SCREW CONVEYOR FOR BIOMASS
/
TRANSPORTOR CU ȘNEC PENTRU BIOMASĂ

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ABSTRACT
The paper presents the way in which a biomass transporter with screw was designed, made and tested by INOE 2000 together with the beneficiary company ROLIX IMPEX SERIES, which is intended for the short-distance transport of the chopped / densified biomass, being able to be placed in the technological flow of biomass processing between the chopping and densification equipment, or between densification and sifting/singing equipment. It is equipped with a rolling system, which gives it increased mobility and maneuverability. The conveyor was made by the company and tested in real conditions with finely chopped biomass and bakery wheat, better results being obtained with bakery wheat.

REZUMAT
Lucrarea prezintă modul în care a fost proiectat, realizat și testat un transportor de biomasă cu șnec de către INOE 2000 împreună cu firma beneficiară ROLIX IMPEX SERIES, acesta fiind destinat transportului pe distanțe scurte a biomasei tocate/densificate, putând fi amplasat în fluxul tehnologic de prelucrare a biomasei între echipamentele de tocare și cele de densificare, respectiv între echipamentele de densificare și echipamentele de cernere/însăcuire. Este prevăzut cu sistem de rulare, care îi confera mobilitate și manevrabilitate sporite. Transportorul a fost realizat de către firmă și testat în condiții reale cu biomasă tocată mărunt și grâu de panificație, rezultate mai bune fiind obținute cu grâul de panificație.

INTRODUCTION
The energy exploitation of biomass has been developed in recent years, in accordance with the indications of the energy policy plans of the European Union and of the renewable energy plan (*Romero, S.R. et al., 2012*). These plans set the target of taking renewable energy as the primary source, which has been set as a target for 2020. In recent years, a very large number of resources have been allocated to the energy exploitation of biomass (*Del Río González, P., 2008*). The use of biomass residues as clean fuels in combustion processes has an economic benefit and a social development of rural areas. In addition, the use of these residues reduces the impact on the environment by removing debris and reducing pollutant emissions into the atmosphere. The use of biomass has a great benefit for the atmosphere, which leads to a favorable balance of CO_2, since organic matter is able to retain more CO_2 than that released by burning it. Biomass can be obtained in a sustainable and renewable manner, where the consumption rates of these residues are not faster than their production speeds, giving a favorable balance for CO_2 (*Kadiyala, A. et al., 2016*). An important component in the use of biomass is the transport system, as part of the machinery or equipment specific to a certain type of processing. Thus, a transport system is a mechanical system used for moving materials from one place to another and is found in most industries of processing and production, such as chemical, mechanical, automotive, mineral, pharmaceutical, electronics, etc.

The screw conveyors (with auger) are used for the transport of cereals, flour, fodder, root feed, chopped/densified biomass, etc., in a horizontal, vertical or inclined direction up to 45^0, over relatively short distances, with low and medium productivity, up to 80-100 t/h.

They are simple, cheap, convenient installations in operation, with small dimensions, offering the possibility of easy loading and unloading at different points. By their construction, they are hermetically sealed and prevent the spread of dust in the atmosphere (*Hristea M.-Al. et al., 2019*).

As disadvantages, there should be listed: high energy consumption, strong wear of the trough and snail, shredding of fragile materials during transport and sensitivity to overload.

The load-bearing organ of the helical conveyors is a closed trough through which the inserted material circulates through one or more points. The material moves by sliding, being pushed by the helical work surface of a rotating snail screw, coaxial with the trough (*Hapenciuc, M., 2004*).

Inclined screw conveyors work the same as most drips, but are used at an inclination between 0-45^0 relative to the horizontal. They work differently because each degree of inclination reduces the efficiency of the conveyor and the amount of material transported. Since more torque is required to convey the material through the conveyor, it must be designed more carefully for the product being transported. The angle of inclination should be as small as possible to maximize efficiency and reduce the need for additional power. Angles of inclination less than 10^0 affect very little efficiency, which can be compensated by increasing snail speed; angles of inclination between 10 and 20^0 reduce the efficiency of the snail by 10-40%; angles above 20^0 reduce efficiency from 30-90%, depending on the angle.

