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Research Article

Kinematic Analysis of Parameters of a Small-sized Potato Digger

Bayboboev Nabijon Gulomovich[1, *], Goyipov Umidjon Glomjonovich[1], Alixonov Abror Azamxon Ugli[1], Toshtillaev Chohrux[1], Bayboboev Ulugbek Nabijonovich[2]

[1]Department Transport, Logistics NamECI, Namangan, Uzbekistan

[2]Department of Informatics, Széchenyi István University, Győr, Hungary

Abstract

Kinematic analysis of mechanisms is one of the types of study of the function of movement in time without taking into account the force factors affecting their links. It is known that in the framework of the kinematic analysis of the mechanisms of tension in the plane, the following problems are solved: identify possible cases of all links of the mechanism in the considered time interval; determine the values of linear absolute and relative velocities and accelerations of the characteristic points of the mechanism, as well as the values and directions of the angular velocities of all links; Usually, in the kinematic analysis of mechanisms, analytical, graphical and grapho-analytical methods are used. Now, with the help of computer equipment and programs, it will be possible to identify this problem clearly and in a short time. For example, let's look at the iterative determination of velocity and acceleration using SolidWorks Motion. To take full advantage of the existing functionality of the program, it will be necessary to provide analytical expressions for how it is built on the basis of analytical dependencies, as well as finding the speed and acceleration of a particular type of movement. This article provides information on the kinematic analysis of the main mechanism of a small potato digger, aggregated with a walk-behind tractor for digging out potatoes, using the SolidWorks software. On the basis of the given initial conditions, graphs of the acceleration and acceleration of the mechanism joints were constructed, and the values were determined and analyzed.

Keywords

Potato Digger, Design, Kinematic Analysis, Mechanism

1. Introduction

When growing potatoes, harvesting is one of the most labor-intensive processes. Today, 75% expenses of all potato production are spent on the harvesting process. Today in Uzbekistan, more than 90% of potatoes are grown in farmers, agricultures and garden plots of less than 2 hectares [1-5].

At the same time, the level of mechanization of work in farmers and garden plots is low, work expenditure for growing potatoes are high [6-8].

Based on the conducted analysis of scientific research and patent information research, proceeding from the purpose

*Corresponding author: ngbayboboev@gmail.com (Bayboboev Nabijon Gulomovich)

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and objectives of the study, a process flow diagram of a small-sized single-row, compact potato digger equipped with a vibrating separating working element has been developed (Figure 1). A prototype of the device, with the ability to attach to Techa type walk-behind tractors, is shown in Figure 2.

An active share and a sieve with spikes are installed on the frame of the potato digger, which ensures the transmission of motion from the power take-off shaft (PTO) through the gearbox. In this case, one end of the connecting rod is connected to a rotating disk (crank), and the second end is connected to one end of the rocker arm by means of hinges. The rocker arm is pivotally connected to the center of the frame so that it oscillates, and the other end is pivotally attached to the end of the triangular link. One end of the triangular link is pivotally attached to the frame using a rod. One end of the sieve is pivotally attached to the triangular hinge, and the other end is pivotally attached to the frame using a suspension [9-12].

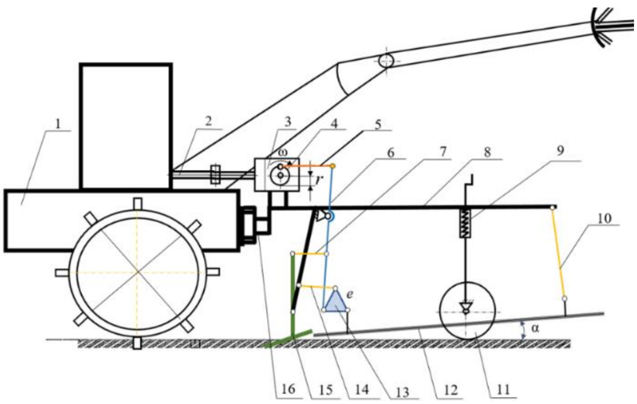

Figure 1. *Flow chart of a small-sized potato digger.*

1-motor block; 2-power take-off shaft (PTO); 3-gearbox; 4-crank; 5-connecting rod; 6-rocker arm; 7-share holder rod; 8-digger frame; 9-regulator wheel; 10 - hook rod; 11-support wheel; 12-rod sieve; 13-triangular link; 14 - rod; 15-active share, 16-connecting device

