -\frac{gf \sin \alpha}{k \sin \theta} e^{-\frac{k \sin \theta}{m} t} + C_3 
\]  
(49)

We transform expression 49 in the following form:

\[
\theta_y = e^{-\frac{k \sin \theta}{m} t} \left(\frac{gm \cos \alpha}{k \sin \theta} e^{-\frac{k \sin \theta}{m} t} + C_3 \right) 
\]  
(50)

\[
\theta_y = \frac{gm \cos \alpha}{k \sin \theta} + e^{-\frac{k \sin \theta}{m} t} \times C_3 
\]  
(51)

Given that \(\theta_y = \frac{dx}{dt}\), we rewrite equation 51, divide the variables and integrate:

\[
y = \int \left(\frac{gm \cos \alpha}{k \sin \theta} + e^{-\frac{k \sin \theta}{m} t} \times C_3 \right) \, dt 
\]  
(52)

Then the final expression of the law of motion of the component of the potato heap is written as:

\[
y = \frac{gm \cos \alpha}{k \sin \theta} \, t - \frac{m}{k \sin \theta} e^{-\frac{k \sin \theta}{m} t} \times C_3 + C_4 
\]  
(53)

In order to evaluate the performance of a potato chain with a transverse agitator, a laboratory research program was developed consisting of the following stages:

1. Study of possible trajectories of parts on a potato chain equipped with a transverse agitator.
2. Study of soil separation at a potato chain.
3.1 Separating ability of a potato chain with a transverse agitator, research method

To determine the separation ability of a potato chain [4,2] with a transverse agitator, a laboratory setup was used.

A transverse agitator with springs having a rubber coating (GOST 5496-78) with an internal diameter of 0.020 m and an external one of 0.025 m was installed on top of the potato chain. Mechanisms were driven by a gear motor (kebantriebstechnikgmbhschneeberg) with a power of 0.55 kW, using belt drive by means of drive wheels.

![Transverse agitator of the potato chain. 1 - flange; 2 - spring with rubber coating; 3 - drive shaft; 4 - bearing in the housing, 5 - pulley with belt](image)

Special bags are provided for collecting soil impurities. They are located at the bottom of the working base of the potato chain. The winch provides the electric drive for a drag trolley.

It includes a shaft on which a metal cable is wound and according to GOST 3066-80 it has a diameter of 3 mm. It also includes a chain drive with a gear ratio (i = 2.5). In this case, the leading main sprocket consists of 48 teeth, and the driven sprocket has 19 teeth. The chain pitch is t = 12.7 mm. The main part of the winch is an engine with a power of 1,000 watts. The number of revolutions is 500 rpm.

When conducting tests, it is likely that the speed of the trolley may be different. When drive belts move between pulleys of different diameters, the frequency of disk agitators’ movement changes.

The soil used in the experiments was moistened with watering the surface and kept for 1 day. To determine the humidity, samples were taken and their total mass should not be less than 1 kg. The samples were taken in three different places at a depth of up to 0.25 m with an interval of 0.05 m. First thoroughly mixed, and then two test samples were taken. The mass of samples was from 15 to 50 g. Next, the samples were dried in a special oven at a temperature of 105±2 °C for an hour, then they were cooled and weighed with an error of not more than 0.1 g.

4. Laboratory test results

The supply of potato heap varied from 50 - 90 kg / s. The finished heap was put onto the working apron of the potato chain. Special templates were used to give it the necessary forms, similar to those supplied from the digging mechanisms of a potato digger. From the bottom of the potato chain apron, bags designed for sieved soil were installed. Electronic scales were used to determine the mass of the screened and supplied heap. The experiment was repeated 3 times.

This technique explores the separation ability of the potato chain equipped with a transverse agitator. The main difference is the applied laboratory setup. If we compare it with mechanisms where the potato chain takes the principle of operation of a real machine as a basis, the trolley moves simultaneously with the surface of the potato chain, which solves the problem with the distribution of soil on the basis of the potato chain and most accurately investigate the effects of the transverse agitator, and reduce the effect of apron oscillations. The most accurate research results are obtained using a laboratory setup.
Important agricultural parameters include different conditions and modes of operation of the device. To determine the degree of impact of the transverse agitator on the separating capacity of the potato chain, a multi-factor study was conducted according to the plan.

A three-dimensional graph of the mass of sieved soil along the width and length of the potato chain is obtained under the influence of a transverse agitator depending on parameters of the separating device, shown in the figure 8.

![Figure 8. Graph of the mass of sieved soil along the width and length of the potato chain when exposed to a transverse agitator](image)

The analysis of the graph shows that the largest masses of soil are sieved at places where the agitator interacts with the potato heap. The rotation of the agitator promotes not only the concentration of tubers in the middle part of the potato chain, but also the separation of the soil of the harvesting machine. The interaction of the transverse agitator with soil lumps also contributes to their destruction.

The effectiveness of the interaction of the transverse agitator in the form of an elastic spring with a potato chain is carried out according to the direction of the process of separating impurities of potato heaps. The completeness of the separation characterizes the process of separation. This trait is set according to the amount of sieved soil in one turn of the potato chain. The analysis of damage to potato tubers showed a slight increase in damage within the agro-technical requirements.

4.1 Discussion of research results
The design of the working mechanisms of the potato harvester affects the quality of the harvested potato crop.

The performance of such machines directly depends on the throughput function of the separation devices.

S.N. Borychev and N.V. Byshov [1, 2] studied the basics of technological development of potato harvesting machines. The considered model represents the technological development of the harvester as a set of separation factors of components carried out on the working mechanisms of potato harvesters in a definite sequence. This model was further developed in scientific works of the followers of the above authors.

The intensification results are manifested to the greatest extent during the separation of plastic and sticky soil, as evidenced by the results of experiments conducted in VISKHOM by G.D. Petrov and A.A. Sorokin and those in VIM.

Professor I.E. Kuschev studied the issue of creating the technological development of potato harvesting machines with a parallel arrangement of separating mechanisms. A “branching” technological project of a potato harvester was created, which, under the influence of external conditions, could change the course of the technological process.
5. Conclusion
Currently, for the primary separation of soil impurities, potato chains are widely used on potato harvesters. The most promising are intensifiers located above the potato chain apron, and having rotation in the direction of its movement, which ensures damage reduction. The use of an agitator in the form of elastic springs, contributes not only to the concentration of tubers in the middle part of the potato chain, but also to soil separation of the harvesting machine.

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