CONSTRUCTIVE CHARACTERISTICS OF HORIZONTAL AND INCLINED SCREW CONVEYORS

In principle, the construction of a horizontal helical conveyor is shown in figure 1. In trough 6, coaxial with it, the snail 8 is mounted, leaning on one or more intermediate bearings 7 and on the end bearings 9. The snail is driven by electric motor 1, by means of reducer 3, coupled through couplings 2 and 4. The loading of the material is done through the power outlet 5 located at the top of the trough, and the discharge through the outlet of the end 10, located at the bottom. If the conveyor also has an intermediate outlet, it must be fitted with a locking device. Another variant is the case of the conveyor with power supply on both ends and with discharge in the middle, in which case the snail propeller has different inclinations, figure 2.

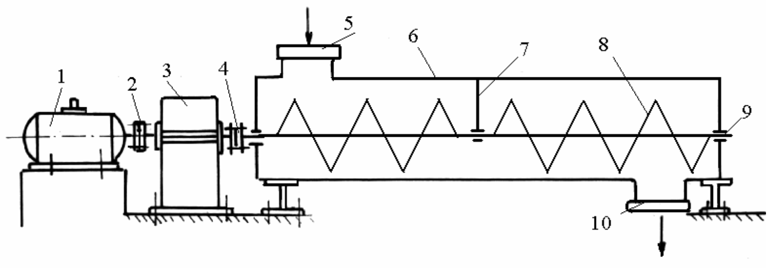

Fig. 1 - Horizontal screw conveyor with one feeding mouth

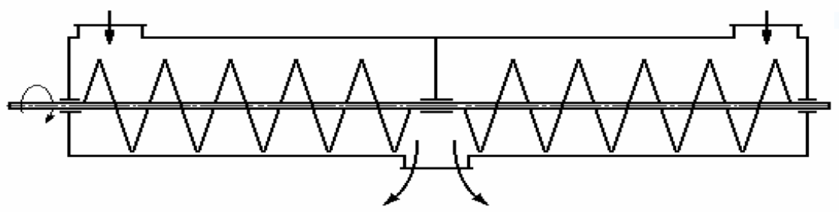

Fig. 2 - Screw conveyor with two feeding mouths

The screw trees are executed with tubular or circular section full, in sections of 2-4 m. At small lengths, preference is given to tubular shafts, the assembly of which is made more conveniently. At long lengths, trees with a full section are preferred, which for the same requests have smaller sections.

Figure 3 shows a frequent construction of a section of the shaft. Tree 1 has a tubular section, on which the propeller 2 of the snail is welded. For assembling the sections of the shaft and supporting it in the intermediate bearings, spindles 4, mounted in bushings 3, on the ends of the sections, are used by means of screws 5 and safety washers 6. The snail propeller is executed by molding of steel sheet with a thickness of 2-8 mm. Smaller thicknesses are recommended at relatively small screw diameters.

Thus, at screw diameters of 200-300 mm, sheet thicknesses of 4-5 mm are recommended, and at diameters of 500-600 mm - thicknesses of 7-8 mm. The propeller sections weld to each other and to the contour of the shaft. Frequently, the snail is executed with a single beginning with diameters ranging from 150mm to 650 mm.

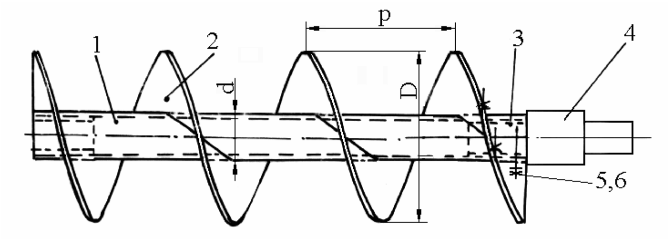

Fig. 3 – Tree section

The trough is made of steel sheet with a thickness of 2-8 mm, of sections with the same length as that of the snail. Larger thicknesses are recommended for larger snail diameters.

The extremities of the sections are rigidized transversely by angles that also serve to assemble the sections between them. To ensure the tightness between the lid and the flanges of the trough, gaskets are mounted.

The screw is mounted so that between it and the trough there is an interstitial of 5-10 mm.

The propeller shaft rests in the bearings; due to the low rev, plain bearings are preferred. One end bearing is radial, and the other is radial axial. The axial radial bearing is mounted at the end where the discharge takes place, in order to take over the axial demand of the shaft.