Figure 2. *Scheme of aggregation of a small-sized potato digger with a walk-behind tractor.*

During operation, i.e. when transmitting motion from the PTO to the unit, due to the vibrational motion of the ploughshare and the sieve, the ploughshare digs up the tuber-soil mixture from a certain depth and transmits this mass to the sieve. The crank, due to rotation, transmits motion to the rocker arm using a connecting rod. The rocker arm, attached to the frame by a hinge, performs an oscillatory motion relative to the center, accordingly, this moves one end of the triangular link in an arcuate manner. As a result of the oscillatory motion, the second end of the triangular link displaces the third tip of the triangular link due to the hinged fastening to the frame, through the rod, and fixed to the sieve moves one end along this trajectory. Due to the fact that the second end of the rod sieve is attached to the frame through the rod hook for oscillations, the first and second ends move in an arcuate oscillation, thus separating the mixture. The soil fractions are sifted and fall out of the gaps of the rod sieve. Potato tubers are separated from the soil and thrown in one row onto the soil surface. The advantage of this type of digger, as opposed to the closest diggers, is that it ensures high-quality separation of potato tubers by changing the direction of the oscillatory movement of the sieve with minimal damage to potato tubers without the use of additional intensifiers, and also ensures high operating efficiency with minimal resource costs [13-16].

The article describes the implementation of a kinematic analysis of the design process of small potato diggers using one of the modern SolidWorks software tools.

2. Materials and Methods

Kinematic analysis of mechanisms is one of the types of study of the function of movement in time without taking into account the force factors affecting their links.

It is known that in the framework of the kinematic analysis of the mechanisms of tension in the plane, the following problems are solved:

1) identify possible cases of all links of the mechanism in the considered time interval;
2) determine the values of linear absolute and relative velocities and accelerations of the characteristic points of the mechanism, as well as the values and directions of the angular velocities of all links;

Usually, in the kinematic analysis of mechanisms, analytical, graphical and grapho-analytical methods are used.

Now, with the help of computer equipment and programs, it will be possible to identify this problem clearly and in a short time. For example, let's look at the iterative determination of velocity and acceleration using SolidWorks Motion. To take full advantage of the existing functionality of the program, it will be necessary to provide analytical expressions for how it is built on the basis of analytical dependencies, as well as finding the speed and acceleration of a particular type of movement. To do this, we present the following expressions.

The linear speed of any of its points during the rotational movement of the link

$$V = \omega \cdot r, \tag{1}$$

here V — point linear speed;

ω – link angular velocity;

r – distance from the center of rotation to the point.

In this case, the direction of the linear velocity is perpendicular to the radius of rotation and directed towards the angular velocity.

The equation of the velocity vector of any point during the movement of the link on the plane can be given as follows:

$$\overrightarrow{V_B} = \overrightarrow{V_A} + \overrightarrow{V_{BA}}, \tag{2}$$

here $\overrightarrow{V_B}$ — absolute speed of the desired point,

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$\overrightarrow{V_A}$ – absolute speed of a point taken as a pole,

$\overrightarrow{V_{BA}}$ – the relative speed of point B around point A, taken as a pole. Its direction is perpendicular to the relative radius of rotation of point B around point A.

The speed of the link during translational motion, like any of its points, is directed in the direction of motion and can be determined analytically at any time as follows:

$$V = \frac{dS}{dt}. \tag{3}$$

The linear acceleration of any point of the link during its rotational motion is defined as the sum of its tangential and normal components, i.e.

$$\vec{a} = \overrightarrow{a_n} + \overrightarrow{a_\tau}, \tag{4}$$

here a – is the acceleration;

a_n – normal component of acceleration;

a_τ – tangential component of acceleration.

To determine the size of the normal component, we use the following expression:

$$a_n = \omega^2 \cdot r, \tag{5}$$

Here ω – link angular speed.

In the expression, the normal acceleration is directed towards the center of rotation.

The tangential component of acceleration can be determined as follows:

$$a_\tau = \varepsilon \cdot r, \tag{6}$$

Here ε – is the angular velocity of the link,

r - the distance from the center of rotation to the point.

The direction of the tangential component of acceleration is perpendicular to the radius of rotation, and the angle is directed toward the acceleration.

