INVESTIGATION OF THE PERFORMANCE OF A SCREW CONVEYOR WITH A WORKING BODY, MADE IN THE FORM OF A SHAFT WITH INCLINED FLAT BLADES
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ДОСЛІДЖЕННЯ ПРОДУКТИВНОСТІ ГВИНТОВОГО КОНВЕЄРА З РОБОЧИМ ОРГАНОМ, ВИКОНАНИМ У ВИГЛЯДІ ВАЛУ З НАКЛАДНИМИ ПЛОСКИМИ ЛОПАТЯМИ

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ABSTRACT
The article presents a study of the design of the working body of a screw conveyor, made in the form of a shaft with inclined flat blades. The productivity of the conveyor with a working body, made in the form of a shaft with inclined flat blades, increases proportionally with an increase in the speed of rotation of the working bodies, and decreases with an increase in the angle of inclination of the fixed body to the horizon. The productivity of the screw conveyor with a working body, made in the form of a shaft with inclined flat blades, increases proportionally with an increase in the speed of rotation of the working bodies, and decreases with an increase in the angle of inclination of the fixed body to the horizon. Within the range of rotational speed from 100 rpm to 600 rpm, productivity increases by 2.0 – 2.4 times, and, when angle of inclination of the fixed body to the horizon changes from 0º to 30º, it decreases by 45 – 55%. It has been established that the productivity of such a conveyor is 1.03 ... 1.05 times greater than the productivity of a conveyor with a screw working body.

АНОТАЦІЯ
В статье представлено исследование конструкции рабочего органа конвейера, выполненного в виде вала с наклонными плоскими лопастями. Производительность конвейера с рабочим органом, выполненным в виде вала с наклонными плоскими лопастями, увеличивается пропорционально увеличению скорости вращения рабочих органов и уменьшается с увеличением угла наклона конвейера к горизонту. В диапазоне частоты вращения от 100 до 600 об/мин производительность увеличивается в 2,0 – 2,4 раза. Установлено, что производительность конвейера с рабочим органом, выполненным в виде вала с наклонными плоскими лопастями, в 1,03...1,05 раза больше, чем производительность конвейера с винтовым рабочим органом.

INTRODUCTION
Technological processes for gathering and processing agricultural products, construction products, etc., consist of a number of labor-intensive loading, unloading and transport operations. Conveyors are widely used for transferring loose and lumpy materials in various production processes. The use of drive shafts with a central drive of technological lines in the screw conveyors can significantly increase the operational reliability of such mechanization tools when performing loading and unloading technological operations *(Bulgakov et al, 2022; Hevko et al., 2018; Mondal and Ghosh, 2018; Roberts and Bulk, 2015).* However, the existing designs of screw conveyors do not fully meet the technological and operational requirements. Their main disadvantages are the increased production costs of the working bodies, increased damage to the bulk material and the design complexity of conveyors, especially considering their significant overall dimensions *(Tian et al., 2018; Govender et al., 2021; Hevko et al., 2016 a).*

Increasing the transportation distance while maintaining the mobility and reliability of the working parts of the screw conveyors is a promising direction for further improvement of such transport vehicles.

Therefore, when making working bodies for the transportation of bulk cargo over long distances, the technology of their manufacture plays an important role. Recently, active exploratory research has been carried out of the screw working bodies, made on the basis of articulated individual sections for flexible screw conveyors *(Hevko et al., 2016 b)*, which ensure the movement of bulk cargo along curvilinear technological routs. In this case it is problematic and technologically difficult to produce separate sections of the screw spirals, the length of which should be 1.2...2.0 screw pitches. Making of such a screw section can be carried out by 4 ... 5 technological operations (winding a spiral into a package; calibration of the spiral; cutting it into separate sections; treatment of the end surfaces; turning grooves on the lateral surfaces). In the known designs of conveyors in which the problems, mentioned above, are partially solved, the process of reloading bulk material becomes much more complicated, and under certain operating modes, the likelihood of congestion increases, which leads to a loss in the screw conveyor performance *(Mondal and Ghosh, 2018; Yao et al., 2014; Klendiy and Hevko, 2005; Pylypaka et al., 2019; Qi et al.,* 2017*).*

