INTRODUCTION
Screw conveyors are widely used for transportation of grain, seed materials, granular mineral fertilizers, that can be seriously damaged during the relocation, which is inadmissible.

The main reasons of bulk solids damages are falling of particles into the gap between rotate reciprocating screw and stationary internal surface of conductor pipe. As a result complete or partial material damages take place and causes increased energy consumption.

Changes of gaps between circumference of reciprocating screw and pipe surface, application of different external edging shape of helical surfaces considering geometrical and rheological characteristics of bulk solids cannot solve the problem completely.

The following papers [1, 2, 3, 4, 6, 7, 8, 10] are dedicated to solving such problems as development of original design for helical working parts and their rational characteristics and operational modes. However, such developments do not solve the problem completely, because existing reciprocating screw designs and production methods are labour-intensive and working parts are specified as those having low reliability and maintainability.

MATERIAL AND METHOD
The objective of this research is to create new reciprocating screw design with changeable flexible helical surface, develop its production methods and experimental benches for investigation purposes. The design of reciprocating screw with flexible helical surface and design styles of flexible units in the form of sheets are shown in fig. 1. It contains central shaft 1, where bearing tape helix 2 with operating flexible spiral on its edge 3 is mounted. Operating flexible spiral 3 is fixed on the bearing tape helix by means of sectional screw sheets 4, and bolt connection with semicircular heads 5 and nuts 6 with spring washers.
Working flexible spiral can be integrated (fig. 1 a, b, c), or consist of separate units (fig. 1 e, f, g). The units of working flexible spiral are fixed onto bearing screw spiral through two gaps at least, and circumferential surface of working flexible spiral can come in the form of cut sheets with different width (fig. 1 e, f, g) according to geometrical and rheological characteristics of material transported.

Fig. 1 – Reciprocating screw with flexible helical surface
During the transportation of agricultural bulk solids in guide pipe 7 they interact with working flexible helical surface. In case of jamming, for instance, grains between surface of the pipe and working flexible helical surface cut sheets are sagged, thus preventing grain damage. The width and rigidity of working flexible helical surface are chosen according to physical and chemical properties of the transported material.

The production method of this working part [5] is shown in fig. 2. The stripe of rectangular crossing is previously coiled on arbor on rib in faggot (fig. 2 a). Then the faggot is pressed on the arbor and according to diameter at the edges of the faggot gaps (fig. 2 b). After that the faggot is mounted on shaft and stretches spiral to the back step until the complete contact of internal spiral with the shaft, then it is welded onto the latter. On the next stage working spiral or its units are fixed to gaps of bearing spiral (fig. 1d).

For definition of deformation value “Δ” of free edge of flexible sheet unit (fig. 1 e, f, g) and its width “W” and value of cantilevered cog “h” experimental bench has been developed and manufactured. During the loading process of flexible sheet unit its free edge was deflected and the deformation value was noticed according to the bulk of measuring loads. Experimental studies have been conducted for the material of flexible sheet “polyurethane PU-60” with thickness of 2,5 mm. The value of cantilevered cog of flexible sheet was discretely set with distance of \( h = 25; 20; 15; 10 \) mm, with discrete values of these sheet widths of \( W = 25; 20; 15; 10; 5 \) mm.
RESULTS AND DISCUSSION

Fig. 3 illustrates the findings of experimental research for cantilevered fixed flexible sheet deformation respectively to its loading value.

The experimental research for evaluation of the seed material damage degree the bench [5] has been developed, as shown in fig. 4.

It consists of cradle, featuring angular position regulator, and the screw conveyor mounted on it. Reciprocating screw working part with flexible helical surface is placed in the guiding pipe. The hopper is mounted on the loading side with the opening in its off-load zone for conveying the material into the container. The working part gear is driven by the electric motor. Frequency converter (Altivar 71) with Power Suite v.2.5.0. software were employed to start the engine and control its rotational speed. Altivar 71 system was wired to the network and computer.