At longer lengths, outside the end bearings, the shaft is also supported on intermediate bearings. The intermediate bearings are mounted at 2-4 m away from each other, this distance corresponding to the length of the snail sections. The bearings are mounted suspended to ensure the passage of the material on the bottom of the trough. The length of the bearings is recommended to be as small as possible, because next to the bearings the snail propeller is interrupted. The longer the length of the interrupted area, the greater the running resistance of the material.

Because the shaft rests on several bearings, in order to ensure installation and exploitation, the bearings are built oscillating. Both at the end and intermediate bearings, a good sealing must be ensured.

PRESENTATION OF THE BIOMASS TRANSPORT EQUIPMENT WITH SCREW

The development of screw conveyors makes it possible to improve the efficiency of overloading bulk materials. However, due to the significant angular speeds of screw rotation in screw telescopic conveyors, the asymmetry of the telescopic screw and external disturbances, fluctuations often occur, which leads to significant dynamic loads in the screw (*Hevko I.B., 2013; Lyashuk O.L., et al., 2016*), especially in cases of resonance.

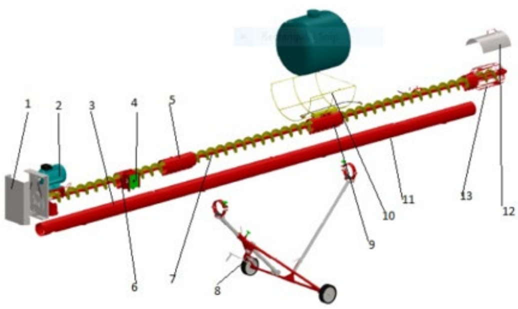

Fig. 4 - Prototype conveyor with auger

1- pulley protection box; 2- engine; 3- tube with biomass outlet mouth; 4- food switch; 5 intermediate tube; 6-sleeve fixing tubes; 7- snail; 8- rolling frame; 9- support biomass treatment basin; 10- sleeve fixing tubes; 11- tube sorb; 12- cap sorb; 13- sorb

The biomass transport equipment with auger made within the project is intended for the transport over short distances of the chopped/densified biomass, being able to be placed in the technological flow of biomass processing between the chopping and densification equipment (pelleting/briquetting presses), respectively between the densification equipment and the sifting/cutting equipment. It is equipped with a rolling system, which gives it increased mobility and maneuverability.

The prototype of the biomass slurry transport equipment was executed in accordance with the Execution Documentation developed by the project partner INOE 2000-IHP. The main subassemblies of the equipment are shown in Figure 4.

The assembled biomass transport equipment is shown in figure 5.

Fig. 5 - Biomass transport screw equipment

DETERMINATIONS UNDER OPERATING CONDITIONS

These tests were carried out in order to determine the main qualitative working and operating indices of the equipment. Improvement of quality indicators during the transport of agricultural production materials, especially seeds, can be provided by screw conveyors, the working surfaces of which are made elastically.

The results of these studies were presented in the papers Tian et al. (2018) and Hevko et al. (2019). Screw conveyors can also move loose materials along curved paths into elastic housings. Theoretical and experimental studies of these types of conveyors were discussed in the research paper Trokhaniak et al. (2020).

Specific electricity consumption

The specific consumption of electricity is the consumption of electricity consumed for the transport of a unit of product.

$$q = \frac{E_{ec}}{Q} = \frac{P_u \cdot t}{Q} = \frac{P_N \cdot \eta_{me} \cdot \eta_{tr} \cdot t}{Q} \left[\frac{kWh}{t}\right] \quad (1)$$

where:

E_{ec} – the electricity consumed for the transport of the product unit

Q – unit of product taken into account, [t]

$$E_{ec} = P_u \,.\, t \;\; [kWh] \quad (2)$$

P_u – useful power of the machine, [kW]

$$P_u = P_N \cdot \eta_{me} \cdot \eta_{tr} \quad (3)$$

P_N – rated electric motor, [kW]

η_{me} - electric motor efficiency, for powers below 10 kW, η_{me} =0.75

η_{tr} – the efficiency of the electric motor transmission - screw; takes into account the efficiency of the belt transmission and the losses in the bearings of the screw; η_{tr} = 0.8

Determination of the electricity consumed

Two methods can be used to measure the electricity consumed:

- direct method, by using a single-phase meter of electricity, which records the electric consumption in kWh;
- indirect method, by measuring the voltage at the supply network by means of a voltmeter and the current absorbed by the electric drive motor by means of an ammeter. The electric power of the motor is determined with the equation

$$P1 = U \cdot I \; [kW] \quad (4)$$

and the energy consumed with the equation

$$W = (P1 \; x \; t)/3600, \; [KWh] \quad (5)$$

in which t - operating time (s).