Therefore, the task of the research and development of new designs of the working bodies of screw conveyors is relevant, providing an increase in their performance while reducing the material consumption and simplifying the design. Therefore, the task of research and development of new designs of the working bodies of the screw conveyors is relevant, providing an increase in their performance while reducing the material consumption and simplifying the design. To improve the process of transportation of bulk cargo, a new design of a screw conveyor is proposed with a working body made in the form of a shaft with inclined flat blades. The purpose of the work is an experimental investigation of the performance of a screw conveyor, the working body of which is made in the form of a shaft with inclined flat blades, depending on the frequency of rotation of its working bodies and the angle of inclination of its body to the horizon.

MATERIAL AND METHODS

In order to reduce the material consumption and simplify the design of the working bodies of the screw conveyors, instead of solid screw spirals, there are used successively arranged (inclined to the axis of rotation) flat blades, attached to the drive shaft. Such blades are easy to make – by stamping sheet material with their subsequent welding to the shaft.

Figure 1 shows a reamer of a blade that can be made by sheet stamping. In contrast to the known design, the proposed design in terms of technology is the simplest, providing stable dimensions of the section of the working body at a low cost of its manufacture.

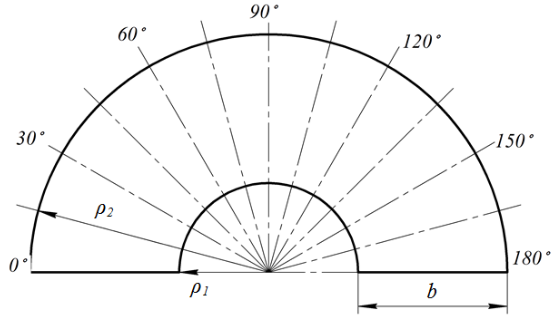

Fig. 1 – The reamer of a flat inclined blade

According to preliminary studies *(Hevko et al., 2004; Pylypaka et al., 2019)*, it has been established that it is rational to make blades with mirror reflection relative to the vertical within the range from 0º to 90º (full range of 180º) based on kinematic and design indicators. Fig. 2 shows a general view of the working body of the conveyor, made in the form of a shaft with inclined flat blades.

Fig. 2 – General view of the working body, made in the form of a shaft with inclined flat blades

To conduct experimental investigations in order to determine the design and kinematic parameters of the conveyor elements for transporting materials, a laboratory experimental setup was developed, including the investigated conveyor with a working body, made in the form of a shaft with inclined flat blades (Fig. 3).