We now determine the vector equation for the acceleration of any point in the motion of the link in the plane:

$$\overrightarrow{a_B} = \overrightarrow{a_A} + \overrightarrow{a_{BA}}, \tag{7}$$

Here $\overrightarrow{a_B}$ – absolute acceleration of the desired point,

$\overrightarrow{a_A}$ – absolute acceleration of a point taken as a pole,

$\overrightarrow{a_{BA}}$ – Acceleration of the relative motion of point B around point A taken as a pole. This acceleration consists of two components, i.e., tangential and normal.

In forward motion the link is accelerating and therefore any point of it is directed along the guide and it can be analytically determined at any time as follows

$$a = \frac{dV}{dt} \tag{8}$$

Based on the above, we will consider the construction of a kinematic scheme of a small potato digger as an example for kinematic verification of mechanisms (Figure 3).

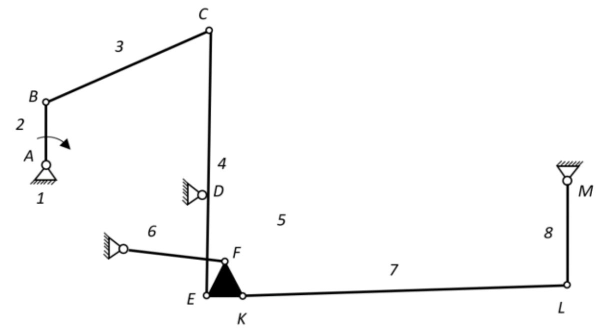


Figure 3. Kinematic diagram of a small potato digger mechanism.

According to the scheme shown in Figure 3, we know: AB = 25 mm, BC = 300 mm, CD = 300 mm, DE = 150 mm, EF = FK = 43 mm, EC = 50 mm.

Kinematic study of the mechanism can be done by solving the following problems:

1) BC The center of the connecting rod and the trajectories of points B, C, E, K, L are drawn.
2) Draw the trajectories of the center of the rod and the points B, C, E, K, L.
3) If the crankshaft speed is 120 rpm, a graph of the change in angular velocity of the crank is constructed.
4) If the curvature rotation frequency is 120 rpm, the graph of the change of the tangential component of the acceleration of the center of the BC rod, points B, C, E, K, L is constructed.
5) In addition, an image of the velocities of the following points is created: the center of the curve, B, C, E, K, L The slope of the curve relative to the horizon 90°.
6) An image of the accelerations of the following points is created: B, C, E, K, L slope of the curve relative to the horizon 90°.

The following sequence of actions is performed to build a kinematic scheme of the mechanism on the given values using information and communication technologies:

SolidWorks 2017 will launch SolidWorks to create engine links in SolidWorks. Click "File" - "New". In the dialog that appears, select "Part". In the Sketch panel, select the Sketch command. The program offers to select the plane in which the sketch is drawn. The "Front" plane is selected.

Using the tools "Sketch" and "Circle" draw a sketch shown in Figure 4. This is a fixed column for all the links made in the form of a handle.

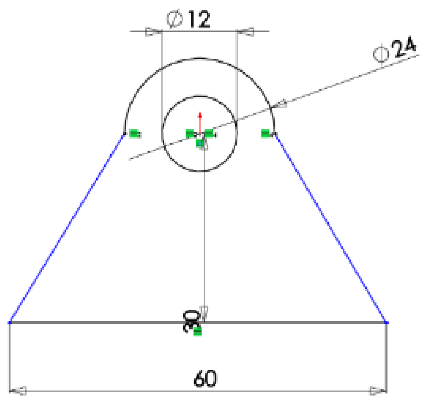
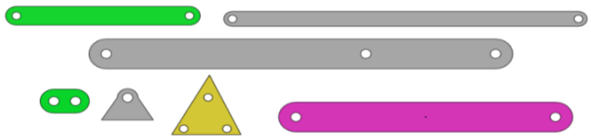


Figure 4. *Definition of a fixed link in the construction of the kinematic scheme of the mechanism.*

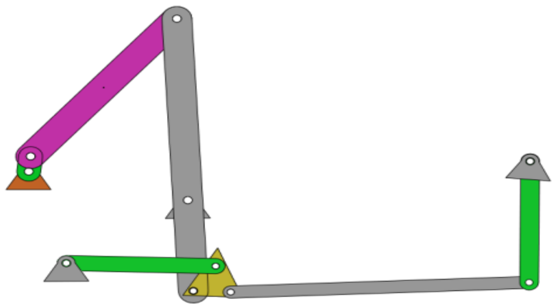
In this case, the width and diameter of the links do not affect the calculation results, so the remaining links can be selected in the same way. To do this, we start creating links from the curve. “Front” is selected as the drawing area on the screen. Draw a curve by left-clicking on the mouse pointer. The exact size of the curve can be determined and changed using the device "Smart Dimention" from the toolbar "Sketch". From the toolbar “Features” select the device "Extrudet boss".

