Loading and transport unit with a tripod manipulator and hybrid drive

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Abstract. The analysis of loading and transport operations during the harvesting of vegetables Packed in bags or nets was carried out. The geometric parameters of the pincer grip are justified and analytical and graphical dependences of the required holding force for different bag masses are obtained. The device of a developed and manufactured loading and transport unit with a tripod manipulator is described. The tasks of further research are defined.

1. Introduction
In agro-industrial production, a large volume of piece cargo is represented by bags, boxes, soft bags and nets with packed vegetable products weighing from 20 to 80 kg. For example, harvesting onions, carrots, and sometimes potatoes is most often done by packing them in nets directly on the field, followed by loading onto vehicles and delivery to the place of sale. In the technological process of harvesting, this is one of the most labor-intensive operations, besides, during loading operations on harvesting vegetables, manual labor predominates [1, 2].

Despite the development of means of mechanization in agricultural production, the volume of manual labor in the procurement of fruits and vegetables reaches up to 40% ... 50%. It is possible to eliminate this drawback only by comprehensive mechanization and automation of loading and unloading operations.

An important indicator of the operation of automatic and semi-automatic lifting mechanisms is the positioning accuracy of the lifting device. Usually, according to the conditions of the technological process, the positioning accuracy of the load-gripping body is lower than the positioning accuracy of the actuators. For agricultural loaders, a low positioning accuracy is required, depending on the value of the permissible deviations of the load positions at the initial position and the unloading position (in the initial and final configuration) [3].

The prospect of creating a lifting and transport robotic unit based on a bag loader is determined by the following criteria:
1) implementation of portable and orienting coordinate degrees of mobility;
2) the use of a load-gripping device in the form of a pincer grip;
3) installation of a manipulation device transfer mechanism on a mobile chassis;
4) the relative uniformity of manipulation objects (bags) in their shape and mass;
5) relatively low required accuracy of positioning of loads;
6) the possibility of organizing a strictly regulated technological process.
2. Computational model

Developed handling unit has one portable global coordinate S, the change which happens with the speed of movement of the chassis $V_{ch}$, the angular coordinate of rotation of the base of the tripod of $\phi$, varying with speed $\omega$ and the three generalized coordinates of the tripod $l_1, l_2$ and $l_3$ providing the displacement of the point $M$ suspension grip with the speeds $V_{MX}, V_{MY}$ and $V_{MZ}$, which is a projection of velocity $V_M$ on the coordinate axis (figure 1).

![Figure 1. A design scheme for loading a transport unit with a manipulator-tripod.](image)

The productivity of loading and transport operations when selecting nets with onions depends on the speeds of the actuators, the technological speed, the uniformity of the distribution of nets (bags) across the field, and, not least, the orientation of the nets in relation to the self-propelled loader. Based on the analysis of technological processes of loading and transport operations during harvesting of root crops Packed in nets or bags, a design and technological scheme of a self-propelled loading vehicle with a robotic manipulator-tripod for loading bags of vegetables is proposed and developed [4, 5, 6].

The structure and required degrees of mobility, geometric and kinematic parameters that ensure the necessary movement of the cargo are justified for the developed manipulator of the loading vehicle. Analytical dependences are obtained between the design parameters of the manipulator, which make it possible to ensure a constant speed of the loading unit [7, 8, 9].

3. Define and build a service area configuration

Guaranteed retention of the load by the gripper is caused either by a geometric closure, or by a force closure, which ensures the impossibility of translational and rotational movements of the captured bodies (figure 2).

The minimum required holding force is determined from the expression

$$P(\phi) \geq \frac{2 \cdot \cos \phi (N \cdot l - 0.25 \cdot Q \cdot a)}{b}$$

(1)

The resulting dependence (1) allows you to select the drives to provide the necessary holding force at the design stage of the gripper. Here, however, it should be remembered that the holding weight is vegetables, which, if a significant force is applied to them, can be damaged.
Figure 2. Calculation scheme of tick capture.

Depending on the size of the mesh, their gross weight also varies within different limits, the graphic dependences of the holding force on the bag weight and the angle of the gripper lever position are shown in figure 3.

Figure 3. Dependence of the holding force on the mass of the bag and the angle of the grip lever position.

Figure 4 shows the dependence of the holding force of the pincer grip on the angle of the position of the levers $\varphi$ and their length $b$. The values of the holding forces in a pincer grip with curved jaws
are 5 times less than in a grip with flat sponges. As a result, the capture scheme in figure 2 was chosen, which is preferable from the point of view of less force on the grid with vegetables and, accordingly, less damage to vegetables.

Figure 4. Dependence of the holding force $P$ on the angle of position $\phi$ and its length $b$ for gross mass.

Taking into account the obtained dependencies, a pincer grip for bags of vegetables was made (figure 5 (a)), mounted on a manipulator-tripod of a loading and transport unit on a self-propelled chassis (figure 5 (b)).

Figure 5. Pincer gripper and loading and transport unit.
The loading and transport unit with a tripod manipulator consists of a self-propelled T-16MG chassis (figure 5 (b)) 1, to the spars 2 of which a composite boom is attached, which is a spatial parallelogram mechanism, which consists of four racks 3, 4, 5, 6, fixed by means of cylindrical hinges to the frame 7, allowing using Executive hydraulic cylinders 8, 9 to implement the rotation angle so that the platform 10 is always kept in a horizontal position. A manipulator-tripod is attached to the platform 10, which has three linear Electromechanical drives 11, 12, 13, the ends of which are attached to the platform 10 with hinges on one side, the rods of the opposite ends of the three linear actuators-actuators are connected to each other and with a two-stage controlled grip 14 by means of a five-moving spherical hinge 15. The drive of the Executive mechanisms is made hybrid, the rotary parallelogram mechanism and the pincer grip are driven by a hydraulic drive, the drive of the Executive links of the manipulator-tripod is electric (supply voltage 24 V).

When performing technological operations for loading bags, the self-propelled chassis 1 moves across the field, the chassis operator controls the tilt of the boom, while positioning the pincer grip to the bag is performed automatically according to the specified program laws [10, 11]. To recognize bags on the field and then determine the capture coordinates, the technical vision system is used (figure 6). Bags are loaded into the body of a self-propelled chassis (pictured in figure 5 (b) the body is removed).

![Figure 6. Screenshot of the program of the technical vision system for recognizing bags on the field.](image)

It is planned to evaluate the effectiveness of the developed robotic loading and transport unit for collecting vegetable nets from the field in terms of productivity, positioning accuracy and movement along specified trajectories, and energy consumption per cycle of technological operations for several control modes:
- fully manual operator control mode;
- semi-automatic control mode, loading and transport unit for collecting bags of vegetables from the field.

In the future, it is planned to fully automate the control of Executive drives by replacing manual hydraulic valves with electrically controlled ones.

4. Conclusion
The design of the manipulator and the parameters of the pincer grip of bags are justified. The design of the manipulator was developed and manufactured, on the basis of which an experimental loading and transport unit was assembled. The developed loading and transport unit with a parallel-
sequential manipulator structure can be installed on a self-propelled chassis "Agromash" SH-50 or vzr-30SSH. The resulting working area of the robot loader arm provides full coverage of the entire body area along the width of the chassis. To control the manipulator actuators, a control system has been developed that allows implementing the specified program laws of motion. The manipulator is equipped with a technical vision system for recognizing the coordinates of grids with vegetables relative to the coordinate system directly connected to the chassis body.

Acknowledgments
The work was supported by the RFBR grant no. 19-38-90067 "Postgraduate students" and the RF President Grant no.MK-210.2020.8.

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