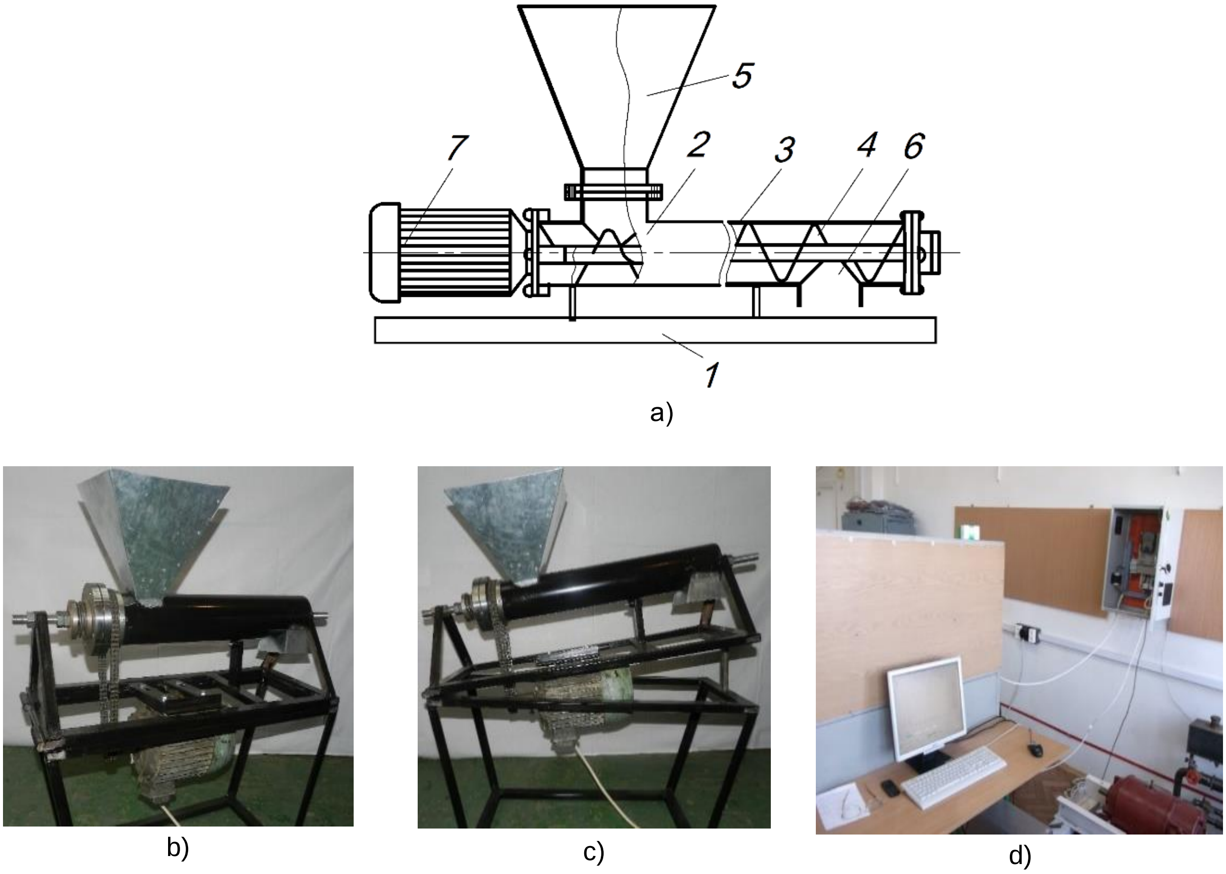

Fig. 3 – Laboratory experimental setup for the investigation of the screw conveyor with a screw, made in the form of a shaft with inclined flat blades

a – structural diagram; b – general view with a horizontal auger;
c – General view with an auger, inclined towards the horizon, d – Altivar 71 frequency converter

The laboratory setup for experimental research of the screw conveyor with a working body, made in the form of a shaft with inclined flat blades, consists of a frame *1* on which a conveyor *2* is located, containing a fixed housing *3*, in which the working body *4* is installed, made in the form of a shaft with inclined flat blades. A loading hopper *5* is installed on the loading side of the bulk material, and a window with an adjustable damper *6* is installed in the area of its unloading. The conveyor is driven in rotation by an electric motor *7* with a chain drive. The Altivar 71 frequency converter and Power Suite v.2.5.0 software were used to start motor *7* and to adjust its speed. The results of experimental research of the operational parameters of a new design screw conveyor in the form of curves for changing the frequency of rotation of its drive shaft, torque and power were recorded on a computer display.

When conducting laboratory experimental studies, peas, wheat, corn and sand were used as bulk transported materials. The specific weight of the transported materials was as follows: peas – 700 $kg{\cdot}m^{-3}$; wheat – 760 $kg{\cdot}m^{-3}$; corn – 800 $kg{\cdot}m^{-3}$; sand – 1480 $kg{\cdot}m^{-3}$. The average moisture content of the materials was W = 12…18%. A fivefold number of repetitions were used in the experiments with various bulk materials.

The quality of the transportation process by the unloading completeness of the bulk material was also additionally evaluated (the remains of the materials were collected and weighed), and the crushing degree of the transported agricultural materials was determined.