Fig. 4 – Bench for research of reciprocating screw conveyor with flexible working part

REЗУЛЬТАТИ

На рис. 3 представлено результати експериментальних досліджень деформації консольно закріпленої еластичної пластини від величини її навантаження.

Для проведення експериментальних досліджень з визначення ступеня пошкодження насінневого матеріалу розроблено стенд [6], загальний вигляд якого зображено на рис. 4.

Він складається із рами, на якій, з можливістю зміни кутового положення, розміщений шнековий транспортер. В напрямлячій трубі транспортера розташований шнековий робочий орган з еластичною гвинтовою поверхнею. Зі сторони завантаження матеріалу встановлений бункер, а в зоні його вивантаження — вікно, з якого транспортуваный матеріал переводився в тару. Привід робочого органу здійснюється від електродвигуна. Для пуску двигуна та регулювання частоти його обертання використовували перетворювач частоти (Altivar 71) з програмним забезпеченням Power Suite v.2.5.0. Система Altivar 71 приєднана до мережі та до комп’ютера.
The percentage of damage has been evaluated prior to the experimental research [2]. Then grain was transported in the conveyor for several times at set angular position and rotational rate. After that the percentage of material damage was evaluated in the same manner. The difference in percentage determined the degree of material damage directly during its transportation at set parameters of working parts for specific distance, which equals the reciprocating screw length multiplied by the number of material passings on the conveyor.

The findings of experimental research during the transportation of grain material with rigid reciprocating screw (solid line) and with flexible surface reciprocating screw (dashed line) at different gaps between reciprocating screw and guide pipe (\(\delta = 2; 6\) mm), angles of obliquity of reciprocating screw \(\beta\) and rotational rate \(n\) are illustrated in fig. 5.

**CONCLUSIONS**

Based on the patent search analysis of screw working parts design and review of literary sources concerning definition of their operation modes, a new design and production method of reciprocating screw with flexible helical surface have been proposed.

The bench for conduction of experimental researches has been developed and produced.

Experimental research findings concerning the definition of influence of width, cantilevered cog size and measuring load mass on the value of flexible sheet deformation.

From characteristic curve analysis as shown in fig. 3, it can be concluded that for the value of cantilevered cog of flexible blade \(h = 10\) mm increasing its width within the range from \(B = 5\) mm to \(B = 25\) mm for providing deformation value of free edge of flexible sheet \(\Delta = 8\) mm the bulk of load must be increased by 2.8 times from 180 to 500 g, for \(h = 15\) mm in 4.8, times, for \(h = 20\) mm in 4.2 times, for \(h = 25\) mm in 4.3 times.

It must be admitted that during the decrease of flexible sheet width \(B\) characteristic curve of cantilevered cog size \(h\) of flexible sheet from bulk of measuring loads \(mg\) are changed from linear to curvilinear.

![Fig. 5](image-url)
Characteristic curve analysis depicted in fig.5 has shown that application of flexible covers on the reciprocating screw surface in comparison with rigid reciprocating screw provides reduction of grain damage degree, which with rotational rate of working part 100...400 r/m is within the range of 1,55...3,0 times and for reciprocating screw working member angles to the pitch of 0...40° is set within 1,63...4,0 times.

Obtained findings can be applied in the development of different types of reciprocating screw working parts with flexible working surfaces taking into account rheological properties of bulk agricultural material and admissible effort value which leads to its damage.

REFERENCES


Analysis of graphic dependences, which are presented on the fig. 5 shows, that by using elastic supports on the screw conveyer, the grain damage reduction is achieved in comparison with rigid screw conveyer. This effect is observed in the range of rotational speed of 100...400 rpm and for working angles of the screw conveyor member to the pitch of 0...40°, which is set within 1.63...4.0 times.

Obtained results can be used in the development of different types of reciprocating screw working parts with flexible working surfaces taking into account the rheological properties of bulk agricultural material and admissible effort value which leads to its damage.

BIBLIOGRAPHY