Given the appropriate thickness, click "OK". The file is saved as "Crank". The rest of the links are created in the same way and kept under their own name.

Once all the links are created, the kinematic scheme of the mechanism is assembled. To do this, a new set of files is created and in the "Location" section are placed links created using "Insert Components" (Instruments - Assembly - Insert Components). Once all the links are installed (Figure 5a), we assemble the mechanism. The distances between the supports are determined and they are immobilized. To do this, left-click on the stand and select "Fixed" from the context menu. The mechanism assembled in this way is shown in Figure 5b.



a)



b)

a) before adding links; b) after adding links

Figure 5. *Links in the kinematic scheme of the mechanism.*

Now the mechanism has only one mobility, that is, the position of all links of the mechanism is determined by a single link - the position of the crank.

To keep the mechanism in a certain position, the crankshaft axis is pressed with the left mouse button and the corresponding turning angle is set in the properties manager – 90°.

To create and explore a movement, right-click in the Explore section of the Motion Study and select Create New Motion Research from the context menu. The research interface is shown in Figure 6. In the drop-down "Type of research" context menu, select "Motion Analysis ".

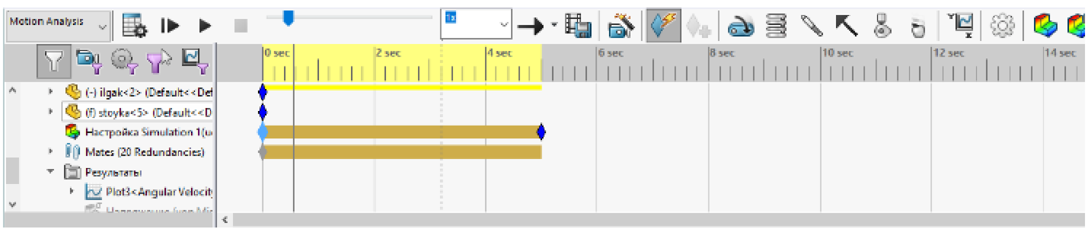


Figure 6. *Solid Works Motion interface.*

We set the parameters of the input link movement. The input link is a crankshaft, which rotates at a constant speed of 120 rpm. To set this parameter, click the "Motion Study Propeties" button and it will be added. In the Engine Properties drop-down manager, the type of rotating motor is selected because the rotating component and the direction of rotation can be selected by the direction of rotation (Figure 7). The motion parameters set a constant angular velocity of 120 rpm.

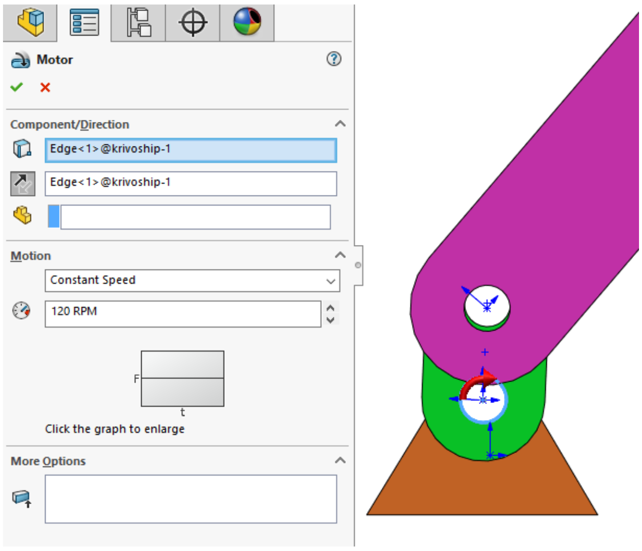


Figure 7. Add the engine.

Motion program counts 25 frames per second in "default" mode. This is not clear enough for our calculation, so we set this parameter to 100 frames per second using the setting button "Frame per seconds".