The main design parameters of the investigated screw conveyor were: the inner diameter of the fixed body was D = 0.1 m, the outer diameter of the screw was d = 0.098 m, the inclination angle of the conveyor body varied within α = 0º...30º, the engine power was N = 2.2 kW.

The sequence of carrying out and the methodology of laboratory experimental investigations were as follows. The loading hopper was previously fully loaded with the bulk material. Then, at a previously set speed of the screw working body and a fixed angle of inclination of the screw conveyor body to the horizon, the material was unloaded into the measuring container.

The rotation frequency of the working body *n* was changed in the range from 100 rpm to 600 rpm. The angle of inclination to the horizon of the fixed body with the working tool was changed within a range of *α* = 0º...30º.

Processing of the obtained experimental data was performed on a PC in accordance with the existing program of statistical calculations (*Savinyh et al., 2016).*

RESULTS

The obtained results of the experimental investigations are presented in the form of graphical dependences of productivity of material transportation upon the number of revolutions *n* of the working body when transported by the screw conveyor of a new design (Fig. 4).

It follows from the analysis of the obtained graphical dependencies that, when a certain amount of bulk material is unloaded from the bunker, the productivity *Q* of the conveyor decreases as the angle of inclination of its body to the horizon increases. Moreover, within the limits of the angle change from 0º to 20º, the decrease in *Q* is insignificant, and for the above mentioned materials it is 19.6%...25.0%.

A sharp decrease in productivity *Q* is observed with a further increase in the angle of inclination to 30º. So, in comparison with the horizontal arrangement of the screw working body and its location to the horizon at an angle *α* = 30º, the decrease in *Q* at a rotation frequency of *n* = 400 rpm is: for wheat – 55%; for peas – 52%; for corn 53%; for sand – 46%.

When the angle of location of the fixed body of the conveyor to the horizon over 20º is increased, the material load factor begins to increase sharply. However, with a stable supply of the transported material to the loading line, this will lead to an increase in the energy consumption for the transportation process.

