Research on a flexible sectional screw working body for recycling damaged soil from the middle of a crater

Oleksandra Trokhaniak[1], Oleksandr Matsuev[2], Volodymyr Martyniuk[1]
[1]National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine
[2]Institute of Mechanics and Automation of Agricultural Production of NAAS of Ukraine, Kyiv Region, Hlevaha, Ukraine

E-mail: klendii_o@ukr.net

Abstract. *The article presents, based on research into the impact of military operations on agricultural soils, the design of a flexible screw sectional working body, which will allow to increase the functional and operational characteristics of screw conveyors during the disposal of the removed contaminated soil layer. For the research, an experimental setup was developed and manufactured, with the help of which the torque on the drive of the flexible screw conveyor was determined. Based on the results of the research, graphical dependences of the change in the value of the torque T on the frequency of rotation of the drive shaft of the working body n, on the radius of curvature $R_к$ of the technological line and on the height h of movement when the technological line is completely filled with loose cleaned damaged soil from the middle of the crater are constructed. The obtained research results make it possible to choose the optimal design, kinematic and technological parameters of the developed screw sectional working body for transporting loose cleaned damaged soil from the middle of the crater.*

KEYWORDS: *AGRICULTURAL SOILS, DRAINAGE, SCREW CONVEYOR, AUGER.*

Introduction

Thousands of hectares of Ukrainian land were bombed during russia's full-scale invasion of Ukraine. Military operations lead not only to mechanical and physical deterioration of the soil, but also to its chemical contamination.

The greatest impact on agricultural lands and soil cover is caused by enemy aviation and artillery, accounting for about 80% of the impact. As a result of rocket and artillery attacks, the fields are covered with craters (crashes) from explosions of shells, mines, and rockets. Craters are of different diameters and depths [1]. The depth of the craters in the fields ranges from 30 cm (82 mm mortar) to 5 m (cruise missiles), and the soil remaining at the impact site is turbulized, subjected to dynamic compaction, and also contains numerous metal fragments with residues of explosive toxic substances, i.e., the physical properties of the soils deteriorate, the granulometric composition changes, compaction and destructuring occur due to a decrease in the content of agronomically valuable fractions, etc. [2, 3].

To restore areas damaged by explosions, it is necessary to remove or clean the surface layer of the soil, since in addition to chemical contamination with heavy metals, the fertile layer of the soil also burns out, dehydration and "sterilization" occur - both pathogenic microorganisms and beneficial biota die [4, 5].

To remove and clean the damaged surface layer of the soil in the crater formed as a result of explosions, it is recommended to use a working body that will allow mechanizing this process. This working body is attached to the boom of an excavator with a hydraulic system [6].

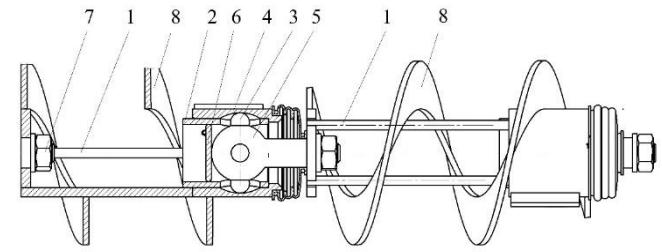
To dispose of the removed contaminated soil layer, a flexible screw conveyor with a sectional screw working body can be used, which will make it possible to reload it into the truck body.

Screw conveyors are used in the transportation of various types of loose agricultural materials, which include: grain, granulated seed materials, clay, sand, loose soil, compound feed, mineral fertilizer granules, etc. From the analysis of literature sources, it can be concluded that the least resource-intensive technology for moving loose and lumpy agricultural materials along curved routes is the use of flexible screw conveyors, which are made on the basis of separate screw sections that are hingedly connected to each other [5, 6]. In works [7-10], the structural, kinematic and technological parameters of screw working elements are substantiated from the point of view of their functional purpose.

However, existing flexible screw working bodies cannot fully satisfy the operational requirements imposed on such types of conveyors. The use of shaftless flexible spirals of screws leads to their rapid destruction when conveyors operate on curved routes, due to the occurrence of alternating cyclic loads. The execution of the working body in the form of a solid or sectional shaft, on which individual elements of the screw ribs are located, leads to a significant complication of the design of the technological body, an increase in its material consumption, which accordingly causes an increase in energy consumption, as well as damage to the materials being transported. Therefore, the task of developing new designs and substantiating the parameters of flexible screw working bodies of conveyors, which will ensure an increase in the functional and operational indicators of the process of recycling the removed contaminated soil layer, is relevant.