The direct method was used, using the monophase meter STILO 10-40A.

The power of the drive motor is given by the power necessary to overcome the friction between the material and the screw conveyor housing (Pf), to which the power necessary for the transport of material at the required speed (Pm) is added. The result obtained is multiplied by the overload factor (Fo), after which it is related to the efficiency of the actuation. Power required for the idling operation of the screw conveyor

$$P_f = \frac{L \cdot n \cdot F_d \cdot F_b}{10^6} \text{ [kW]} \tag{6}$$

Power required for a screw conveyor to move the material:

$$P_m = \frac{C \cdot L \cdot W \cdot F_f \cdot F_m \cdot F_p}{10^6} \text{ [kW]} \tag{7}$$

Total power required for the screw conveyor:

$$P_{total} = \frac{(Pf + P_m) \cdot F_0}{e} \text{ [kW]} \tag{8}$$

The following factors determine the power requirement of the screw carrier operating in optimal conditions: P_f - the power to be exceeded when rubbing between the material and the screw conveyor housing (kW); P_m - power for the transport of material at the specific speed (kW); L - the total length of the conveyor (m); n- operating speed (rot/min); F_d - the diameter factor of the screw carrier; F_b - the bearing factor; C - the capacity of the helical conveyor (m^3/h); W – material density (kg/m^3); F_f - the load factor of the snail; F_m - the power factor for the material to be transported; F_p - turn factor, when necessary; F_0 - overload factor; e - the efficiency of the screw conveyor

There were made 3 measurements, on time intervals of 15 min, the average electricity consumption being of 0.88 kWh when idling, respectively 1.32 kWh when going on load.

Determination of the working capacity of the screw conveyor

The theoretical working capacity of the helical conveyor is determined starting from the size of the linear load, which, for a snail with the outer diameter D and the diameter of the axis d, is:

$$q = 1000\frac{\pi(D-d)^2}{4}\gamma\psi \text{ ,în kg/m} \tag{9}$$

in which: ψ is the filling coefficient;

γ - the volumetric mass of the material

The speed of movement of the material along the conveyor is:

$$v = \frac{pn}{60} = \frac{kD}{60}n \tag{10}$$

where n is the snail's speed, in the rpm; p – snail step, in m (p = kD);

With these data, the working capacity of the screw conveyor becomes:

$$Q = 3{,}6qv = 3{,}6 \cdot 1000\frac{\pi(D-d)^2}{4}\frac{pn}{60}\gamma\psi = 15\pi(D-d)^2 pn\gamma\psi \tag{11}$$

If the helical conveyor works at an angle between 0-20^0, then its productivity will be affected by a coefficient that decreases with the angle of inclination, from 1.0 for the horizontal direction, to 0.65 for an angle of 20^0.

Q= 4.875 m^3/h at operation at an angle of 20^0

The experiments in real exploitation conditions confirmed the results obtained by calculation, for the operation of the conveyor at an angle of 20^0 the working capacity being 5.35 m^3/h.

The transported product was chopped biomass, with a maximum granulation of 35 mm, figure 6.

Fig. 6 - Handling of chopped biomass (chopped branches, with maximum granulation of 35 mm)

Superior results were obtained when handling the bakery wheat, the production capacity of the conveyor (as an average of three determinations) reaching 8.3 m^3/h, due to a better filling coefficient.

Fig. 7 - Handling of bakery wheat

CONCLUSIONS

The design and execution of the prototype of the screw conveyor was made together with Rolix Impex Series and tested at a farm in Fundeni. The working capacity obtained for the chopped biomass with the 35 mm granulation, at an angle of 200 is 5.35 m^3/h. Following the experiments, it was noticed that when transporting the bakery wheat, at an angle of 20^0 the working capacity is 8.3 m^3/h. These characteristics are similar to the ones of the equipment on the market.

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