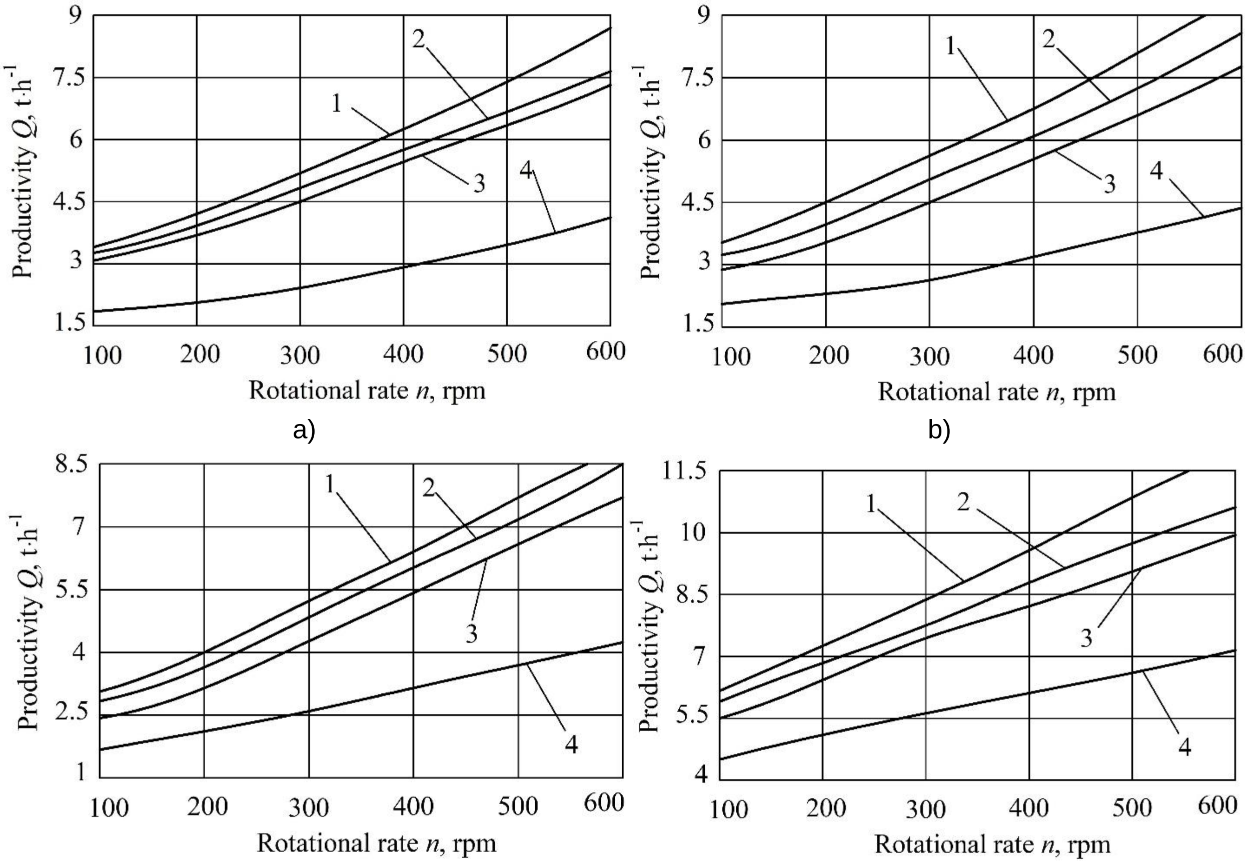

Fig. 4 – Dependences of productivity *Q* of the conveyor upon the frequency of rotation *n* of the working body, made in the form of a shaft with inclined flat blades at different values of angle *α* of the conveyor inclination to the horizon during transportation

a – wheat; b – peas; c – corn; d – sand (1 – α = 0º; 2 – α =10º; 3 – α = 20º; 4 – α = 30º)

Figure 5 shows the dependences of productivity *Q* on the speed of rotation of the working bodies *n* when transporting various materials and the angles of inclination of the conveyor body to the horizon α = 0º and α = 30º.

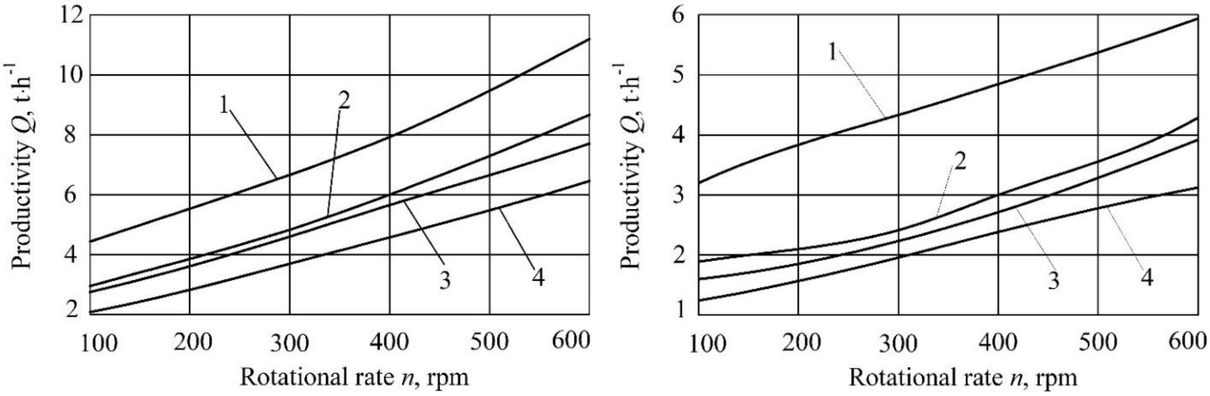

Fig. 5 – Dependences *Q = f (n)* during transportation: 1 – sand; 2 – peas; 3 – wheat; 4 – corn – at the angles of inclination of the conveyor to the horizon

a – α = 0º and b – α = 30º

The analysis of these dependencies shows that the highest productivity of the conveyor is when transporting sand. For peas and wheat the productivity is actually the same, and for corn the lowest. The productivity of the conveyor with a working body, made in the form of a shaft with inclined flat blades *Q*, increases with an increase in the screw rotation speed *n*.