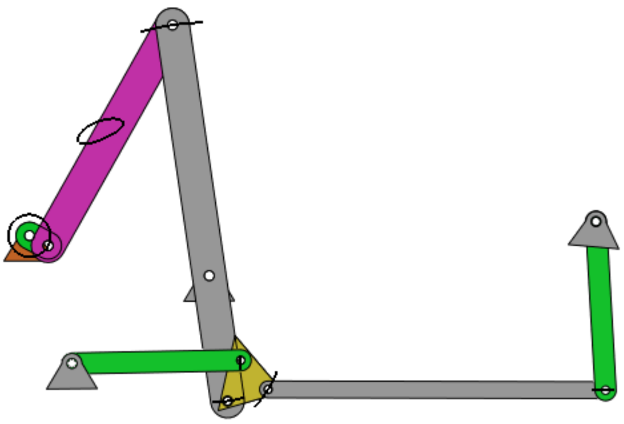


Figure 8. Determining the trajectories of the points of motion of the mechanism.

The study time can be limited to 5 seconds because the operating cycle of the mechanism and the duration of one cycle is 1 second. Now you need to calculate the motion parameters (press the "Calculate" button). New motion diagrams are created when constructing the trajectories of the points of the mechanism. To do this, select "Results and Plots" from the "Motion manager" tab. From the "Results" settings, set the sequence Displacement/Speed/Acceleration - Path Tracking and set the point where the trajectory will be drawn (initially, the center of the rod). The trajectory of this point is shown in the kinematic diagram of the mechanism. The same is done at all other points where you need to create a trajectory of motion (Figure 8).

3. Results

In determining the velocities of the points of the links of the mechanism, a new plot of the results of the movement is created. In the Properties Manager of the survey results, "Displacement/Velocity/Acceleration" is selected, if we need to find the linear velocity, "Liner Velocity" and if we need to determine the angular velocity, "Angular velocity" is selected. To find the angular velocity, the direction in which the velocity shown in the component field that appears is selected.

For the forward velocity of a point, the direction of the axis on which it moves is selected as the resulting component, and the point at which it wants to determine the velocity is selected as the element. The tangent direction is selected as the resulting component for the linear rotation speed, and the point element we want to determine the speed is selected. For the angular velocity, the direction of the axis perpendicular to the moving plane of the point is chosen as the resulting component, and the line of rotation and the point of rotation around it must be selected as the element.

Figure 9. shows a graph of the change in angular velocity of the gearbox, where the Z axis is selected as the resulting component because it is perpendicular to the kinematic diagram of the mechanism, with the axis of the moving gearbox and the center of the seat support resting on the arm.

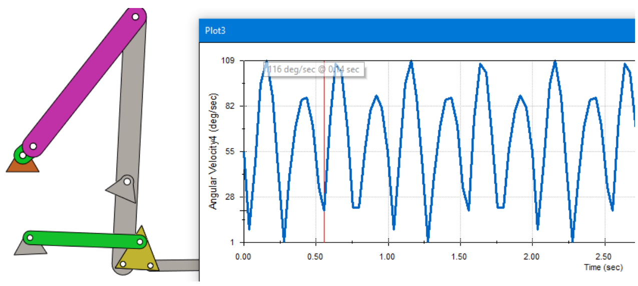


Figure 9. Schematic of the change in the angular velocity of the koromislo.

In determining the acceleration points of the links of the mechanism, a new plot of the results of the movement is created. In the Properties Manager of the survey results, in the category field "Displacement/Velocity/Acceleration" is selected, if you want to determine the linear acceleration, in the sub-category field "Liner acceleration" and if you need to determine the angular acceleration, select "Angular acceleration". The direction in which the given acceleration moves in the area of the resulting angular acceleration component is selected.

As a component formed to determine the forward acceleration of a point, it is selected as the direction of the axis it is moving and the point element we want to determine the acceleration.

In addition, a tangential direction (tangential component) or a normal direction (normal component) can be selected as the component generated for the linear rotational acceleration, and the point at which we want to determine the acceleration can be selected. The direction of the axis perpendicular to the plane of motion of the point is chosen as the component formed for the angular acceleration, and the rotating line (connection axis) and the rotating point around it must be chosen as the element.

When constructing the full velocity and acceleration vectors of the points of the engine links, you need to call the speed or acceleration-corresponding property manager to display the velocity and acceleration vectors in the kinematic diagram (right-click on the already created plot and select the line to edit the description). in the graphic window». Figure 10 shows a kinematic diagram of the points with the velocity vectors obtained.