Results and discussion

In order to improve the functional and operational performance of screw conveyors when transporting cleaned damaged soil, a design of a flexible sectional screw working element was developed, the structural diagram of which is shown in Fig. 1.



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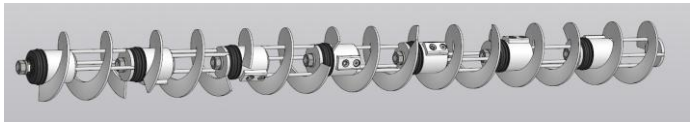

b

Figure 1. *Structural diagram (a) 3D model (b) of a flexible sectional screw working body*

This working body consists of separate sections of the same diameters and lengths, which are made in the form of welded structures containing rods 1, to which at one end is rigidly fixed cylindrical sleeve 2, which is made with a system of axial parallel grooves, placed evenly around the circumference, which interact with balls 3. On the other side, balls 3 interact with spherical holes of the housing 4, which allows axial and angular rotation of the spherical finger 5. In addition, from above, cylindrical sleeve 2 is in rigid interaction with spherical housing 4, the inner surface of which interacts with the outer surfaces of balls 3. From the second end of the welded cylindrical section, a connecting sleeve 6 is rigidly installed in the inner hole perpendicular to the axis, which interacts with the corresponding end of the spherical finger 5 of the adjacent section and its rigid fixation by means of a bolted connection 7. On the outer diameter cylindrical section rigidly welded screw section 8.

The work of the screw working body is carried out as follows. During the rotation of the spiral section 8, the rotational motion is transmitted through the balls 3 to the spherical pin 5 and adjacent sections of the screw working body.

Fig. 2 shows a general view of the manufactured flexible screw sectional working body.

Figure 2. *General view of the manufactured flexible screw sectional working body*

To conduct experimental research, a research setup was developed and manufactured, the structural diagram of which is presented in Fig. 3.

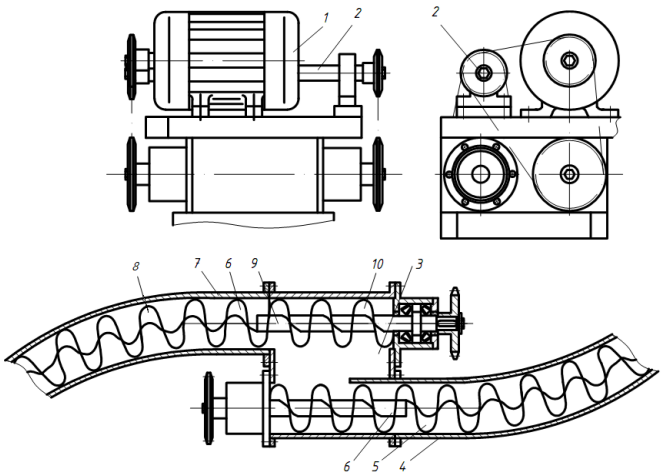

Figure 3. *Structural diagram of the experimental setup*

The loading branch of the experimental screw conveyor installation (Fig. 3) contains loading and unloading mains, made in the form of casings 7 and 4 and loading 8 and unloading 5 working spirals of the screws installed in parallel in them. The latter, respectively, are fixed on the drive shafts 9 and 6, which are located in the loading branch 3. The intermediate shaft 2 is installed parallel to the drive shafts and fixed on the loading branch. The drive and intermediate shafts outside the loading branch are kinematically connected to the shaft of the electric motor 1.

The general view of the experimental installation is shown in Fig. 4.

During operation, the kinematically connected drive shafts, the intermediate shaft and the shaft of the electric motor ensure the rotation of the working spirals of the screws. When feeding loose material, the spiral 8 moves it in the casing towards the overloading nozzle. Since the drive shafts are located in a horizontal plane, the material is transferred to the unloading line by radial flat plates.

Figure 4. *General view of the experimental setup*

The parameters of the working body used were as follows: inner diameter of the casing – 100 mm; outer diameter of the auger spiral – 96 mm; inner diameter of the auger spiral – 46 mm; spiral pitch – 65 mm.

The experimental methodology was as follows. During the research, the cleaned damaged soil is fed from the hopper into the loading line and, when the working body rotates, is transported to the overload pipe of the experimental installation and, using the unloading line, which consists of a hinged-sectional working body, to the unloading zone.

To start the engine and regulate its rotation frequency, the Altivar 71 frequency converter and PowerSuite v.2.5.0 software were used.

After the material transportation process was completed, data on the change in torque and engine power over time were obtained in the Power Suite program window on the computer display.