Within the range of changes in the number of revolutions of the working bodies from 100 rpm to 600 rpm the productivity increases by 2.0 – 2.4 times. There is also a clear dependence of the productivity decrease *Q* from the increase in the angle α of its inclination to the horizon. So, when changing angle α of inclination from 0º to 30º, the productivity *Q* decreases by 45 – 55%. The results of comparative experimental investigations in order to determine productivity *Q* of the conveyor with a screw working body (solid line) and a bladed one (dashed line) at a rotation frequency of *n* = 300 rpm from the angle of inclination of the conveyor to the horizon are presented in Fig. 6.

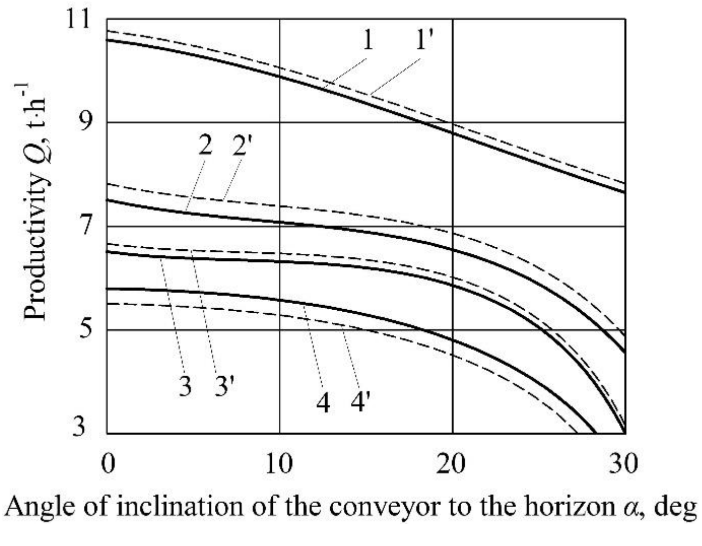

Fig. 6 – Graphical dependences of productivity *Q* of the conveyor with a screw working body (solid line) and the bladed one (dashed line) at a speed of rotation *n* = 300 rpm on the angle of inclination to the horizon

1 – sand; 2 – peas; 3 – wheat; 4 – corn

According to the results of the laboratory experimental investigations it was found that the performance of a conveyor with a working body, made in the form of a shaft with inclined flat blades, is 1.03...1.05 times greater than the productivity of a conveyor with a conventional screw working body. This gives grounds to assert that the bladed working body is expedient for use in screw conveyors since one of the promising directions for determining the manufacturability of the working bodies of screw conveyors is the use of blades that are rather long, flat, inclined to the axis of rotation, which are attached to the carrying shaft. It is advised to make such blades by stamping sheet material with their subsequent welding to the shaft, which is much cheaper than manufacturing a helical screw with a continuous spiral. The proposed design of the bladed working body provides stable dimensions of the working body section at a low cost and a simpler technology for its manufacture.

CONCLUSIONS

The productivity of the screw conveyor with a working body, made in the form of a shaft with inclined flat blades, increases proportionally with an increase in the speed of rotation of the working bodies, and decreases with an increase in the angle of inclination of the fixed body to the horizon. Within the range of rotational speed from 100 rpm to 600 rpm, productivity increases by 2.0 – 2.4 times, and, when angle of inclination of the fixed body to the horizon changes from 0º to 30º, it decreases by 45 – 55%.

The productivity of a conveyor with a working body made in the form of a shaft with inclined flat blades is 1.03...1.05 times greater than the productivity of a conveyor with a screw working body. Given that the manufacturing technology of flat blades is less complicated, this design can be used in the manufacture of conveyors for grain and other bulk products.

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