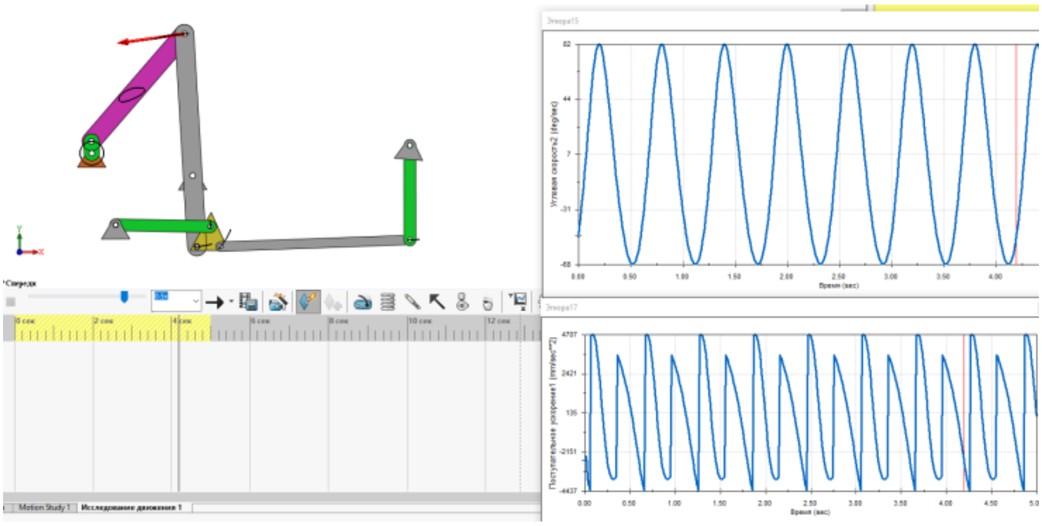


Figure 10. *Velocity vectors of mechanism connection points.*

Figure 11 shows the acceleration vectors of the points of the mechanism links.

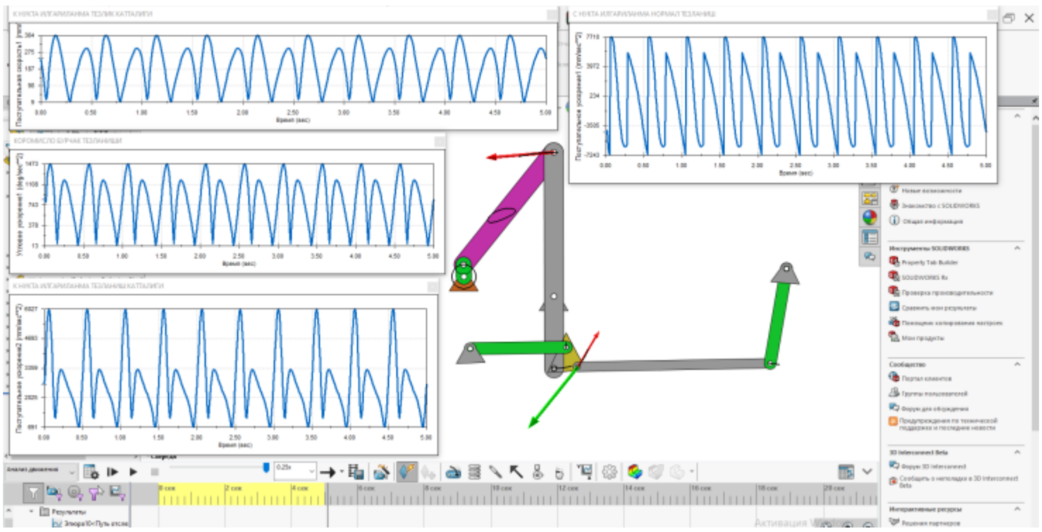


Figure 11. *The acceleration vectors of the points of the mechanism links.*

4. Conclusions

Thus, the application of the motion of the mechanism in a graph-analytical way using SolidWorks clearly demonstrates the structural analysis of the mechanism and the movement of its links, and, in addition to obtaining high-precision calculations, is effective for researchers in this field.

Author Contributions

Bayboboev Nabijon Gulomovich: formulating the basic concept of the study.

Goyipov Umidjon Glomjonovich: development of a flowchart.

Alixonov Abror Azamxon ugli: development the planter design.

Bayboboev Ulugbek Nabijonovich: development of a research methodology.

Toshtillaev Chohrux: literary and patent analysis, preparation of the initial version of the text and formation of conclusions.

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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