The results were obtained in the format of graphical dependencies in the program window of the computer display.

To analyze the results obtained, graphical dependences of the torque T on the frequency of rotation of the working body n were constructed, at different values of the lifting height of the bulk material h and the radius of curvature of the technological line $R_к$. To construct graphical dependences, the peak (maximum) values of the data obtained as a result of the research were used.

The values of the torque and engine power were fixed as a percentage of the nominal. The engine power was determined from the product of the nominal engine power (2.2 kW) and the maximum percentage value for the selected mode. Similarly for the torque. The nominal value of the torque for our case is equal to M_n = 14.39 Nm.

The excess of the nominal power and torque is explained by the fact that the frequency converter can briefly exceed its nominal current by up to 170%. If the converter is selected with a margin, then 170% of the converter can be 210% of the engine overload.

According to the results of the obtained studies, graphical dependences of the change in the value of the torque T on the frequency of rotation of the drive shaft of the working body n, different values of the height of soil lifting h and the radius of curvature of the technological highway $R_к$ when the technological highway is completely filled with cleaned damaged soil (Fig. 5) were constructed.

From the analysis of the graphical dependences, it was established that with an increase in the frequency of rotation n of the working body from 200 to 500 rpm, the torque T decreases by 5.8%.

It was established that with an increase in the radius of curvature of the technological highway $R_к$ from 0.5 m to 2.2 m, the torque T decreases by 21%.

It was also established that with an increase in the height of material movement h from 0.2 m to 1.8 m, the torque T increases by 33%.

Conclusions

The impact of armed aggression and military actions on the soil cover has been studied and analyzed, in particular, damage and destruction of the fertile soil layer due to the detonation of various types of explosives (rockets, air bombs, artillery shells, etc.). As a result of rocket and artillery shelling, fields are covered with craters (crashes) from explosions of shells, mines, rockets. Craters are of different diameters and depths. The soil remaining at the impact site is turbulized, undergoes dynamic compaction, and also contains numerous metal fragments with residues of explosive toxic substances, i.e., the physical properties of soils deteriorate, the granulometric composition changes, compaction and destructuring occur due to a decrease in the content of agronomically valuable fractions, etc.

It has been established that to restore soil fertility, it is necessary to remove the damaged surface layer and level the relief of agricultural lands. To do this, it must be cleared. During further disposal of the cleaned contaminated soil layer that will be at the bottom of the crater, a flexible screw conveyor with a sectional

screw working body can be used, which will allow its transportation into the vehicle body.

To select rational design parameters of the screw working body for transporting damaged soil, a method has been developed for conducting experimental studies of the torque *T* during the transportation of loose agricultural material by the developed screw sectional working body of the conveyor.

It has been established that with an increase in the rotation frequency *n* of the working body, the torque *T* decreases, with an increase in the radius of curvature of the technological line $R_к$, the torque *T* decreases, and with an increase in the height of material movement *h*, the torque *T* increases.

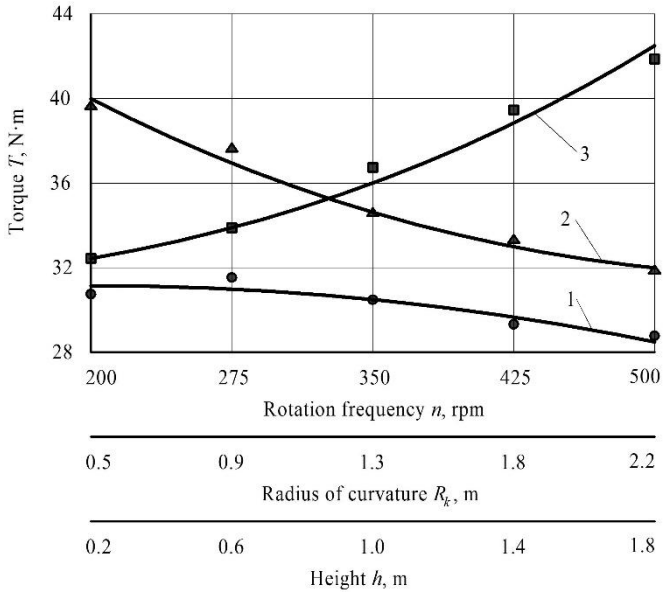

Figure 5. Graphs of torque T from changes in:
1 – frequency of rotation of the drive shaft of the working body n;
2 – height of soil lifting h;
3 – radius of curvature of the technological main $R_к$

The obtained research results make it possible to select the optimal structural, kinematic and technological parameters of the developed screw sectional working body for transporting loose agricultural materials.

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